Ethnicity, Pressor Reactivity, and Children's Blood Pressure
Five Years of Observations
Joseph K. Murphy, Bruce S. Alpert, and Sammie S. Walker

During the 5 years of this investigation, resting blood pressure and pressor reactivity were measured in 292 white children and 46 black children in 1987, 1988, 1989, and 1991. In 1987, all children were in the third grade; in 1991, the children were in the seventh grade. Reactivity was assessed with a standardized psychological stressor, a television video game. Children displayed significant stability of absolute blood pressure and heart rate reactivity between grades 3 and 7. At all examinations, black children demonstrated blood pressure reactivity that was significantly greater in magnitude (both absolute level and change from resting measurements) than that of white children. Black children exhibited significantly greater heart rate reactivity only when defined as change from the resting measurements; absolute levels of heart rate reactivity were comparable for blacks and whites. For black children, blood pressure reactivity in 1987 was the strongest predictor of resting blood pressure (both systolic and diastolic) in 1991. Among white children, resting blood pressure was the strongest predictor of future resting blood pressure. Further research is needed to determine if ethnic differences in children's pressor reactivity are associated with ethnic differences in the prevalence of hypertension.

KEY WORDS • ethnic groups • blood pressure • heart rate

Although several studies have shown the magnitude of pressor reactivity to be related to subsequent blood pressure (BP) and the development of hypertension, results have not been consistent, and the relevance of reactivity to subsequent BP has not been established. However, these studies have failed to examine the stability of pressor responses; unreliable responses could contribute to inconsistent results. In addition, previous research has not examined the influence of ethnicity on the association between reactivity and subsequent BP, despite black-white differences in both the magnitude of reactivity and the prevalence of hypertension. The present investigation sought to elucidate the associations among ethnicity, reactivity, and BP in a cohort of school children; reactivity examinations have been a feature of the study since 1987. We have focused our studies on children and adolescents because the precursors of cardiovascular disease have their origins in childhood.

Methods

Subjects

Eligible subjects for this study were all children who in 1987 were enrolled in the third grade at the public schools in Obion County, Tennessee (n=484). In the first year of study, BP and heart rate (HR) measurements both at rest and during a television video game were obtained from 474 children who were black (n=68) or white (n=406). The present study reports on children who were subsequently examined in 1988 (fourth grade), 1989 (fifth grade), and 1991 (seventh grade). The sample was composed of 46 black children and 292 white children (71.3% of the initial sample). In grade 3, the longitudinal sample did not differ from children who were lost to follow-up in resting BP and HR, video game BP and HR, or Quetelet index (kg/m², all p>0.05). Children lost to follow-up were, however, older, i.e., 9.3 versus 9.2 years in grade 3 (p=0.05).

Procedures

All procedures were reviewed and approved by the institutional review board and the school boards of participating schools. Examinations, described previously, were conducted in the schools during regular school hours. Because examinations were considered part of the school health curriculum, a passive consent procedure was used. Each year, schools and families were notified of examination dates and parents who did not wish to have their child participate were to notify the investigators or the school; none did. In 1987, eight schools were visited between February and May. In subsequent years, seven schools were visited between

From the Department of Psychiatry and Human Behavior (J.K.M.), The Miriam Hospital and Brown University School of Medicine, the Department of Pediatrics (B.S.A.), University of Tennessee, Memphis, and the West Tennessee Regional Health Office (S.S.W.).

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Address for correspondence: Joseph K. Murphy, PhD, Division of Behavioral Medicine, The Miriam Hospital, 164 Summit Avenue, Providence, RI 02906.

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January and April. The reduction in the number of schools was due to a consolidation of two schools. Examinations were not conducted in 1990 due to a lapse in funding.

Procedures were very similar in each of the 4 years. Briefly, each student was dismissed from classroom activities for the evaluation. Upon reporting to the examination room, an empty classroom, students identified themselves and their record was located. The examination began with the measurement of height (anthropometric measuring board) and weight (balance beam scale). Students did not wear shoes for height and weight measurements. Next, an appropriate-size BP cuff was attached to the right arm, and children sat quietly for 5 minutes. Then three measurements of BP and HR were obtained at 1-minute intervals with a Dinamap BP monitor (Critikon, Inc., Tampa, Fla.). Dinamap monitors have been shown to provide accurate resting measurements (versus intra-arterial recordings), as well as reactivity measurements (versus standard mercury sphygmomanometers).

