Dietary Nutrients and Blood Pressure in Urban Minority Adolescents at Risk for Hypertension

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Objective: To determine if blood pressure (BP) level is associated with dietary micronutrients in adolescents at risk for hypertension.

Design: Adolescents aged 14 to 16 years, with BP higher than the 90th percentile on 2 separate measurements in a school setting, had diet assessments. A 24-hour intake recall was obtained on 180 students (108 boys and 72 girls). Folic acid intake was used as an index of fruit, vegetable, and whole grain intake; the high folate group had a folate intake greater than the recommended daily allowance and the low folate group had a folate intake less than the recommended daily allowance. Data were analyzed by 2-way analysis of variance.

Results: Mean diastolic BP was significantly higher in the low folate vs the high folate group (boys: 72 vs 67 mm Hg; girls: 76 vs 73 mm Hg; \( P = .008 \)). The difference in systolic blood pressure was not significant. There was no difference in body mass index between the diet groups. Sodium intake per 4184 kJ was not different. The low folate group had significantly lower intakes per 4184 kJ of potassium \( (P = .002) \), calcium \( (P = .001) \), magnesium \( (P < .001) \), and total intake of beta carotene, cholecalciferol, vitamin E, and all B vitamins.

Conclusions: Among adolescents at risk for hypertension, BP was lower in those with higher intakes of a combination of nutrients, including potassium, calcium, magnesium, and vitamins. Dietary benefits on BP observed on diets rich in a combination of nutrients derived from fruits, vegetables, and low-fat dairy products could contribute to primary prevention of hypertension when instituted at an early age.


Hypertension is a major health problem in adults, and contributes to cardiovascular disease. Current estimates indicate that approximately 25% of the US population have hypertension.\(^1\) Moreover, it is now recognized that the origins of hypertension are rooted in the young. Children and adolescents with blood pressure (BP) levels in the higher range of the BP distribution are at risk of developing hypertension as young adults.\(^2\)

Strategies for primary prevention of hypertension have focused on lifestyle modifications, in particular, diet patterns that may lower BP levels.\(^3\) Both epidemiological and experimental research, as well as clinical observation, indicate that sodium intake is strongly related to BP level, with higher sodium consumption correlating with higher BP levels.\(^4,5\) While there is also some evidence that other diet nutrients, including potassium, calcium, and magnesium, are inversely related to BP levels,\(^6\) most intervention efforts have been directed at reducing sodium intake. Investigations in children and adolescents on the effect of specific diet nutrients on BP levels, including sodium intake, have yielded inconclusive results.\(^6\)

More recently the Dietary Approach to Stop Hypertension (DASH)\(^7\) clinical trial in adults with high, normal, and untreated stage I hypertension demonstrated that significant BP reduction occurred on a diet high in fruits and vegetables and low-fat dairy products. The diet effect on blood pressure was independent of a reduction in sodium intake or weight loss, indicating that a combination of nutrients conferred benefit in BP reduction.\(^7\) The question of a relationship of combined dietary nutrients with BP levels in childhood has not been examined. The purpose of this study was to determine if BP level is associated with multiple dietary micronutrients in a sample of urban minority adolescents at risk for hypertension.
SUBJECTS AND METHODS

This study was conducted on a sample of minority adolescents at risk for development of hypertension. Cardiovascular risk factor screening was conducted on all grade 9 and 10 students at 4 inner-city public high schools in Philadelphia, from 1993 to 1994. Screening consisted of measurement of BP, height, and weight, and obtaining a family history of heart disease. The BP levels were measured by trained observers in the right arm, in the seated position by auscultation and mercury column sphygmomanometer, using appropriate cuff size. Since the subjects were all adolescents, the cuff determined to be appropriate for a given adolescent, based on upper-arm size, was the “adult” cuff, “large adult” cuff, or “obese adult” cuff. The first Korotkoff sound (K1) was used to determine the systolic BP level and the fifth Korotkoff sound (K5) was used to determine the diastolic BP level. The average of 2 measurements was used as the BP measurement for each student. Students with a BP measure that was at the 90th percentile or higher for age and sex had a second screening BP measurement 1 week later. Students with BP measurements that continued to be at the 90th percentile or higher on the second measurement were invited to participate in a risk reduction program.

A third BP measurement, which was again the mean of 2 separate readings, was obtained on enrollment. The third BP measure was the BP value used in the data analysis. Weight was measured in kilograms and height was measured in centimeters. Body mass index (BMI) was calculated as weight in kilograms divided by the square of height in meters.

