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HEREDITY, STRESS AND BLOOD PRESSURE, A FAMILY SET METHOD—II

RESULTS OF BLOOD PRESSURE MEASUREMENT*

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Abstract—This second article, in a series of five, reports the blood pressure of the family set sample, excluding spouse of index, $N = 1844$ persons or 461 family sets. The blood pressures of members of these sets were tested for known correlates, specifically, sex, race, age and present overweight. Statistically significant relations were obtained between elevated pressure, both systolic and diastolic, and sex, race, age and per cent overweight. Age and per cent overweight appear as the most consistent predictors of blood pressure variance across sex–race groups among all continuous variables studied. In this sample, there was a higher per cent of diastolic hypertensive pressures than systolic in all race–sex groups. These findings are important in establishing conformity of results with other studies, but more pertinent, the analyses describe certain critical influences on blood pressure which can be adjusted for or taken into account in estimating the influence of a genetic factor on blood pressure.

INTRODUCTION

IN THIS article we describe the blood pressure of the family set sample used in analyzing the familial and genetic aspects of blood pressure to be reported in subsequent articles in this series [1–3]. It is important that the blood pressure results in the family set sample be compared to other known correlates, e.g. age, weight, sex and race in order to test for external validity. The specific aims of the second article in this series therefore, are to describe the measurement of blood pressure, explore its variability due to uncontrolled factors, show its distribution in the family set sample used for analyses of hereditary traits, and compare results with other studies. The larger objective pursued in the Project is to estimate the

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contribution of heredity directly to blood pressure variations, and provide a method of inquiry for other investigators to partition heredity and environmental factors related to other biological and behavioral events [4].

METHOD

The design and sample have been described in the first article [5]. Briefly, the City of Detroit's census tracts were divided into majority black and white tracts, then rank ordered by a socioecological stressor score derived from factor analyses of rates indicating quality of life variables. Four areas were selected from the top and bottom quartiles of stressor scores—a black high stress area, a black low stress, white high stress, and white low stress [6]. Each area was censused and screened for potential index persons. These persons were married and living with a spouse, aged 30–55, resident of the area, and had a sibling and first cousin within 6 yr of age who resided in the greater Detroit area. Interviewers were then sent to verify these traits, and list the relatives by age and address. Sibs and first cousins nearest in age to their index person were selected for verification and finally a list of verified family sets was sampled. Nurse interviewers then obtained an interview and a blood pressure reading from each of five persons in the family set which included: the Index, Spouse, Sib, First Cousin and an Unrelated person who was matched to the Index on race, sex, age, and residential area. Starting from index persons in each of the four stress areas, 461 family sets or 2305 persons were interviewed. All persons in *completed* family sets, that is, index, spouse, sib, first cousin, unrelated persons, we call the Family Set Sample. Index persons from each area were also balanced for sex and were of similar mean age. In each family set, however, it should be noted that the sex, marital and socio-economic status of the sibs and cousins were allowed to vary. Methods of adjusting statistically for these variation as they may relate to blood pressure are discussed elsewhere [2].

Measurement of blood pressure

A number of nurse applicants were considered for work on the Project. Nurses who had any fears of working in high stress areas, or who were unable to properly complete and edit pretest interviews or achieve high reliability with the nurse supervisor based on double-stethoscope blood pressure readings across several subjects, were screened out. Only those nurses who passed these criteria formed the team which carried out the 9-month data collection (October 1968–June 1969). This team consisted of 15 female nurse-interviewers who were subsequently given a minimum of 20 hr of training in both survey technique and standard blood pressure technique [7].

A Latin-Square design was executed before field work by the 15 staff nurses on 15 subjects who varied by age, race and sex in a classroom setting to test for both (a) nurse, and (b) instrument differences. Data not shown indicate that no significant differences in the classroom were found for either the effects of nurse variation or instrument for either systolic of diastolic pressures. However, for readings in the home during field work, digit-preference differences were present, with the usual preference for '0' in both systolic and diastolic readings, i.e. about 29% readings of zero for each of three diastolic readings, and 26%

for systolic readings. The low order of these per cents attests to the quality control and intensive training of the nurse observers. It bears repeating that nurse assignment to all respondents was designed such that the nurses were randomly assigned by time of day, and alternated between residence areas weekly, and were randomly assigned to family set members.

Readings in the home were taken at the start of the interview, about 10 min later, and again, about 10 min later during the first half hour of medical history. A standard new Baumanometer (mercury sphygmomanometer) was used, with Velcro cuff (at heart level), and all parts were checked each day for effectiveness [8]; nurse performance was quality controlled at various time-points during the data collection by double stethoscope readings with the supervisor. Readings to the nearest 2 mm in the home were taken on the left arm, with the respondent seated and arm resting on a table. First, a palpatory pressure was read to relax the person and allow the nurse to estimate the initial systolic reading. Next, an ausculatory reading was taken; systolic was recorded at the first sound, and diastolic at the cessation of sound, or fifth Korotkoff point. At the end of the interview, two more readings were taken.

