Original Article

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A high-carbohydrate diet lowered blood pressure in healthy Chinese male adolescents

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Summary **Different diets consumed by individuals of different ethnicities, gender, and age may cause changes in blood pressure. The current study sought to investigate changes in blood pressures after consumption of a high-carbohydrate (high-CHO) diet by healthy Chinese adolescents. As a population, the Chinese consume a diet with a high carbohydrate content and they have a low incidence of hypertension and coronary artery disease. Dietary data were collected using a 3-day diet diary. Subjects were 672 high school students who were divided into a high-CHO diet group (≥ 55% carbohydrates) and a non-high-CHO diet group (< 55% carbohydrates, < 40% fats). Plasma glucose levels, heart rate, systolic blood pressure (SBP), and diastolic blood pressure (DBP) were measured. Body mass index (BMI), waist-to-hip ratio (WHR), pulse pressure (PP), and mean arterial pressure (MAP) were calculated. Results indicated that males had a higher BMI, glucose level, SBP, DBP, PP, and MAP than females. When diet was taken into account, males in the non-high-CHO diet group had a higher SBP and PP than females. Males in the high-CHO diet group had a higher glucose level than females. Males in the high-CHO diet group had a lower SBP ($p = 0.004$) and PP ($p = 0.002$) than males in the non-high-CHO diet group and females in the high-CHO diet group had a lower glucose level ($p = 0.003$) than females in the non-high-CHO diet group. After adjusting for age, BMI, WHR, heart rate, the total daily energy intake, and the intake of vitamin C, calcium, sodium, potassium and magnesium, significant differences in SBP and PP were noted in males. These results indicate that male adolescents consuming a high-CHO diet had a lower SBP and PP than males consuming a non-high-CHO diet.**

Keywords: Diastolic blood pressure, high-carbohydrate diet, mean arterial pressure, pulse pressure, systolic blood pressure

1. Introduction

Coronary artery disease (CAD) is the leading cause of death worldwide (*1*). A series of risk factors for CAD, including age, gender, obesity, hypertension, and dyslipoproteinemia, has been identified over the past few decades (*2*). Hypertension, a common condition in many countries (*3*), is closely associated with an increased risk of CAD (*4*) and seriously affects the health and the quality of life of both the elderly and children. In China, the overall prevalence of a relatively high blood pressure among children aged 7-17 years has increased markedly, rising from 19.29% for boys and 14.69% for girls in 2000 to 26.16% for boys and 19.77% for girls in 2010 (*5*). The increased prevalence of hypertension may be one explanation for the steadily increasing risk of CAD in younger populations over the past few decades (*6*). The treatment and control of hypertension is a crucial and effective intervention

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to deal with CAD. A reduction of 3 mmHg in systolic blood pressure (SBP) has been found to result in a 5% reduction in CAD mortality (*7*). Pulse pressure (PP) is a well-established independent predictor for cardiovascular outcomes (*8*). However, hypertension control in younger individuals has received less attention than that in middle-aged individuals and the elderly (*9*). Therefore, further efforts must be made to understand the development of hypertension and to identify more effective ways to control it in youth.

Studies have indicated that there is a significantly lower risk of hypertension (*10*) and CAD (*11*) in the Chinese population. Interestingly, more than 67% of this population's dietary energy is derived from carbohydrates (*12,13*). A study of this traditional diet has found that a higher percentage of energy intake in the form of carbohydrates is significantly associated with a lower risk of hypertension (*14*). In fact, a host of studies suggests that high-carbohydrate (high-CHO) diets can lower blood pressure levels (*15-17*). However, data also indicate that there are no significant changes in blood pressures after a high-CHO dietary intervention (18). A meta-analysis of intervention trials shows that high-CHO diets may be associated with slightly higher blood pressure than high-cis-monounsaturated fat diets (*19*). This inconsistency may be the result of different genetic and environmental backgrounds (*20*) and ethnicities (*21*) or even gender. However, few studies have been sought to investigate the effects of high-CHO diets on blood pressure in healthy adolescents of different genders. These effects have not been reported yet in healthy boys and girls, much less in Chinese, despite the fact that this population consumes a diet with a high carbohydrate content and this population has a lower incidence of hypertension and CAD. Therefore, a cross-sectional study was conducted to investigate changes in blood pressure induced by the high-CHO diet in healthy Chinese Han adolescents of different genders.

