The Association of Caffeinated Beverages With Blood Pressure in Adolescents

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Objective: To assess the association between the consumption of caffeinated beverages and blood pressure in African American and white adolescents.

Design: This study was part of ongoing research examining stress-induced hemodynamic responses in adolescents. African American and white adolescents (n = 159) selected foods and beverages for a 3-day sodium-controlled diet. Caffeine in these foods was used to stratify participants into 3 categories (0-50 mg/d, >50-100 mg/d, and >100 mg/d). Before menu selection, blood pressure readings were obtained.

Statistical Analysis: A general linear model (multiple regression with both categorical and continuous variables) was developed to assess the effects of race, category of caffeine intake, and interaction of race and caffeine intake on systolic and diastolic blood pressure controlling for sex and body mass index (calculated as weight in kilograms divided by height in meters squared).

Results: The association between systolic blood pressure and caffeine category varied by race (P = .001). African Americans consuming more than 100 mg/d of caffeine had higher systolic blood pressure readings than the groups consuming 0 to 50 mg/d (mean difference, 6.0 mm Hg; 95% confidence interval [CI], 2.3 to 9.7) or more than 50 to 100 mg/d (mean difference, 7.1 mm Hg; 95% CI, 3.4 to 10.7). The effect on diastolic blood pressure was less pronounced (P = .08). The diastolic blood pressure of the group consuming more than 100 mg/d was 3.7 mm Hg (95% CI, 0.41 to 7.0) higher than the group consuming more than 50 to 100 mg/d and was not statistically different from the group consuming 0 to 50 mg/d (mean difference, 2.4 mm Hg; 95% CI, −0.9 to 5.8). There was no evidence that the association between diastolic blood pressure and caffeine intake varied by race (P = .80).

Conclusions: For adolescents, especially African American adolescents, caffeine intake may increase blood pressure and thereby increase the risk of hypertension. Alternatively, caffeinated drink consumption may be a marker for dietary and lifestyle practices that together influence blood pressure. Additional research is needed owing to rising rates of adolescent hypertension and soft drink consumption.


The prevalence of hypertension among youth is rising. By adolescence, African American girls and boys have higher systolic blood pressure than white individuals. To reduce the risk of hypertension among this vulnerable group, a better understanding is needed of the environmental (including dietary) and genetic factors that contribute to the blood pressure differences between African American and white adolescents. One such dietary factor is caffeine consumption. Caffeine is considered a preventable risk factor for hypertension and cardiovascular disease. In adults the primary source of caffeine is coffee, whereas in adolescents the major source is caffeinated soft drinks. It is estimated that 68% of boys and 62% of girls aged 12 to 17 years drink 1 or more soft drinks daily and that 21% of boys and 22% of girls consume coffee or tea on a daily basis. The percentage of adolescents drinking caffeinated soft drinks is more than double the percentage of those who consume noncaffeinated soft drinks. The question of whether caffeine in the quantities consumed by many adolescents can affect blood pressure has not been extensively evaluated.
among the participants who consumed the largest quantity of caffeinated drinks. The purpose of the present study was to extend our earlier finding and examine the association between the consumption of caffeinated beverages and blood pressure in a sample of both African American and white adolescents.

METHODS

Data for this investigation were obtained in the course of an ongoing research program to examine hemodynamic responses to competitive stress in healthy adolescents. Subjects completed the study protocol between February 2, 2002, and May 8, 2003. The protocol was approved by the Human Assurance Committee of the Medical College of Georgia (Augusta). Subjects were volunteers throughout the public and private high schools in Richmond County and Columbia County, Georgia. Subjects were recruited according to their interest in participating via school announcements, flyers, and handouts to 1 high school (900 students) and through word of mouth from subjects who had already participated in similar research projects.

