Race and Sex Differences in the Correlates of Blood Pressure Change

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SUMMARY Potential predictors of systolic and diastolic blood pressure change between 1960 and 1967 in the biracial population of Evans County, Georgia, were investigated. An all possible regressions multiple linear regression analysis was used. For systolic blood pressure change, the level of systolic blood pressure, age, and change in Quetelet index were significant (p < 0.05) correlates in white men. The level of systolic blood pressure, the level and change of socioeconomic status, change in Quetelet index, and change in cholesterol were significant correlates for white women. The level of Quetelet index was of borderline significance (p < 0.055) when the other significant variables were included in the model for white women. The change in Quetelet index was the only significant correlate of systolic blood pressure change in blacks. For diastolic blood pressure change, age, change in hematocrit, and change in Quetelet index were significant correlates for white men. Age, level and change of socioeconomic status, level and change of Quetelet index, and change in hematocrit were the significant correlates in white women. In black men, change in Quetelet index and age were significant. In black women, only age was a significant correlate of diastolic blood pressure change. These results indicate that there may be important differences in these correlates between race-sex groups and thus in the mechanism of blood pressure change for different race-sex groups.

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KEY WORDS
race • sex
blood pressure • systolic blood pressure • diastolic blood pressure •
Quetelet index

ELEVATED blood pressure has been shown to be a major risk factor for cardiovascular disease morbidity and mortality. 1-4 Epidemiological studies have shown that blood pressure is continuously distributed in populations, with the associated risk of morbidity and mortality increasing as blood pressure levels increase.4 In a number of studies, age, sex, race, obesity, heart rate, blood glucose, hematocrit, and socioeconomic status have been shown to correlate with blood pressure levels.5-13

Blood pressure levels in individuals are not static, however. Most of the studies on the determinants of the level of blood pressure have been cross-sectional in design, so it has not been possible to study how these factors correlate with changes in blood pressure over time. In the longitudinal studies that have been done, initial level of blood pressure, baseline weight, change in weight, baseline skinfold thickness, body mass index, baseline hematocrit, and age were found to be correlates of change in blood pressure.14-15 These longitudinal blood pressure studies have studied only white men who were normotensive at the onset of the study. The Evans County (GA, USA) Study provides the opportunity to study differences in the correlates of blood pressure change among the four major race-sex groups with subjects representing the entire range of blood pressure at the initiation of the study.

Subjects and Methods
The study population consists of the adult residents of a biracial southeastern community, Evans County, Georgia. At the initiation of the study in 1960, a 100% sample of residents aged 40 to 80 years and a 50% random sample of residents aged 15 to 39 years were invited to participate. Of the 3371 eligible, 3102 (92%) participated in the initial phase of the study and received a complete medical examination. Of the origi-
nal 3102 subjects, 2530 (81%) were reexamined in 1967–1969. Of those not reexamined, 320 had died, 157 had moved away, 55 refused to participate, and 40 could not be located. Black men had the lowest frequency of reexamination (83.2%), while white women had the highest (94.3%). Younger subjects and black subjects were more likely to have migrated out of the county between the two examinations. A detailed description of the study population has been presented elsewhere.16

Measurements obtained in both 1960–1962 and 1967–1969 include systolic and diastolic blood pressure (mm Hg), age (years), height (inches), weight (pounds), hematocrit, serum cholesterol (mg/dl), and socioeconomic status. Blood pressure was measured in the left arm with the subject seated. A standard mercury sphygmomanometer with appropriate size cuff was used. Blood pressure was measured by the examining physician. In 1960–1962, a single blood pressure measurement was made. In 1967–1969, three blood pressure readings were performed. For the purposes of this investigation, the first reading from the 1967–1969 examination was compared with the single reading taken in 1960–1962. Serum cholesterol was measured in both phases of the study after clot retraction by means of a modified Abell-Kendall method standardized by the Centers for Disease Control (Atlanta, GA, USA).17 Hematocrit was measured in both phases by a microhematocrit centrifuge technique. The Quetelet index of body mass (100 × weight/height²) was determined for each subject in both phases of the study. Socioeconomic status was measured in both phases using the McGuire-White index, which is a modified Warner scale adapted for rural populations (McGuire C., White G.D., unpublished observations, 1955). The composite index, which ranges from 12 (highest status) to 84 (lowest status), is derived by weighting scores on three prestige scales: occupation, education, and income. In the 1960–1962 examination, the socioeconomic status of the head of the household was measured; in 1967–1969 the socioeconomic status of each subject was measured.