Children next participated in the reactivity evaluation, which was usually conducted in an adjacent classroom. Children were seated at a table on which the game controller, a rotating dial, was mounted. Children played the video game (Breakout; Atari, Inc., Sunnyvale, Calif.) with their dominant hand. A BP cuff from a second Dinamap monitor was attached to the non-dominant arm. The assistant demonstrated the operation of the game and gave children a brief practice period to familiarize themselves with the game. The video game procedure consisted of three games. In the first game, children were told to play the game to see how they did, i.e., how many points they scored. In the second game, children were instructed to try harder and to beat the score from the first game. In the third game, children were again instructed to try harder and told that if they beat the average score of their classmates they would get a reward of some money. Because all children had to be tested to calculate the average score, children could not be told the score required to earn money. Children exceeding the average score were paid from $1 to $5. Irrespective of video game scores, all children were congratulated on their effort and thanked for their participation.

During each of the three video games, a measurement of BP and HR was initiated after 15–30 seconds of game play. Throughout the measurement cycle, children continued playing the game. If a game was completed before the BP determination, the game was immediately reset and play continued. Occasionally, a second BP measurement was obtained during a game due to sustained play. In such instances, the BP with the higher mean arterial pressure (one third systolic BP plus two thirds diastolic BP) was considered the game BP. The corresponding HR was considered the game HR. Excessive speech and movement were discouraged during the video game procedure. The entire video game procedure lasted approximately 10 minutes.

Statistical Analysis

Each year, resting measurements of BP and HR were averaged. Similarly, the BP and HR measurements from the three video games were averaged. The race-specific stability of resting and reactivity measurements was examined with Pearson product moment correlations between values in 1987 and 1991. The significance of the difference between correlation coefficients was tested with Fisher’s z transformation.

Longitudinal comparisons were made with repeated measures analysis of variance (ANOVA). Ethnicity was a between-subjects effect, and examination year (1987, 1988, 1989, and 1991) was a within-subjects effect. A separate ANOVA was performed for each hemodynamic variable, i.e., systolic BP (SBP), diastolic BP (DBP), and HR. Because previous reports have analyzed reactivity in terms of both absolute values, e.g., HR of 100 beats per minute and Δ values, e.g., HR change from rest of 10 beats per minute, both ANOVAs were performed.

The ability of the reactivity measurements from 1987 to predict resting BP in 1991 was analyzed with stepwise regression procedures. Variables eligible for entry were the corresponding resting BP value (SBP or DBP), resting HR, age, Quetelet index, the appropriate BP reactivity value (measured level), and the HR reactivity value. To avoid collinearity, only systolic measurements were used in systolic models and only diastolic measurements in diastolic models. In the standard forward stepwise regression procedure, the computer selects the one variable from the potential predictors (measurements in 1987) that has the largest F statistic with the modeled variable (resting BP in 1991). In an iterative process, variables are added to the model according to the magnitude of F statistics. Thus, the computer is the decision maker. However, most of the data collected in the present study (resting BP and HR, height, weight, and age) are data that would be collected routinely during a visit to a physician’s office. Therefore, hierarchical regression procedures were also performed with resting BP and HR, Quetelet index, and age entered into the model before the reactivity values. This type of regression permits an evaluation of the additional predictive power that is provided by reactivity measurements.

All tests were two-tailed; values of p<0.05 were considered significant. Analyses were performed with SAS programming.

Results

Resting Measurements

Analyses of resting BP and HR (Table 1) indicated a significant effect for examination year in all three analyses (SBP and DBP, p<0.0001; HR, p<0.02). Both SBP and DBP increased from 1987 to 1991, whereas HR decreased. In addition, Quetelet Index increased significantly (p<0.0001). Finally, race had a significant effect on resting HR (black less than white, p<0.0001). The effects of race on resting SBP and DBP were nonsignificant, as were all interactions between race and year. Resting measurements of BP and HR exhibited significant stability (Table 2; all p<0.01).