Interested subjects contacted research assistants and were screened by telephone. Inclusion criteria were African American or white ethnicity, aged 13 to 19 years, not taking any medications including contraceptives, and having no food allergies by parental and self-report as well as the ability to meet the dietary and testing requirements of the protocol. Written informed parental consent and subject assent were obtained from 194 subjects prior to participation. Of these, 35 were excluded before testing as a result of exceeding the age requirement between consent and their availability for testing, rescheduling owing to conflicts, relocation out of the area, pregnancy as determined by pregnancy testing, illness on test day, failure to comply with the dietary protocol (determined by daily overnight urine samples), or withdrawal of parental consent or subject assent.

Measurements, which included systolic and diastolic blood pressure readings as well as height and weight, were obtained during an initial orientation session. Trained research assistants measured blood pressure levels using a mercury manometer. Normotensive status and values used in subsequent statistical analyses were determined using the mean of 3 successive blood pressure readings. Subjects were considered normotensive if their mean blood pressure reading was lower than the 95th percentile based on weight, height, and age norms. A digital eye-level scale with a height rod (Detecto 6439; Cardinal Scale Manufacturing Company, Webb City, Mo) was used to measure weight in kilograms and standing height in centimeters. Body mass index was calculated as weight in kilograms divided by height in meters squared. Race was based on self-report as well as the ability to meet the dietary and testing requirements of the protocol.

The sample (n = 159) included 32 African American boys, 49 African American girls, 56 white boys, and 22 white girls with a mean±SD age of 16.4±1.0 years. Girls and boys were similar in regard to age, with a mean difference of 0.14 years (95% CI, −0.2 to 0.5). African Americans were younger than white adolescents, with a mean difference of −0.58 year (95% CI, −0.88 to −0.27). African American girls had a higher body mass index compared with white girls (25.9 vs 22.4; mean difference, 3.5; 95% CI, 0.7 to 6.2). African American boys and white boys had a similar body mass index (23.6 vs 23.4) with a mean difference of 0.19 (95% CI, −2.1 to 2.4).

Participants were stratified into 3 caffeine-intake categories (0–50 mg/d, >50–100 mg/d, and >100 mg/d). The total amount of foods and beverages selected minus the amount returned was used to determine subjects’ dietary intake during the 3 days. Caffeine content for all foods and beverages on the menu was determined using the University of Minnesota nutrient database. The amount of caffeine consumed during the 3 days was calculated for each subject based on the amount of caffeine in each food and the quantity of each food consumed by that subject. Examination of the distribution of caffeine intake showed a skewed distribution due to the large numbers of subjects consuming less than 50 mg/d of caffeine. For this reason, caffeine intake was treated as a categorical variable by stratifying subjects into 3 caffeine-intake categories based on their mean daily caffeine intake.

A general linear model (multiple regression including both continuous and categorical variables) was used to assess the effects of race and category of caffeine intake on systolic and diastolic blood pressure and determine if the association between caffeine intake and blood pressure varied by race. Sex and body mass index were controlled for in the model. The amount of variance explained ($R^2$) by the model and the unique contribution of each variable in the model are provided. We used t tests to compute individual pairwise comparisons of least squares regression means in the model. Differences between least squares regression means were reported using mean differences and 95% confidence intervals (CIs).

RESULTS

The sample (n = 159) included 32 African American boys, 49 African American girls, 56 white boys, and 22 white girls with a mean±SD age of 16.4±1.0 years. Girls and boys were similar in regard to age, with a mean difference of 0.14 years (95% CI, −0.2 to 0.5). African Americans were younger than white adolescents, with a mean difference of −0.58 year (95% CI, −0.88 to −0.27). African American girls had a higher body mass index compared with white girls (25.9 vs 22.4; mean difference, 3.5; 95% CI, 0.7 to 6.2). African American boys and white boys had a similar body mass index (23.6 vs 23.4) with a mean difference of 0.19 (95% CI, −2.1 to 2.4).