Heart rate values were available only from the 1960–1962 phase of the study. Fasting blood glucose levels were obtained only in the 1967–1969 phase.

Difference or change variables were derived for each subject for each variable that was measured in both phases of the study by subtracting the 1960–1962 value from the 1967–1969 value. To minimize the effects of regression to the mean, level variables were derived by taking the mean of the two measurements from 1960–1962 and 1967–1969.18 As Peto19 has suggested, it is usually more valid to study the relationship between the rate of change in a set of measurements and the mean of all the measurements than to study the correlation between the initial value and the subsequent rate of change. For variables that were measured only once, that value was used in the analysis.

After stratification by race and sex, an all possible regressions multiple regression analysis was used to test the relationship of the independent baseline, level, and change variables to the two dependent variables, systolic and diastolic blood pressure change. The independent variables included the level value of the blood pressure change variable being studied (e.g., the level of systolic blood pressure was used for the analysis of systolic pressure change), age, baseline value for heart rate and fasting blood glucose, level and change of Quetelet index, level and change of hematocrit, level and change of serum cholesterol, and level and change of socioeconomic status.

The hypothesis tested was whether any of the independent, baseline, level, or change variables had a significant effect on systolic or diastolic blood pressure change (or on both). For each race-sex group, the model that best explained the variance of the dependent variable and contained only independent variables with regression coefficients significantly (p < 0.05) different from zero was chosen. In this analysis, each independent variable had an equal chance to enter the model for systolic or diastolic blood pressure change (or both) in each race-sex group.

**Results**

Descriptive data for systolic and diastolic blood pressure as well as selected independent variables at Survey Points 1 (1960) and 2 (1967) are presented in Table 1. The change in systolic and diastolic blood pressure in each race-sex group over the period of the study is shown in Table 2. There were significant mean increases in systolic blood pressure during the study for each race-sex group except black women. For diastolic blood pressure, white men and women showed an average increase, while blacks demonstrated an average decrease. None of the changes in diastolic pressure was statistically significantly different from zero, however.

The best regression model for explaining the variation of systolic and diastolic blood pressure change in each race-sex group is presented in Tables 3 and 4. The number of subjects may differ between the systolic and diastolic blood pressure analyses within a race-sex group due to differences in missing data for the different independent variables included in the models. In this analysis, a positive regression coefficient for an independent baseline or level variable indicates that higher levels are associated with greater increase in the dependent variable (blood pressure). A negative regression coefficient for an independent baseline or level variable means that higher levels of that variable are associated with greater decrease in the dependent variable. A positive regression coefficient for an independent change variable indicates that an increase in that variable is related to an increase in the dependent variable. A negative regression coefficient for an independent change variable signifies that an increase in that independent variable is associated with a decrease in the dependent variable. In addition, when the regression coefficient is larger for a particular independent variable in one race-sex group compared with another, the influence of that independent variable on blood pressure change is greater for that group.
The change in the Quetelet index was a significant correlate of systolic blood pressure change in all four race-sex groups (see Table 3). This was the only significant correlate for blacks. The level of systolic blood pressure was also a significant correlate of systolic blood pressure change in whites. The additional correlate for white men was age at baseline. For white women, the level and change of socioeconomic status and the change in cholesterol level were also significant correlates of systolic blood pressure change, whereas the level of the Quetelet index was of borderline significance (p = 0.054) when the other significant independent variables were included in the regression model.