2. Methods

This study was *i*) approved by The Ethical Committee of Sichuan University, and *ii*) was conducted with the understanding and the written consent of each high school participant and her/his guardian.

2.1. *Subjects*

This study was conducted at a boarding high school (grades 11 and 12) located on the outskirts of the City of Chengdu, Sichuan Province, the People's Republic of China. This western province has been influenced by industrialization far less than China's eastern provinces. Volunteers were recruited via advertisements seeking healthy students. Students with health problems and students taking medication that might affect their blood pressure were excluded from final analysis. In total, 672 students (280 males and 392 females) aged 15-18 years served as subjects. These individuals were apparently healthy, as indicated by medical questionnaires and physical examinations. All of the students were of the Chinese Han ethnic group.

2.2. *Dietary data collection*

Based on the results of a preliminary study at this high school, dietary data were collected in a 3-day diet diary for the 3 days before blood samples were taken and anthropometric variables were determined. Actual foods by item and amount were displayed on a table in front of each classroom to help the students more accurately estimate what and how much they consumed during each meal. The students were instructed to complete questionnaires in their classrooms. Dietary components were calculated using computer software developed by the Department of Nutrition and Food Safety of the Chinese Center for Disease Control (Beijing, China). Dietary intake by the students was categorized as a high-CHO diet and a non-high-CHO diet on the basis of fat and carbohydrate contributions to total energy. A high-CHO diet was defined as no less than 55% of total energy derived from carbohydrates (*22*) while a non-high-CHO diet was defined as less than 55% of total energy derived from carbohydrates and less than 40% of total energy derived from fats.

2.3. *Physical examinations and laboratory analyses*

Venous blood samples were collected after fasting for 12 hours. Collection took place between 7:00 and 8:00 a.m. after which the subject's height, weight, waist circumference, hip circumference, heart rate, SBP, and diastolic blood pressure (DBP) were measured (blood pressure was measured using a standard mercury sphygmomanometer with 1 of 5 cuff sizes chosen on the basis of the circumference of the participant's arm).

Plasma glucose levels were determined using an enzymatic method as previously described (*23*). Inter- and intra-assay coefficients of variation were less than 6%. Each variable was measured three times independently, and the average of the three measurements was used for statistical analyses. Each subject's body mass index {BMI, =weight (kg)/[height (m)]^2}, waist-to-hip ratio [WHR, = waist circumference (cm)/hip circumference (cm)], pulse pressure [PP, =SBP (mmHg)-DBP (mmHg)], and mean arterial pressure [MAP, =1/3SBP (mmHg)+2/3DBP (mmHg)] were calculated.

2.4. *Statistical analyses*

The normality of the data for each variable was tested using a Shapiro-Wilk test. Subjects consuming the high-

CHO diet (denoted here as the "high-CHO diet group") and those consuming the non-high-CHO diet (denoted here as the "non-high-CHO diet group") were compared using the mean values of variables and both genders were compared using an independent-samples *t*-test. Multiple linear regression analysis was used to adjust for confounding variables. Statistical significance was defined as $p \leq 0.05$. Results are expressed as the mean ± standard deviation (S.D.) unless stated otherwise.

3. Results

3.1. *Characteristics of the two diets*

Characteristics of the non-high-CHO diet and the high-CHO diet consumed by the subjects in this study are shown in Table 1. The non-high-CHO diet group consumed a diet consisting of 12.75% proteins, 36.08% fats, and 51.51% carbohydrates while the high-CHO diet group consumed a diet consisting of 11.76% proteins, 27.00% fats, and 61.58% carbohydrates. There were significant differences between the two groups in terms of total daily energy intake and the intake of calcium, sodium, potassium, and magnesium except for vitamin C intake ($p = 0.068$).