Reactivity Measurements

Analysis of absolute video game values (Table 1) indicated significant effects for examination year on SBP, DBP, and HR reactivity (all p<0.001). SBP tended to increase in each examination year, whereas DBP and HR decreased with successive examinations. Race sig-
significantly affected both SBP and DBP reactivity (black greater than white, both \( p<0.006 \)). Blacks and whites had comparable levels of HR during the video game. All interactions were nonsignificant.

With respect to \( \Delta \) values (Table 1), all three hemodynamic variables diminished with repeated examinations (all \( p<0.01 \)). Nonetheless, black children demonstrated greater \( \Delta \) values than white children for SBP, DBP, and HR (all \( p<0.01 \)). Interactions between race and examination year were nonsignificant.

All absolute reactivity measurements exhibited significant stability (Table 2; all \( p<0.01 \)), whereas the stability of black children's BP \( \Delta \) values (0.25 and 0.26) was nonsignificant. More often than not, absolute reactivity was significantly more stable than \( \Delta \) reactivity. In addition, HR reactivity (absolute and \( \Delta \)) of black children was significantly more stable than that of white children.

**Prediction of Follow-up Blood Pressure**

Regression of 1987 measurements on resting BP in 1991 indicated that video game measurements in 1987 were the best predictors of black children's future BP levels (Table 3). The measurements of resting BP were secondary to the reactivity measurements. The sum of the partial \( R^2 \) for blacks' SBP (0.39) and DBP (0.31) represent multiple correlations of 0.62 and 0.56, respect-

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**TABLE 1. Blood Pressure, Heart Rate, and Quetelet Index by Race and Examination Year**

<table>
<thead>
<tr>
<th></th>
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<tbody>
<tr>
<td>Black SBP (mm Hg)</td>
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<td></td>
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<tr>
<td>Video</td>
<td>120.8±10.8</td>
<td>122.2±10.0</td>
<td>122.4±10.7</td>
<td>126.2±11.6</td>
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<tr>
<td>Rest</td>
<td>103.1±7.6</td>
<td>112.1±8.0</td>
<td>111.2±9.9</td>
<td>115.4±9.5</td>
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<tr>
<td>( \Delta )</td>
<td>17.7±9.0</td>
<td>10.1±7.8</td>
<td>11.2±8.7</td>
<td>10.8±9.8</td>
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<tr>
<td>DBP (mm Hg)</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Video</td>
<td>71.4±9.1</td>
<td>72.1±10.1</td>
<td>69.0±8.6</td>
<td>68.8±9.2</td>
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<tr>
<td>Rest</td>
<td>57.5±5.5</td>
<td>62.9±6.8</td>
<td>60.7±7.5</td>
<td>61.2±7.7</td>
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<tr>
<td>( \Delta )</td>
<td>13.9±8.4</td>
<td>9.3±10.5</td>
<td>8.3±7.9</td>
<td>7.5±8.6</td>
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<td>HR (bpm)</td>
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<td></td>
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<tr>
<td>Video</td>
<td>96.6±13.2</td>
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<td>95.7±16.2</td>
<td>90.4±17.8</td>
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<td>Rest</td>
<td>84.5±11.3</td>
<td>81.5±10.8</td>
<td>81.4±10.7</td>
<td>81.0±13.8</td>
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<tr>
<td>( \Delta )</td>
<td>12.1±10.3</td>
<td>15.7±13.8</td>
<td>14.3±13.5</td>
<td>9.5±12.8</td>
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<td>Quetelet index (kg/m²)</td>
<td>18.4±3.4</td>
<td>19.2±3.8</td>
<td>20.0±4.5</td>
<td>21.8±4.9</td>
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<td>White SBP (mm Hg)</td>
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<tr>
<td>Video</td>
<td>115.5±9.7</td>
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<td>117.9±10.1</td>
<td>122.4±10.6</td>
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<tr>
<td>Rest</td>
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<td>111.5±9.5</td>
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<td>( \Delta )</td>
<td>11.0±8.7</td>
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<td>6.3±8.7</td>
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<td>DBP (mm Hg)</td>
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<td>Video</td>
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<td>66.9±8.0</td>
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<td>Rest</td>
<td>58.9±6.6</td>
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<tr>
<td>( \Delta )</td>
<td>8.9±8.6</td>
<td>4.4±7.1</td>
<td>4.3±7.5</td>
<td>4.0±8.5</td>
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<tr>
<td>HR (bpm)</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Video</td>
<td>97.7±13.7</td>
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<td>97.3±14.0</td>
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<td>Rest</td>
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<td>88.7±11.1</td>
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<td>85.5±12.2</td>
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<tr>
<td>( \Delta )</td>
<td>9.2±8.8</td>
<td>8.5±10.2</td>
<td>8.6±10.0</td>
<td>4.8±9.1</td>
</tr>
<tr>
<td>Quetelet index (kg/m²)</td>
<td>18.3±3.2</td>
<td>19.1±3.6</td>
<td>19.8±4.3</td>
<td>21.7±4.6</td>
</tr>
</tbody>
</table>