At enrollment to the risk reduction program, dietary intake was determined by use of a standardized 24-hour food recall. The 24-hour diet recall of the previous day’s intake was conducted by an experienced registered dietitian, using food models to help determine portion sizes. Each food recall was based on food intake from a typical school day, with attention to salting practices as well as consumption of salted and unsalted foods. Nutrient analysis of each food record was performed using the Nutritionist III nutrient analysis program (N-Squared Computing, San Bruno, Calif). The program was customized to accurately quantify the nutrients in regionally consumed foods. The intakes of total energy, macronutrients, and micronutrients per 24 hours were determined. Specific nutrients were also computed as intake per 4184 kJ. The 24-hour diet recall method has limitations in accurately assessing nutrient intake within individuals; however, this method is considered to be reliable in examining groups of individuals.

Folic acid is a dietary nutrient present in fresh fruits, vegetables, and whole grains. We therefore used dietary folic acid intake as a diet index to reflect intake of fruits and vegetables. The sample of high-risk adolescents was stratified according to the folate intake computed from their 24-hour diet intake. Subjects were assigned to the high-folate group if the folate intake was greater than the recommended daily allowance for folate (boys, >200 µg/d; girls, >180 µg/d). If the folate intake was less than the recommended daily allowance, subjects were assigned to the low folate group. A 2-way analysis of variance was applied to the BP level, weight, BMI, and diet parameters of the low vs high folate groups. The analysis of variance was also performed on BP and dietary components, with adjustment for BMI. Values of P<.05 were considered to be significant.

RESULTS

One hundred eighty high-risk adolescents, with or without obesity, were enrolled after informed consents were signed by the child and his/her parent. This sample represents approximately 40% of those students who qualified for enrollment after screening. The reasons students declined participation was time conflict with other after-school activities, lack of interest, or absence of parental consent. There were no differences between those enrolled and those who declined participation in the parameter of BP level, body size, race, or sex. Racial distribution of participants was 79% African American and 21% Hispanic, which is consistent with the race distribution of the high school students. Mean age of the sample at the time of study was 15.6 years. No subject was taking supplemental vitamins. The stratification of the adolescent sample by dietary folic acid intake resulted in 86 (56 boys and 30 girls) in the low folate group and 94 (52 boys and 42 girls) in the high folate group. Table 1 provides the mean age, weight, height, and BMI values, as well as the mean folate intake, for boys and girls in the low and high folate groups. The mean BMI (>29 in the boys and >30 in the girls) reflects the high prevalence of obesity in this high-risk sample. Although there was a trend for higher BMI in girls compared with boys, there was no significant difference in BMI between the high and low folate groups in boys or girls.

Table 2 provides the mean values for total energy, protein, fat, carbohydrate, and cholesterol intake, as well as the distribution of macronutrients, calculated as percentage of total energy. Total energy intake reported in the 24-hour intake assessment was lower in the low folate group, both in boys and girls. However, the distribution of protein, fat, carbohydrate, and cholesterol in terms of percentage of total energy intake was similar in the high and low folate groups; there was also no sex difference in the distribution of macronutrient intake. Table 3 provides the mean values for the cations potassium, calcium, magnesium, and sodium. These values are provided as intake per 24 hours and also as intake per 4184 kJ to adjust for the lower energy intake reported in the low folate group. Highly significant differences were present between the low and high folate groups, with the low folate group having lower intakes of potassium (P<.001), calcium (P<.001), and magnesium (P<.001). Potassium, calcium, and magnesium intakes continued to be significantly lower in the low folate group when adjusted for energy intake and expressed as milligrams per 4184 kJ. Sodium intake per 24 hours was significantly lower in the low folate group (P=.02). However, there was no significant difference in sodium...
intake between the low and high folate group in milligrams per 4184 kJ of sodium intake.

Dietary intakes of vitamins were also examined in the diet analysis. The 24-hour intakes of beta carotene, ascorbic acid, cholecalciferol, vitamin E, and B vitamins for boys and girls in the low and high folate groups are provided in Table 4. With the exception of ascorbic acid, there were significant differences between the low and high folate groups in vitamin intake, with lower vitamin intake in both boys and girls in the low folate group.

Table 5 provides the mean values for BP levels in the 4 folate/sex groups. The systolic BP level was higher in boys vs girls ($P = .02$); the diastolic BP level was higher in girls vs boys ($P = .002$). The diastolic BP level was significantly higher in the low folate group vs the high folate group ($P = .008$); the calculated mean arterial BP level was also significantly higher in the low folate vs the high folate group ($P = .01$). While there was no significant sex difference in mean arterial BP level, there was a trend for higher levels in girls. Significant BP differences were pres-
The results of this investigation indicate that diet patterns may contribute to BP levels in urban minority adolescents who have screening BP levels higher than the 90th percentile, putting them at risk for the development of hypertension. Using dietary folic acid intake as an index of a combination of nutrient intake, those with low folate intakes also had lower intakes of potassium, calcium, magnesium, and vitamins compared with adolescents with high folate intakes. Moreover, the low folate intake group also had higher BP levels than the adolescents in the high folate intake group, despite no difference in sodium intake or BMI.