3.2. *Subject characteristics*

The baseline characteristics of the subjects are shown in Table 2. All of the subjects were of the Chinese Han ethnicity and all were high school students aged 16.85 ± 0.59 years. Males were older, they had a greater BMI, they had higher plasma glucose levels, they had a higher SBP, PP, and MAP, and they had a lower WHR and heart rate than females.

3.3. *Blood pressure of the high-CHO diet group and the non-high-CHO diet group*

The blood pressure of subjects consuming the high-CHO diet or the non-high-CHO diet is shown in Table 3, along with their age, BMI, WHR, heart rate, and plasma glucose levels. Males who consumed the non-high-CHO diet were older and had a higher SBP and PP compared to females who consumed the same diet. Males who consumed the high-CHO diet were older and had higher plasma glucose levels than females who consumed the same diet. In addition, females had a higher WHR and heart rate than males, regardless of the diet.

Subjects consuming the high-CHO diet had significantly lower glucose levels and a lower SBP, PP, and MAP than subjects consuming the non-high-CHO diet. After adjusting for age, gender, BMI, WHR, heart rate, the total daily energy intake, and the intake of vitamin C, calcium, sodium, potassium, magnesium, significant differences in SBP, PP, and MAP were noted. After adjusting for age, gender, BMI and the total daily energy intake, significant differences in glucose levels were not noted. When gender was taken into account, males in the

Table 1. Dietary characteristics of the non- high-CHO diet and the high-CHO diet consumed by subjects in this study

Variables	Non-high-CHO diet	High-CHO diet	*p*
Number of subjects	*n* = 266	*n* = 406	
Total energy (kilocalories/d)	3.129 ± 1.469	2.346 ± 1.065	< 0.001
Proteins (% of total energy intake)	12.75 ± 2.58	11.76 ± 2.85	< 0.001
Fats (% of total energy intake)	36.08 ± 2.50	27.00 ± 5.70	< 0.001
Carbohydrates (% of total energy intake)	51.51 ± 2.64	61.58 ± 5.57	< 0.001
Vitamin C (mg/d))	62.84 ± 45.30	56.51 ± 42.82	0.068
Calcium (mg/d)	427.3 ± 340.2	319.8 ± 253.0	< 0.001
Potassium (g/d)	2.086 ± 1.426	1.619 ± 1.142	< 0.001
Sodium (g/d)	3.812 ± 1.777	2.732 ± 1.580	< 0.001
Magnesium (mg/d)	349.9 ± 205.4	275.5 ± 156.6	< 0.001

Data are the mean ± S.D. *p* represents the non-high-CHO diet *vs*. the high-CHO diet in an independent-samples *t*-test.

Table 2. Baseline characteristics of the subjects in this study

Variables	Total (*n* = 672)	Males (*n* = 280)	Females (*n* = 392)	*p*
Age (years)	16.85 ± 0.59	16.95 ± 0.61	16.78 ± 0.56	< 0.001
BMI (Kg/m^2)	20.46 ± 3.19	20.80 ± 3.28	20.21 ± 3.10	0.019
WHR	0.78 ± 0.05	0.77 ± 0.04	0.79 ± 0.05	0.001
Heart rate (bpm)	82.29 ± 11.06	79.53 ± 10.64	84.27 ± 10.94	< 0.001
Glucose (mg/dL)	90.94 ± 7.60	92.53 ± 8.03	8 9.81 ± 7.07	< 0.001
SBP (mmHg)	118.5 ± 11.80	120.80 ± 11.97	116.86 ± 11.41	< 0.001
DBP (mmHg)	72.42 ± 10.63	73.24 ± 10.33	71.84 ± 10.81	0.092
PP (mmHg)	46.08 ± 9.19	47.56 ± 8.85	45.02 ± 9.30	< 0.001
MAP (mmHg)	87.78 ± 10.14	89.09 ± 10.07	86.85 ± 10.10	0.005