SBP, systolic blood pressure; DBP, diastolic blood pressure; HR, heart rate; bpm, beats per minute; \( \Delta \), video value minus resting value. Values are mean±SD.

**TABLE 2. Pearson Correlation Coefficients for Resting and Video Game Blood Pressure and Heart Rate in Grades 3 and 7 by Race**

<table>
<thead>
<tr>
<th>Race</th>
<th>HR Rest</th>
<th>Absolute video</th>
<th>( \Delta ) Video</th>
<th>SBP Rest</th>
<th>Absolute video</th>
<th>( \Delta ) Video</th>
<th>DBP Rest</th>
<th>Absolute video</th>
<th>( \Delta ) Video</th>
</tr>
</thead>
<tbody>
<tr>
<td>Black</td>
<td>0.52†</td>
<td>0.76†∗§</td>
<td>0.64†∗§</td>
<td>0.42†</td>
<td>0.67†§</td>
<td>0.25†</td>
<td>0.44†</td>
<td>0.55†∗§</td>
<td>0.26†</td>
</tr>
<tr>
<td>White</td>
<td>0.38‡</td>
<td>0.54†</td>
<td>0.41†§</td>
<td>0.51‡</td>
<td>0.56†</td>
<td>0.18‡</td>
<td>0.48‡</td>
<td>0.46‡§</td>
<td>0.32†</td>
</tr>
</tbody>
</table>

HR, heart rate; SBP, systolic blood pressure; DBP, diastolic blood pressure. All values were significant at the p<0.01 level except where indicated otherwise.

†‡§ Different superscripts denote \( p<0.05 \) within the row.

†ª§ Significant ethnic difference within the column.

‡Nonsignificant.
Discussion

These data indicate the black children's BP and HR responses to a standardized psychological stressor are different from the responses of white children. Black children's BP reactivity responses, whether measured as absolute levels or as changes from resting levels, were significantly greater than white children's responses. As shown in Table 1, black-white differences in SBP reactivity ranged from 2.3 to 6.7 mm Hg (SBP-video in 1988) to 2.9 to 7.2 mm Hg (SBP-D in 1987). Black-white differences in DBP reactivity ranged from 1.9 to 6.7 mm Hg (DBP-video in 1988) to 1.9 to 7.2 mm Hg (DBP-D in 1987). Although absolute levels of HR reactivity were comparable for blacks and whites, black children's HR Δ values were significantly greater than those of white children. The black-white differences in HR Δ values ranged from 2.7 beats per minute in 1987 to 7.2 beats per minute in 1988. Although Δ values for both blacks and whites tended to decrease with successive examinations, the differences between blacks and whites were enduring, i.e., interactions between race and time were nonsignificant. Although several large-sample childhood studies have reported black-white differences in pressor reactivity, reactivity examinations were not repeated in these investigations. Thus, we cannot say with any certainty that the stability of black-white reactivity differences shown in this study are either idiosyncratic to this sample and this video game procedure or can be generalized to other samples and other pressor procedures. In addition, our data indicated that both resting and absolute reactivity measurements demonstrated significant stability over the 5 years of study. The generally greater stability of resting and absolute reactivity compared with Δ reactivity extends earlier results. Nonetheless, measurements exhibited only moderate reproducibility with only one grade 3 measurement associated with more than 50% of the variance in grade 7 measurements (black children's absolute video heart rate; Table 2). These data, although comparable to other longitudinal childhood studies, point to the difficulty in predicting children's BP. Reactivity studies have been based, in part, on the premise that reactivity measurements may enhance prediction.