The best model for explaining the variance of diastolic blood pressure change in each of the four race-sex groups is shown in Table 4. Age was a significant correlate of diastolic blood pressure change for each race-sex group and was the only significant correlate for black women. The change in the Quetelet index was a significant correlate of diastolic blood pressure change in every race-sex group except black women. For whites, the change in hematocrit was also a significant correlate of diastolic pressure change. The additional significant correlates for white women were the level of the Quetelet index and the level and change of socioeconomic status.

Variables that were significant correlates of systolic or diastolic blood pressure change (or both) for each race-sex group are presented in matrix form in Table 5.

The level of hematocrit and cholesterol and baseline values of heart rate and fasting blood glucose were not found to be correlates of either systolic or diastolic blood pressure change in any of the four race-sex groups.

**Discussion**

Much attention has been focused on the observed decline in cardiovascular disease mortality. The decline is well established in the four major race-sex groups in the United States, 21-22. One explanation offered for this decline has been the change in risk factor status in the population.22 For this and other public health–related reasons, it is important to identify potential determinants of risk factor change and discover whether these determinants are the same for the different race-sex groups. Blacks have hypertension more frequently than do whites, and the mechanisms for the development of essential hypertension may be different for blacks. 25-26 To our knowledge, no study has previously investigated race-sex differences in correlates of change in blood pressure. These data from a prospective study of a biracial population provide information on the factors associated with change in systolic and diastolic blood pressure.

The change in the Quetelet index was a significant positive correlate of systolic blood pressure change in all four race-sex groups and was also a significant positive correlate of diastolic blood pressure change in all groups except black women. In all groups, the positive regression coefficient for the change in the Quetelet index indicates that an increase in the Quetelet index was a significant correlate of systolic blood pressure change in all four race-sex groups (see Table 3). This was the only significant correlate for blacks. The level of systolic blood pressure was also a significant correlate of systolic blood pressure change in whites. The additional correlate for white men was age at baseline. For white women, the level and change of socioeconomic status and the change in cholesterol level were also significant correlates of systolic blood pressure change, whereas the level of the Quetelet index was of borderline significance (p = 0.054) when the other significant independent variables were included in the regression model.

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TABLE 3. Multiple Linear Regression Coefficients for Systolic Blood Pressure Change and Significant (5% Level) Independent Variables

<table>
<thead>
<tr>
<th>Independent variable</th>
<th>Coefficient</th>
<th>SEM</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>White men (n = 656; multiple r = 0.217)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intercept</td>
<td>-14.9</td>
<td>5.32</td>
<td>&lt;0.005</td>
</tr>
<tr>
<td>Level of systolic blood pressure (mm Hg)</td>
<td>0.09</td>
<td>0.04</td>
<td>&lt;0.025</td>
</tr>
<tr>
<td>Change in Quetelet index</td>
<td>11.59</td>
<td>2.48</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Age (yr)</td>
<td>-0.15</td>
<td>0.06</td>
<td>&lt;0.011</td>
</tr>
<tr>
<td>White women (n = 708; multiple r = 0.285)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intercept</td>
<td>-13.2</td>
<td>5.69</td>
<td>&lt;0.020</td>
</tr>
<tr>
<td>Level of systolic blood pressure (mm Hg)</td>
<td>0.12</td>
<td>0.03</td>
<td>&lt;0.0006</td>
</tr>
<tr>
<td>Level of socioeconomic status*</td>
<td>-0.94*</td>
<td>0.36</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>Change in socioeconomic status*</td>
<td>-0.47</td>
<td>0.19</td>
<td>&lt;0.015</td>
</tr>
<tr>
<td>Change in cholesterol (mg/dl)</td>
<td>0.04</td>
<td>0.02</td>
<td>&lt;0.025</td>
</tr>
<tr>
<td>Change in Quetelet index</td>
<td>12.44</td>
<td>2.20</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Level of Quetelet index</td>
<td>2.15</td>
<td>1.12</td>
<td>&lt;0.055</td>
</tr>
<tr>
<td>Black men (n = 295; multiple r = 0.152)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intercept</td>
<td>3.69</td>
<td>1.56</td>
<td>&lt;0.02</td>
</tr>
<tr>
<td>Change in Quetelet index</td>
<td>12.76</td>
<td>4.81</td>
<td>&lt;0.0085</td>
</tr>
<tr>
<td>Black women (n = 423; multiple r = 0.095)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intercept</td>
<td>1.95</td>
<td>1.30</td>
<td>&gt;0.10</td>
</tr>
<tr>
<td>Change in Quetelet index</td>
<td>5.32</td>
<td>2.69</td>
<td>&lt;0.05</td>
</tr>
</tbody>
</table>