Data are the mean ± S.D. *p* represents females *vs*. males in an independent-samples *t*-test.

high-CHO diet group had a significantly lower SBP and PP than males in the non-high-CHO diet group (Table 3). Females in the high-CHO diet group had a lower glucose level (Table 3). After adjusting for various variables, significant differences were still noted (Table 3).

4. Discussion

The lower prevalence of hypertension and CAD in the Chinese population has been well documented (*10,11*). The traditional Chinese diet has a high carbohydrate content (*12,13*) that may help to limit risk factors for hypertension and CAD. The current results showed that in the healthy Chinese adolescents of this study, the male subjects taking the high-CHO diet had lower SBP and PP than the males taking the non-high-CHO diet.

The results of most observational studies that investigated the effects of both type and amount of carbohydrate intake on blood pressure are contradictory (*15,16,18*). For example, diets with a high carbohydrate content coming mainly from sucrose and fructose are reported to raise blood pressure (*24-26*). However, results of the International Population Study on Macronutrients and Blood Pressure (INTERMAP), which included 4,680 subjects aged 40-59 years from 4 countries (the People's Republic of China, Japan, the United Kingdom, and the United States), have suggested a weakly inverse or even an indirect relationship between blood pressure and starch intake (*27*). In contrast, results of the Multiple Risk Factor Intervention Trial (MRFIT) indicated that dietary starch consumption was positively associated with blood pressure (*28*). The traditional Chinese diet mainly consists of white rice, and most of the carbohydrates in white rice are starch (*29*). The current results provide significant evidence that male adolescents in the high-CHO diet group had a significantly lower SBP and PP than male adolescents in the non-high-CHO diet group after adjusting for confounding variables that might influence blood pressure. Since high-CHO diets have a lower proportion of energy from fats, a lower blood pressure may be the result of reduced fat since a lower blood pressure after consuming a high-CHO diet is independent of changes in plasma insulin levels (*30*). Similarly, males in the current study who did not have lower plasma glucose levels nonetheless had a lower SBP and PP compared to males in the non-high-CHO diet group. However, females in the high-CHO diet group who did not have a lower blood pressure had even lower plasma glucose levels.

The current findings indicate that the high-CHO diet affected blood pressure differently in males and females. A significant decrease in blood pressure after consuming a high-CHO diet was noted only in males and not in females. The different outcomes resulting from a high-CHO diet might be due, at least in part, to physiological (*31*), pathological (*32*), or psychological

Table 3. Age, BMI, glucose levels, and blood pressure of subjects on the non-high-CHO diet or the high-CHO diet