The results of this study are compatible with the results of the DASH trial, although the design of this investigation was different from the design from the DASH trial. We are reporting on data obtained in a cross-sectional examination, while the DASH trial was a well-controlled prospective diet intervention conducted at several sites. Our study examined urban minority adolescents, while the DASH trial enrolled subjects with mild untreated hypertension, with a mean age of 51 years. Despite the age and design difference, a significant relationship was detected of lower BP levels with diets enriched with a combination of nutrients. In both our data and the data obtained in the DASH trial, the effect of diet on BP level was independent of sodium intake or BMI difference.

The dietary micronutrient that has been most extensively examined as a potential contributor to hypertension in adults is sodium intake. The body of data in adults from epidemiologic and experimental research, and from clinical observation, indicates that sodium intake correlates directly with BP level. Evidence for a direct relationship of sodium intake with BP level in children and adolescents has been less conclusive. In an extensive review of published studies on diet on BP levels in children and adolescents by Simons-Morton and Obarzanek, the authors examined 37 observational and intervention studies on sodium and BP level in childhood. There was variation among the reviewed studies with regard to whether enrolled subjects represented normal children, as in schools, or children drawn from a high BP stratum. Also, there were differences in diet assessment methods and inclusion of other parameters to assess sodium intake, such as urine sodium. Despite many inconclusive or negative reports, these authors concluded that the results of methodologically stronger studies suggest that higher sodium intake is related to higher BP levels in children and adolescents. An interventional study in the young that applied highly rigorous methods was con-

### Table 4. Dietary Intake of Vitamins*

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Boys</th>
<th>Girls</th>
<th>Boys</th>
<th>Girls</th>
<th>ANOVA P Values†</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vitamin A, RE</td>
<td>745 ± 1318 (338 ± 571)</td>
<td>640 ± 1552 (391 ± 875)</td>
<td>1397 ± 1424 (609 ± 741)</td>
<td>1059 ± 864 (669 ± 881)</td>
<td>.005 .25</td>
</tr>
<tr>
<td>Thiamin, mg</td>
<td>1.28 ± 0.90 (0.6 ± 0.4)</td>
<td>1.11 ± 0.63 (0.8 ± 0.6)</td>
<td>2.23 ± 0.94 (0.9 ± 0.6)</td>
<td>2.02 ± 0.95 (1.2 ± 0.7)</td>
<td>.001 .16</td>
</tr>
<tr>
<td>Riboflavin, mg</td>
<td>1.35 ± 0.75 (0.6 ± 0.3)</td>
<td>1.26 ± 0.72 (0.9 ± 0.4)</td>
<td>2.50 ± 1.06 (1.0 ± 0.6)</td>
<td>2.21 ± 0.85 (1.3 ± 0.7)</td>
<td>.001 .13</td>
</tr>
<tr>
<td>Niacin, mg</td>
<td>25.4 ± 16.5 (12.4 ± 9.9)</td>
<td>19.9 ± 12.4 (14.1 ± 9.4)</td>
<td>37.4 ± 20.1 (15.7 ± 10.6)</td>
<td>32.1 ± 15.1 (18.6 ± 9.9)</td>
<td>.001 .04</td>
</tr>
<tr>
<td>B6, mg</td>
<td>1.71 ± 0.92 (0.8 ± 0.5)</td>
<td>1.39 ± 0.83 (1.0 ± 0.6)</td>
<td>2.60 ± 1.25 (1.1 ± 0.7)</td>
<td>2.09 ± 1.03 (1.2 ± 0.7)</td>
<td>.001 .008</td>
</tr>
<tr>
<td>B12, µg</td>
<td>3.44 ± 2.98 (1.6 ± 1.4)</td>
<td>2.94 ± 2.59 (1.9 ± 1.5)</td>
<td>6.74 ± 4.33 (2.9 ± 2.3)</td>
<td>4.99 ± 3.65 (3.0 ± 2.7)</td>
<td>.001 .03</td>
</tr>
<tr>
<td>Vitamin C, mg</td>
<td>161 ± 283 (81 ± 142)</td>
<td>144 ± 303 (75 ± 122)</td>
<td>242 ± 184 (97 ± 73)</td>
<td>162 ± 129 (93 ± 83)</td>
<td>.11 .15</td>
</tr>
<tr>
<td>Vitamin D, µg</td>
<td>2.26 ± 2.58 (1.0 ± 1.0)</td>
<td>1.78 ± 2.73 (1.2 ± 1.7)</td>
<td>4.51 ± 3.84 (1.9 ± 1.6)</td>
<td>4.14 ± 4.23 (2.6 ± 3.8)</td>
<td>.001 .42</td>
</tr>
<tr>
<td>Vitamin E, mg</td>
<td>5.82 ± 9.57 (2.5 ± 3.5)</td>
<td>2.51 ± 2.49 (1.6 ± 1.6)</td>
<td>8.12 ± 11.29 (2.9 ± 3.7)</td>
<td>9.48 ± 17.50 (5.5 ± 11.0)</td>
<td>.02 .66</td>
</tr>
</tbody>
</table>