Multiple r = multiple correlation coefficient. Quetelet index = 100 x weight/height^2.
*Unit of measurement described in Subjects and Methods.

Let index was associated with an increase in blood pressure. The regression coefficients for the change in the Quetelet index for whites and black men were about twice the magnitude of the coefficient for black women. This finding suggests that, after controlling for the other significant variables, the change in the Quetelet index has less importance in systolic blood pressure change for black women than for the other race-sex groups. Harlan et al.14 noted that weight change was correlated with change in systolic and diastolic blood pressure in white men.

In the present study, the level of the Quetelet index was also a positive independent correlate of both systolic and diastolic blood pressure change only for white women. Sparrow et al.15 found that baseline skinfold thickness was associated with systolic pressure change, while baseline body mass index was associated with diastolic pressure change in white men. However, they did not investigate the change in these measures of ponderosity over time.

Although the epidemiological association between obesity and level of blood pressure has been well established,27 the pathophysiological mechanism by which obesity influences blood pressure is not completely understood. The mass of fat may play a role in raising blood pressure by raising cardiac output with a...
Our findings suggest that an increase in ponderosity may be more important than the level of ponderosity in the change of blood pressure. It appears to have a greater effect on whites and black men than on black women. Clinical trials of weight reduction and its effects on blood pressure may help to further evaluate this relationship.

The level of systolic blood pressure was a significant positive correlate of systolic blood pressure change for whites in our study. Age at the initiation of this study was a significant negative correlate of systolic blood pressure change for white men, but not for the other three groups. Age was a significant negative correlate of change in diastolic blood pressure for all four groups. This means that a younger age at baseline was associated with a greater increase in diastolic blood pressure.

A relationship among baseline blood pressure, age, and follow-up blood pressure levels has been previously reported. However, the reported results are not consistent in all studies. Sparrow et al. showed both age and the baseline systolic blood pressure to be associated with systolic pressure change in white men. They also found that baseline diastolic blood pressure, but not age, was associated with diastolic blood pressure change. Svardssudd and Tibblin reported a positive relationship between initial level and change in systolic pressure, but a negative one for diastolic blood pressure. Wu et al. found a positive association between the initial level and subsequent change in systolic pressure. Hofman and Valkenburg reported a negative correlation between initial levels of both systolic and diastolic blood pressure and subsequent blood pressure change in white children aged 5 to 19 years after adjustment for regression to the mean.

The level and change of socioeconomic status were significant correlates of both systolic and diastolic blood pressure change in white women. The scale for socioeconomic status uses lower numbers to indicate higher status. Therefore, the negative regression coefficients indicate that a low socioeconomic status or a decrease in socioeconomic status (or both) was associated with a decrease in blood pressure for white women. The change in cholesterol level was a positive correlate of systolic blood pressure change in white women. These two variables, along with the level and change in the Quetelet index, may reflect dietary habits. These factors were significant after adjustment for body mass, which suggests that components of diet other than caloric content may be important in systolic and diastolic blood pressure change. These findings indicate that these dietary factors may have more importance in the change of blood pressure for white women than for other race-sex groups. One factor not included in the study that may have importance and should be investigated further is the use of alcohol and changes in alcohol use.