Variables	Total				Males				Females			
	Non-high-CHO diet (n = 266)	High-CHO diet (n = 406)	p	p^a	Non-high-CHO diet (n = 153)	High-CHO diet (n = 127)	p	p^a	Non-high-CHO diet (n = 113)	High-CHO diet (n = 279)	p	p^a
Age (years)	16.86 ± 0.58	16.85 ± 0.59	0.809	-	16.97 ± 0.59	16.94 ± 0.63	0.678	-	16.72 ± 0.53[g]	16.81 ± 0.57[f]	0.136	-
BMI (kg/m^2)	20.72 ± 2.99	20.28 ± 3.30	0.082	-	20.96 ± 2.97	20.61 ± 3.63	0.379	-	20.41 ± 3.00	20.13 ± 3.14	0.428	-
WHR	0.78 ± 0.05	0.78 ± 0.05	0.682	-	0.77 ± 0.04	0.77 ± 0.04	0.919	-	0.79 ± 0.05[f]	0.79 ± 0.05[f]	0.507	-
Heart rate (bpm)	82.04 ± 12.04	82.46 ± 10.38	0.631	-	79.24 ± 10.28	79.87 ± 11.10	0.618	-	85.84 ± 13.20[g]	83.64 ± 9.84[g]	0.111	-
Glucose (mg/dL)	92.34 ± 8.50	90.03 ± 6.80	< 0.001	0.086[b]	92.96 ± 8.68	92.01 ± 7.17	0.327	0.795[e]	91.49 ± 8.21	89.13 ± 6.44[g]	0.003	0.023[e]
SBP (mmHg)	120.83 ± 12.42	116.97 ± 11.12	< 0.001	0.003[d]	122.68 ± 12.22	118.53 ± 11.29	0.004	0.013[e]	118.34 ± 12.31[f]	116.26 ± 11.00	0.103	0.109[e]
DBP (mmHg)	73.21 ± 10.66	71.91 ± 10.59	0.122	0.150[d]	73.68 ± 10.18	72.71 ± 10.53	0.435	0.338[e]	72.57 ± 11.29	71.54 ± 10.61	0.397	0.316[e]
PP (mmHg)	47.63 ± 9.47	45.06 ± 8.87	< 0.001	0.033[d]	49.00 ± 9.66	45.82 ± 7.44	0.002	0.027[e]	45.77 ± 8.92[f]	44.72 ± 9.46	0.310	0.445[e]
MAP (mmHg)	89.08 ± 10.36	86.93 ± 9.92	0.007	0.029[d]	90.01 ± 9.90	87.98 ± 10.21	0.093	0.102[e]	87.82 ± 10.86	86.45 ± 9.77	0.224	0.185[e]

Data are the mean ± S.D. p represents the Non-high-CHO diet *vs.* High-CHO diet in an independent-samples *t*-test. [a] Adjusted p value obtained from multiple linear regression; [b] After adjusting for age, gender, BMI, and energy intake; [c] After adjusting for age, BMI, and energy intake; [d] After adjusting for age, gender, BMI, WHR, heart rate, energy intake, and intake of vitamin C, calcium, sodium, potassium, and magnesium; [e] After adjusting for age, BMI, WHR, heart rate, energy intake, and intake of vitamin C, calcium, sodium, potassium, and magnesium; [f] $p \leq 0.05$ compared to males in the group on the same diet according to an independent-samples *t*-test; [g] $p \leq 0.001$ compared to males in the group on the same diet according to an independent-samples *t*-test.

variation or to different hormonal effects (*33,34*). For example, previous studies have indicated that estrogen can lead to a lower level of serum angiotensin-converting-enzyme (ACE) activity (*33*) and higher level of ACE2 activity (*34*), leading to higher blood pressure in male mice (*34*). The detailed mechanism by which a high-CHO diet affects blood pressure needs to be elucidated in further studies.

A 3-day diet diary was used to collect dietary information in the present study. The total daily energy intake, the intake of vitamin C, calcium, sodium, potassium, and magnesium, and the proportion of energy derived from carbohydrates, fats, and proteins with respect to the total energy intake was calculated using software. The data obtained by these methods may not accurately reflect the dietary habits of the individuals studied. Therefore, this limitation should be taken into account when the results of the present study are cited.

In summary, the current results indicate that healthy Chinese male adolescents consuming a high-CHO diet had a lower SBP and PP than males consuming a non-high-CHO diet. The beneficial effects on blood pressure of the high-CHO diet may be one explanation for the lower prevalence of hypertension and CAD as has been documented in the Chinese population. Further studies have the potential to reveal the underlying mechanisms of a high-CHO diet, which may reduce the risk of hypertension and CAD.