*ANOVA indicates analysis of variance; RE, retinol equivalents. Values are mean ± SD unless otherwise indicated; values in parentheses indicate vitamin intake per 4184 kJ.
†The ANOVAs were calculated with an adjustment for body mass index.

### Table 5. Blood Pressure Values in Adolescents According to Diet Group*

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Low Folate</th>
<th>High Folate</th>
<th>ANOVA P Values†</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of subjects</td>
<td>56</td>
<td>30</td>
<td>52</td>
</tr>
<tr>
<td>SBP, mm Hg</td>
<td>122.2 ± 1.4</td>
<td>117.4 ± 2.1</td>
<td>119.9 ± 1.5</td>
</tr>
<tr>
<td>DBP, mm Hg</td>
<td>71.9 ± 1.7</td>
<td>75.8 ± 2.0</td>
<td>66.5 ± 1.4</td>
</tr>
<tr>
<td>MBP, mm Hg</td>
<td>88.7 ± 1.4</td>
<td>89.7 ± 1.6</td>
<td>84.3 ± 1.1</td>
</tr>
</tbody>
</table>

*ANOVA indicates analysis of variance; SBP, systolic blood pressure; DBP, diastolic blood pressure; and MBP, mean blood pressure. Values are mean ± SD unless otherwise indicated.
†The ANOVAs were calculated with an adjustment for body mass index.
ducted by Rocchini et al. These investigators demonstrated a direct effect of sodium intake on BP level in obese adolescents. However, the other significant aspect of that study was the finding that the obese adolescents reduced body fat through a combination of reduced energy intake and exercise, the effect of sodium intake on BP level was extinguished. Thus, metabolic factors related to obesity may permit expression of a sodium-induced increase in BP levels among obese adolescents. Our cross-sectional analysis did not detect a relationship of BP level with sodium intake in this sample. Our data indicate somewhat greater sodium intake in the high folate group compared with the low folate group. However, when corrected for energy intake and expressed as milligrams per 4184 kJ, there were no group differences in sodium intake; there continued to be significant differences in other cations when expressed as milligrams per 4184 kJ. It is possible that some underreporting of total intake in the low folate group could explain the difference in total sodium intake.

The possible effect of other individual cations on BP level in the young has also been investigated in both observational and intervention studies. Watson et al examined BP levels and potassium excretion, a measure of potassium intake. These authors suggested that lower potassium intake among black women could explain some racial differences in BP level. Sinaiko et al studied the effect of potassium supplementation on BP levels and found a very slight effect on the upward trend in BP levels in girls only. A relationship of calcium and magnesium intake with BP levels in the young has also been studied, with variable results. In their review of the reported investigations on the effect of other dietary cations on BP level, Simons-Morton and Obarzanek could not identify a clear association of potassium or calcium with BP level in the young, but found some limited evidence that higher dietary magnesium levels may be associated with lower BP levels in children and adolescents.

Investigational efforts to detect an independent effect of a dietary cation on BP level is complicated by the intercorrelation of multiple nutrients in the diet. In this report, our efforts were directed toward determining if a combination of cations and vitamins were associated with BP level in high-risk adolescents. We used folic acid intake as a strategy to stratify the sample of adolescents by multiple nutrients. The mean and range of folate intake was consistent with recent data reported from the National Health and Nutrition Examination Survey (NHANES) for minority adolescents. Dietary intake data from NHANES were also obtained by 24-hour intake assessment. Diet data from the adolescents in our study were obtained before 1998, and preceded the Food and Drug Administration requirement that manufacturers must add folic acid to cereal and grain products. Therefore, the sources of dietary folic acid intake in this sample should be linked with fruits, vegetables, and grain foods in the diet.

In this sample of urban minority adolescents with risk factors for hypertension, the BP level is higher in those with diets lower in potassium, calcium, magnesium, and vitamins. The difference in BP levels observed between the diet groups could not be explained by differences in sodium intake or BMI. These results suggest that diets deficient in multiple nutrients may contribute to the development of hypertension in adolescents having risk factors for cardiovascular disease. These observations are consistent with the dietary benefits on BP level observed in the DASH trial, and suggest a possible strategy for a dietary approach to primary prevention of hypertension when instituted at an early age.

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