Participants were stratified into 3 caffeine-intake categories (0–50 mg/d, >50–100 mg/d, and >100 mg/d). The model using systolic blood pressure as the dependent variable accounted for 33% ($P<.001$) of the variance in systolic pressure. There were unique effects for

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body mass index ($R^2=13\%$; $P<.001$), sex ($R^2=7\%$; $P<.001$), caffeine-intake group ($R^2=7\%$; $P=.006$), and the association between race and caffeine-intake group ($R^2=6\%$; $P=.001$). There was no statistically significant effect for race ($R^2<0.001$; $P=.70$). For the covariates of body mass index and sex, there was a positive relationship between systolic blood pressure and body mass index. Boys had higher systolic blood pressure, with a mean difference of 5.8 mm Hg (95% CI, 3.0 to 8.6). The highest caffeine-intake group had a higher systolic blood pressure when compared with the other 2 groups, with differences of 6.0 mm Hg (95% CI, 2.3 to 9.7) for subjects consuming 0 to 50 mg/d and 7.1 mm Hg (95% CI, 3.4 to 10.7) for those consuming more than 50 to 100 mg/d. The difference in systolic blood pressure between the 2 racial groups was not statistically significant (0.9 mm Hg; 95% CI, −5.6 to 3.8). As shown in Figure 1, the effects of race and caffeine intake were best understood by considering how systolic blood pressure for each racial group varied by caffeine-intake category. For African Americans, the systolic blood pressure was higher in the highest caffeine-intake group compared with the lower intake groups, with differences of 12.5 mm Hg (95% CI, 6.8 to 18.2) for those consuming 0 to 50 mg/d and 12.9 mm Hg (95% CI, 7.1 to 18.2) for subjects consuming more than 50 to 100 mg/d. In the case of white subjects, all 3 caffeine-intake categories had similar systolic blood pressure readings. The mean differences in caffeine intake between the highest group and the lower 2 groups were not statistically significant, with differences of −0.5 mm Hg (95% CI, −5.1 to 4.2) for those consuming 0 to 50 mg/d and 1.3 mm Hg (95% CI, −3.2 to 5.7) for subjects consuming 50 to 100 mg/d.

The model with diastolic blood pressure as the dependent variable accounted for 23% ($P<.001$) of the variance in diastolic pressure with unique effects for body mass index ($R^2=11\%$; $P<.001$), race ($R^2=3\%$; $P=.04$), and caffeine-intake category ($R^2=3\%$; $P=.08$). There was no evidence that the association between diastolic pressure and caffeine-intake category varied by race ($R^2<0.001$; $P=.80$). For the covariates of body mass index and sex, there was a positive relationship between diastolic blood pressure and body mass index and similar diastolic blood pressure readings for both sexes (mean difference, 1.77 mm Hg; 95% CI, −0.8 to 4.3). African Americans had a higher diastolic blood pressure, with a mean difference of 4.4 mm Hg (95% CI, 0.2 to 8.6). There was a difference in diastolic blood pressure between the highest caffeine-intake group and those consuming more than 50 to 100 mg/d (3.7 mm Hg; 95% CI, 0.41 to 7.0), but the mean difference between the highest group and subjects consuming 0 to 50 mg/d (2.4 mm Hg; 95% CI, −0.9 to 5.8) was not statistically significant. Figure 2 shows how diastolic blood pressure readings were similar within