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References

1. Peden JF, Farrall M. Thirty-five common variants for coronary artery disease: The fruits of much collaborative labour. Hum Mol Genet. 2011; 20:R198-205.
2. Cheng TO. Cardiovascular health, risks and diseases in contemporary China. Int J Cardiol. 2011; 152:285-294.
3. Conroy RM, Pyörälä K, Fitzgerald AP, *et al*. Estimation of ten-year risk of fatal cardiovascular disease in Europe: The SCORE project. European Heart J. 2003; 11:987-1003.
4. Foody J, Huo Y, Ji L, Zhao D, Boyd D, Meng HJ, Shiff S, Hu D. Unique and varied contributions of traditional CVD risk factors: A systematic literature review of CAD risk factors in China. Clin Med Insights Cardiol. 2013; 7:59-86.
5. Zhang YX, Zhao JS, Sun GZ, Lin M, Chu ZH. Prevalent trends in relatively high blood pressure among children and adolescents in Shandong, China. Ann Hum Biol. 2012; 39:259-263.
6. Saleheen D, Frossard P. CAD risk factors and acute myocardial infarction in Pakistan. Acta Cardiol. 2004; 59:417-424.
7. Stamler R. Implications of the INTERSALT study. Hypertension. 1991; 17:I16-20.
8. Dart AM, Kingwell BA. Pulse pressure. A review of mechanisms and clinical relevance. J Am Coll Cardiol. 2001; 37:975-984.
9. Egan BM, Zhao Y, Axon RN. US trends in prevalence, awareness, treatment, and control of hypertension, 1988-2008. JAMA. 2010; 303:2043-2050.
10. Pereira M, Lunet N, Azevedo A, Barros H. Differences in prevalence, awareness, treatment and control of hypertension between developing and developed countries. J Hypertens. 2009; 27:963-975.
11. Gaziano TA, Bitton A, Anand S, Abrahams-Gessel S, Murphy A. Growing epidemic of coronary heart disease in low- and middle-income countries. Curr Probl Cardiol. 2010; 35:72-115.
12. Lee MM, Wu-Williams A, Whittemore AS, *et al*. Comparison of dietary habits, physical activity and body size among Chinese in North America and China. Int J Epidemiol. 1994; 23:984-990.
13. Chen Z, Shu XO, Yang G, Li H, Li Q, Gao YT, Zheng W. Nutrient intake among Chinese women living in Shanghai, China. Br J Nutr. 2006; 96:393-399.
14. Chen CM, Zhao W, Yang Z, Zhai Y, Wu Y, Kong L. The role of dietary factors in chronic disease control in China. Obes Rev. 2008; 9:100-103.
15. Muzio F, Mondazzi L, Harris WS, Sommariva D, Branchi A. Effects of moderate variations in the macronutrient content of the diet on cardiovascular disease risk factors in obese patients with the metabolic syndrome. Am J Clin Nutr. 2007; 86:946-951.
16. Lim SS, Noakes M, Keogh JB, Clifton PM. Long-term effects of a low carbohydrate, low fat or high unsaturated fat diet compared to a no-intervention control. Nutr Metab Cardiovasc Dis. 2010; 20:599-607.
17. Appel LJ, Sacks FM, Carey VJ, Obarzanek E, Swain JF, Miller ER 3rd, Conlin PR, Erlinger TP, Rosner BA, Laranjo NM, Charleston J, McCarron P, Bishop LM; OmniHeart Collaborative Research Group. Effects of protein, monounsaturated fat, and carbohydrate intake on blood pressure and serum lipids: Results of the OmniHeart randomized trial. JAMA. 2005; 294:2455-2464.
18. Brehm BJ, Seeley RJ, Daniels SR, D'Alessio DA. A randomized trial comparing a very low carbohydrate diet and a calorie-restricted low fat diet on body weight and cardiovascular risk factors in healthy women. J Clin Endocrinol Metab. 2003; 88:1617-1623.
19. Shah M, Adams-Huet B, Garg A. Effect of high-carbohydrate or high-cis-monounsaturated fat diets on blood pressure: A meta-analysis of intervention trials. Am J Clin Nutr. 2007; 85:1251-1256.
20. Appel LJ, Brands MW, Daniels SR, Karanja N, Elmer PJ, Sacks FM; American Heart Association. Dietary approaches to prevent and treat hypertension: A scientific statement from the American Heart Association. Hypertension. 2006; 47:296-308.
21. Svetkey LP, Erlinger TP, Vollmer WM, Feldstein A, Cooper LS, Appel LJ, Ard JD, Elmer PJ, Harsha D, Stevens VJ. Effect of lifestyle modifications on blood pressure by race, sex, hypertension status, and age. J Hum Hypertens. 2005; 19:21-31.
22. Parks EJ, Hellerstein MK. Carbohydrate-induced hypertriacylglycerolemia: Historical perspective and review of biological mechanisms. Am J Clin Nutr. 2000;