Our previous cross-sectional and longitudinal reports have been consistent in demonstrating greater reactivity among black children than among white children. Generally, other studies of race and reactivity have reported that blacks exhibit greater reactivity than whites. We have hypothesized that the greater reactivity of black children may be related to the greater prevalence of hypertension among black adults. Results indicating that the reactivity measurements were the best predictors of black children's future SBP and DBP provide further evidence of ethnic differences in BP regulation before differences in resting BP. In the hierarchical regression analysis with resting BP and HR, Quetelet index, and age entered before the reactivity measurements, the reactivity measurements continued to be stronger predictors of black children's BP than...
that of white children. As with our data indicating that black–white differences in reactivity were stable over multiple examinations, longitudinal studies of the effects of ethnicity and reactivity on the prediction of children's BP are lacking. The Bogalusa Heart Study provided 2-year follow-up data indicating that reactivity was a significant predictor of children's BP but did not examine the effects of ethnicity. Other investigations of black adolescents with borderline hypertension and black, normotensive adults have provided contradictory evidence.3,29

Despite the consistency of our studies, as of 1991 ethic differences in resting BP were not evident. At the same time, the lack of differences was not unexpected; the most recent report of the Task Force on Blood Pressure Control in Children did not find that ethnicity was associated with BP.15 Ethnic differences in resting BP may not emerge until late adolescence or early adulthood and then increase with advancing age.30,31 Although the results of this investigation suggest that reactivity is more important to BP regulation in blacks than in whites, we do not hypothesize that the relevance of reactivity is race-specific. Studies of sympathetic function, the putative mechanism linking reactivity with subsequent BP, have infrequently examined ethnicity22–34; the presence of ethnic differences in sympathetic function has yet to be established.35,36 In the present investigation, both SBP and HR reactivity were significant predictors of white children's SBP. Other investigations of both black children and white adults have shown reactivity to be a significant predictor of future BP.3,4,5 Thus, ethnic differences in reactivity may resemble differences shown for other variables potentially associated with BP regulation.37–39

As opposed to the positive associations between BP reactivity and future BP, HR reactivity was negatively associated with future SBP for both blacks and whites (negative β in Tables 3 and 4). In light of evidence indicating that both resting HR and HR reactivity were positively associated with BP,40–42 this result was unexpected. Although this evidence has not been consistent,43 a statistical explanation for the negative association shown in the present study may be most parsimonious. For both blacks and whites, HR reactivity and SBP reactivity in grade 3 were correlated significantly (r = 0.37 and 0.24, respectively). In contrast, the correlations between HR reactivity and resting BP in grade 7 were negative and nonsignificant for both blacks and whites, r = -0.06 and -0.11, respectively. These correlations suggest a degree of multicollinearity and the significant negative β weights may represent a suppressor effect between HR and SBP reactivity.

We have mentioned previously our concern with the lack of comparable data on the stability of black–white differences in reactivity. Another consideration in the evaluation of our results is the number of black children in our sample. Although the percentage of blacks in our sample, 46 of 338 (13.6%), slightly exceeds the percentage of black residents of the United States,44 these data may have limitations. A third consideration is the small number of potential predictors of BP that were examined. Though constrained by finances, personnel, and the need to perform examinations expeditiously, the measurement of additional variables, e.g., cation transport45 or socioeconomic status,46 might have altered the results. Despite these limitations, the data were consistent: black children demonstrated greater pressor reactivity than white children at every examination, and pressor reactivity was more strongly associated in blacks than whites with future BP. Further research is needed to document the role of pressor reactivity within the mosaic of BP risk factors and the development of hypertension.

Acknowledgments

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References


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