### Characteristics of African American and White Participants in Each Caffeine-Intake Category

<table>
<thead>
<tr>
<th>Variable</th>
<th>0-50 mg/d</th>
<th>&gt;50-100 mg/d</th>
<th>&gt;100 mg/d</th>
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<tr>
<td></td>
<td>African American</td>
<td>White</td>
<td>African American</td>
</tr>
<tr>
<td></td>
<td>(n = 38)</td>
<td>(n = 20)</td>
<td>(n = 32)</td>
</tr>
<tr>
<td>Girls, %</td>
<td>55.3</td>
<td>20.0</td>
<td>55.6</td>
</tr>
<tr>
<td>Caffeine, mg</td>
<td>26.1 ± 15.5</td>
<td>25.0 ± 18.0</td>
<td>74.8 ± 12.7</td>
</tr>
<tr>
<td>Age, y</td>
<td>16.2 ± 1.0</td>
<td>16.8 ± 1.0</td>
<td>15.9 ± 1.0</td>
</tr>
<tr>
<td>Body mass index, kg/m²</td>
<td>24.0 ± 5.8</td>
<td>22.0 ± 2.9</td>
<td>25.6 ± 6.2</td>
</tr>
<tr>
<td>Dietary sodium, mg/d</td>
<td>3023 ± 885.0</td>
<td>3261 ± 773.0</td>
<td>3040 ± 781.0</td>
</tr>
<tr>
<td>Systolic blood pressure, mm Hg</td>
<td>105.4 ± 10.5</td>
<td>105.2 ± 10.5</td>
<td>105.5 ± 10.2</td>
</tr>
<tr>
<td>Diastolic blood pressure, mm Hg</td>
<td>68.1 ± 7.9</td>
<td>63.3 ± 7.3</td>
<td>67.4 ± 7.5</td>
</tr>
</tbody>
</table>

*Data are presented as mean ± SD unless otherwise indicated.

### Figure 1
Systolic blood pressure by category of caffeine intake in African American and white adolescents. Data points were means derived from least squares regression adjusted for sex and body mass index, and error bars represent standard error of the means.

### Figure 2
Diastolic blood pressure by category of caffeine intake in African American and white adolescents. Data points were means derived from least squares regression adjusted for sex and body mass index, and error bars represent standard error of the means.
Soft drink consumption represents the major source of caffeine for adolescents. The association of adults’ caffeine consumption from coffee with blood pressure has been widely reported. To our knowledge, no studies have explored the relationship between caffeine consumption from soft drinks and blood pressure in adolescents. Exploring this question, particularly in African Americans, is important as the rates of soft drink consumption and hypertension continue to rise.

Data from this observational study indicate that the choice of large amounts of caffeinated soft drinks by African American adolescents may be associated with elevated blood pressure readings. These results suggest the need for further research on the direct effect of caffeine on the blood pressure of African American youths and the high consumption of soft drinks as an indicator of lifestyle behaviors that increase the risk of hypertension.

In this observational study, we identified a group of adolescents who chose and subsequently consumed large amounts of caffeinated beverages during a 3-day sodium-controlled diet. The African Americans in the highest caffeine-intake group compared with the other 2 groups were 3.4 mm Hg (95% CI, −1.8 to 8.5) for those consuming 0 to 50 mg/d and 4.7 mm Hg (95% CI, −0.5 to 9.9) for subjects consuming more than 50 to 100 mg/d. For white participants, the differences in mean diastolic blood pressure between the highest caffeine-intake group compared with the other 2 groups were 1.5 mm Hg (95% CI, −2.7 to 5.7) for those consuming 0 to 50 mg/d and 2.7 mm Hg (95% CI, −1.3 to 6.8) for subjects consuming 50 to 100 mg/d.

**COMMENT**

In this observational study, we identified a group of adolescents who chose and subsequently consumed large amounts of caffeinated beverages during a 3-day sodium-controlled diet. The African Americans in the highest caffeine-intake group had higher systolic blood pressure readings than all other adolescents in the study, including white participants in the highest caffeine-intake category. There was a modest main effect of caffeine for diastolic blood pressure that was present when the highest caffeine-intake group was compared with the middle intake group. Unlike systolic blood pressure, this effect occurred across both races. These results are consistent with our earlier findings in a different sample of only African American youth that found a greater change in blood pressure (diastolic) in response to a competitive stress challenge (video game) for subjects who consumed large quantities of caffeinated beverages, as assessed by the same dietary protocol.