Sparrow et al. found that baseline hematocrit was associated with both systolic and diastolic blood pressure change in white men. In the present study, the level of hematocrit was not found to be a significant correlate of blood pressure change in any race-sex group. We did find that an increase in hematocrit was associated with an increase in diastolic blood pressure in whites. The relationship of hematocrit to blood pressure is not well understood. In the Framingham Study, there was a stronger association between hematocrit and diastolic blood pressure than for systolic pressure. The hematocrit may reflect underlying changes in blood volume or a relationship between blood pressure and the production or destruction of red blood cells. Hematocrit may also be sensitive to smoking status and could be a marker of smoking. However, smoking has been shown not to be a significant correlate of either systolic or diastolic blood pressure change in Evans County.

There are potential sources of bias in this study. The problem of losses to follow-up presents the possibility of selection bias. Lost subjects included those who died between the two phases of the study, those who moved away, those who could not be located, those who refused reexamination, and those who had missing values for one of the variables studied. However, as the magnitude of this loss was relatively small in the Evans County Study, it is unlikely that significant bias was introduced.

Another potential source of bias is the use of antihypertensive medication by the subjects. However, Heyden et al. reported that only 6.5% of hypertensive white subjects and 4.6% of hypertensive black subjects had effective control of hypertension in Evans County in 1967–1969. Antihypertensive medication was reported as a probable reason for decreased blood pressure in only five of 21 whites and six of 20 blacks surveyed. Nevertheless, ineffective use of medication to lower blood pressure may have modified the blood pressure change in some subjects. Unfortunately, the Evans County data do not include specific information on antihypertensive use for each subject and so do not allow investigation of the use of antihypertensive medication as an independent variable. Some of the
significant correlates of blood pressure change observed in this study, such as ponderosity, confirm current thought on nonpharmacological prevention and treatment of elevated blood pressure. However, the systematic use of these measures to treat hypertension was also uncommon in Evans County during the study period.

Sample sizes of the four race-sex groups were not equal, which may affect the statistical significance of the independent variables. Although the sample size for each group was relatively large, the larger sample size for white women and men may have allowed the regression coefficients of certain variables to reach statistical significance for those groups, but not for blacks. It is unlikely that this had a major effect on the results of the study. The magnitude of the regression coefficients for variables that were significant for whites but not for blacks was not similar. Furthermore, variables of borderline significance were allowed to enter the regression models.

As has often been the case in previous studies of the correlates of blood pressure, the multiple correlation coefficient (multiple r) for each of the models was relatively low, indicating that a large portion of the variance of both systolic and diastolic blood pressure change remains unexplained by these models. This suggests that other factors, such as diet, exercise, and family history, which were not included in the study, may be important determinants of blood pressure change. Another reason for not explaining a large portion of the variance in blood pressure change may be due to measurement error, since only single blood pressure values were used for each subject at each examination.

The Evans County Study offers a unique opportunity to examine a free-living biracial population before the widespread, systematic use of pharmacological and nonpharmacological interventions to lower blood pressure. We observed that certain predictors of blood pressure change are common to most race-sex groups. For example, the change in the Quetelet index is a predictor of change in both systolic and diastolic blood pressure for each race-sex group except black women. However, the range of the regression coefficients indicates that the strength of the association is not the same for each group. Age was a consistent correlate for each race-sex group for diastolic, but not systolic, blood pressure change. For other variables, there was a considerable difference in their ability to predict change in blood pressure between race-sex groups. We believe these findings represent differences in the mechanisms and natural history of blood pressure change between race-sex groups. It may be possible to test this hypothesis by examining the relative effectiveness of various nonpharmacological interventions to prevent and treat elevated blood pressure between the race-sex groups. Further study and elucidation of these mechanisms may provide useful information for the development of different strategies to prevent and treat blood pressure elevation in the different race-sex groups.
Race and sex differences in the correlates of blood pressure change.
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