71:412-433.
23. Fang DZ, Liu BW. Polymorphism of HL +1075C, but not -480T, is associated with plasma high density lipoprotein cholesterol and apolipoprotein AI in men of a Chinese population. Atherosclerosis. 2002; 161:417-424.
24. Jalas DI, Smits G, Johnson RJ, Chonchol M. Increased fructose associates with elevated blood pressure. J Am Soc Nephrol. 2010; 21:1543-1549.
25. Hulman S, Falkner B. The effect of excess dietary sucrose on growth, blood pressure, and metabolism in developing Sprague-Dawley rats. Pediatr Res. 1994; 36:95-101.
26. Daly ME, Vale C, Walker M, Alberti KG, Mathers JC. Dietary carbohydrates and insulin sensitivity: A review of the evidence and clinical implication. Am I Clin Nutr. 1997; 66:1072-1085.
27. Brown IJ, Elliott P, Robertson CE, Chan Q, Daviglus ML, Dyer AR, Huang CC, Rodriguez BL, Sakata K, Ueshima H, Van Horn L, Zhao L, Stamler J; INTERMAP Research Group. Dietary starch intake of individuals and their blood pressure: The International Study of Macronutrients and Micronutrients and Blood Pressure. J Hypertens. 2009; 27:231-236.
28. Stamler J, Caggiula A, Grandits GA, Kjelsberg M, Cutler JA. Relationship to blood pressure of combinations of dietary macronutrients. Findings of the Multiple Risk Factor Intervention Trial (MRFIT). Circulation. 1996; 94:2417-2423.
29. Chen CM, Zhao W, Yang Z, Zhai Y, Wu Y, Kong L. The role of dietary factors in chronic disease control in China. Obes Rev. 2008; 9:100-103.
30. Straznicky NE, O'Callaghan CJ, Barrington VE, Louis WJ. Hypotensive effect of low-fat, high-carbohydrate diet can be independent of changes in plasma insulin concentrations. Hypertension. 1999; 34:580-585.
31. Reik W, Walter J. Evolution of imprinting mechanisms: The battle of the sexes begins in the zygote. Nat Genet. 2001; 27:255-256.
32. Koskinen J, Magnussen CG, Viikari JS, Kähönen M, Laitinen T, Hutri-Kähönen N, Lehtimäki T, Jokinen E, Raitakari OT, Juonala M. Effect of age, gender and cardiovascular risk factors on carotid distensibility during 6-year follow-up. The Cardiovascular Risk in Young Finns study. Atherosclerosis. 2012; 224:474-479.
33. Proudler AJ, Ahmed AI, Crook D, Fogelman I, Rymer JM, Stevenson JC. Hormone replacement therapy and serum angiotensin-converting-enzyme activity in postmenopausal women. Lancet. 1995; 346:89-90.
34. Gupte M, Thatcher SE, Boustany-Kari CM, Shoemaker R, Yiannikouris F, Zhang X, Karounos M, Cassis LA. Angiotensin converting enzyme 2 contributes to sex differences in the development of obesity hypertension in C57BL/6 mice. Arterioscler Thromb Vasc Biol. 2012; 32:1392-1399.

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