The dietary protocol, which was designed to control sodium intake, provided a unique opportunity to observe the food choices of these participants. The adolescents were able to choose from a wide array of beverages, so their choices likely reflect their preferences for certain foods and beverages instead of others. In this study, we used subjects’ menu selections as a surrogate measure for a beverage preference survey. We were then able to adjust intake amounts for participants who were unable to consume all of the foods and beverages they had selected.

We compared the soft drink intake found in this study with the levels reported by adolescents in nationwide dietary surveys. Harnack et al reported 4 categories of soft drink consumption from the Continuing Survey of Food Intakes by Individuals (1994) for a sample containing 423 adolescents aged 13 to 18 years. The mean soft drink consumption for each category was none, 0.1 to 12.9 oz/d, 13.0 to 25.9 oz/d, and 26 oz/d or more. In our study, the amounts of soft drinks per day in each category were slightly higher than those reported by Harnack and colleagues. Their sample combined intakes from adolescents aged 13 to 18 years. Our subjects were aged 15 to 19 years, possibly reflecting the increased consumption pattern of older adolescents and youths living in the Southeast. The Bogalusa Heart Study reported caffeine intake among children and adolescents in 1988. The mean daily caffeine intakes in our study were similar to levels obtained from the 15- and 17-year-old participants in the Bogalusa Heart Study. Consistent with our findings, that study reported that white individuals consumed more caffeine than African Americans. We recognize that this was a single evaluation of a small group of adolescents able to participate in a structured dietary protocol. Replication of these findings is needed with a larger sample size of adolescents who are following their normal dietary patterns.

The effects of caffeine consumption on blood pressure in adults have been widely reported. Individuals who habitually consumed caffeine experienced elevations in blood pressure throughout the day in response to a single caffeine dose. There is limited information about the effects of caffeine on the blood pressure of adolescents. Among healthy, nonobese young women (aged 17-22 years), Stickland et al examined the effects of 2 levels of caffeine (3 mg and 250 mg) on cardiovascular reactivity in a crossover study of a sample stratified according to race (African American and white subjects) and parental history of hypertension. Systolic blood pressure during stress was 5 mm Hg higher for subjects receiving the higher dose of caffeine, but there were no effects for race or parental history of hypertension.

These results did not demonstrate a dose-response relationship for systolic or diastolic blood pressure. The 2 groups of African American adolescents who consumed smaller amounts of caffeine had the same systolic blood pressure readings, and there was no effect across the 3 caffeine-intake categories for white subjects. The African American adolescents who selected large quantities of soft drinks may have been more sensitive to the effects of caffeine than the white subjects who consumed even larger amounts of caffeine. Wide individual variations in caffeine metabolism may influence adaptation to its long-term use and its effects on blood pressure. African Americans, who have a higher risk of hypertension, may be more susceptible to the pressor effects of caffeine than other populations. An alternative explanation is that although some African American and white subjects consumed large amounts of soft drinks, their other lifestyle behaviors such as exercise, smoking, and other food choices differed. These behavioral differ-
ences along with soft drink consumption may have contributed to the higher systolic blood pressure in the African American adolescents.

Our findings demonstrate an association between systolic blood pressure and caffeine intake in African American adolescents. These subjects did not have hypertension, so it is not known if caffeine is related to the development of hypertension or to blood pressure levels in adolescents who have hypertension. For adolescents who consume large quantities of caffeinated soft drinks, 2 questions should be addressed. First, does caffeine have a direct effect on blood pressure control for adolescents who consume amounts of caffeine similar to levels consumed by adults? Second, does high soft drink consumption indicate an array of dietary and lifestyle practices that together increase the risk of developing hypertension? Further research is needed to separate the direct effect of caffeine on blood pressure from soft drink consumption as 1 of several lifestyle behaviors associated with the risk of hypertension among young African Americans.

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