Table 1 displays the means, standard deviations and range of intercorrelations among the first three readings. The first reading was significantly higher than the second reading for females across all groups; this effect also appears, but with less frequency, for the males. Differences between the second and third readings are negligible and non-significant with one exception out of 16 tests. The

TABLE 1. MEANS AND STANDARD DEVIATIONS OF BLOOD PRESSURE READINGS BY SEX, RACE, RESIDENCE GROUP AND ORDER OF READING WITH RANGES OF INTERCORRELATIONS

		Order of readings*						
		First		Second		Third		Range of Pearson r's
Social group		($\bar{X}$)	(SD)	($\bar{X}$)	(SD)	($\bar{X}$)	(SD)	among 3 readings
				Males				
Black High†	Sys.	131.6	20.1	130.9	19.3	130.6	19.6	0.91–0.95
(N = 217)	Dias.	85.6	12.5	85.8	12.3	85.7	12.2	0.88–0.92
Black Low	Sys.	129.4	20.4	127.9	19.7	127.9	19.3	0.92–0.95
(N = 240)	Dias.	83.5	11.2	83.1	11.2	83.3	11.5	0.85–0.90
White High	Sys.	127.1	16.4	125.9	16.2	126.4	16.2	0.88–0.91
(N = 236)	Dias.	81.7	11.1	81.3	10.9	81.8	10.9	0.84–0.88
White Low	Sys.	129.9	17.5	129.3	16.5	129.3	17.1	0.92–0.95
(N = 234)	Dias.	82.7	11.9	82.8	11.8	82.8	11.6	0.85–0.90
				Females				
Black High	Sys.	130.4	21.7	128.8	21.5	128.7	21.2	0.92–0.96
(N = 231)	Dias.	84.2	13.9	83.2	13.1	83.6	13.3	0.90–0.93
Black Low	Sys.	125.3	22.1	123.9	20.7	123.9	20.9	0.93–0.96
(N = 228)	Dias.	82.1	13.4	81.2	13.2	80.3	13.4	0.88–0.90
White High	Sys.	124.0	21.4	122.1	20.7	122.1	21.4	0.92–0.95
(N = 230)	Dias.	78.6	11.9	77.8	11.6	77.7	11.8	0.91–0.93
White Low	Sys.	120.7	18.6	119.0	18.9	118.9	19.6	0.91–0.94
(N = 226)	Dias.	77.3	11.8	76.3	11.6	76.6	11.8	0.89–0.91

*Readings were taken 10 min apart with the cuff deflated in interim and removed after the third reading.

†High = High Stress area; Low = Low Stress area. These are areas where the index and unrelated resided.

range of intercorrelations indicates the three readings were highly related. We therefore used the average of the first three blood pressure readings for our analyses because of certain advantages: (1) These readings were taken during the first half-hour in the medical history part of the interview and preceded the hour of reports about stressor perceptions; data not shown reveals the mean diastolic pressure of the two readings taken after the interview were significantly higher than the mean pressures of the three taken before the interview in seven out of the eight sex–race–area groups. Taking the mean of the first three readings therefore allows replications and comparison with other studies; (2) the variability of a single, casual reading has been frequently cited as undesirable by a variety of reports; averaging reduces the variability of digit preference and the initial effects of the first reading; (3) averaging, therefore, may also serve to improve test–retest reliability by reducing extraneous variability.

Analyses are performed with four dependent variables: Mean Systolic, Mean Diastolic, Grouped Systolic, and Grouped Diastolic. (1) Mean Systolic: mean average of the first three systolic readings taken in the first half hour of the interview, about 10 min apart; (2) Mean Diastolic: the mean average of the first three diastolic (fifth phase) readings; (3) Grouped Systolic: (a) $\leq$ 139 mm, (b) 140–159 mm, (c) 160+ mm; and (4) Grouped Diastolic: (a) $\leq$ 89 mm, (b) 90–94 mm, (c) 95+ mm. These are coded groupings having clinical import as Normotensive, Borderline, and Hypertensive, suggested by the World Health Organization [9].

Several other measures used in this series of articles must be briefly described: *Race*: black and white persons were differentiated by observation, by respondent confirmation during interview, and by cross-validation among sibling, first cousin, and spouse; *Age*: by reported date of birth and cross-validation among other family set members; *Per cent overweight*: computed from reported weight and comparison with Metropolitan Life Tables for weight by sex and height [10]; *Height*: reported height by respondents; *Skin color*: rated on a four-point scale by the nurse interviewers. The four categories were, for Blacks/Whites (1) 'very light/fair (white),' (2) 'somewhat light (tan)/somewhat fair,' (3) 'somewhat dark (brown)/somewhat dark,' and (4) 'very dark (brown or black)/dark.' The nurses who were the same race as their respondent were instructed to choose a person whom they knew, who had the rank-order of skin color specified by the scale, and use this person's image as a standard for comparing with the respondent. They were told to take the area on the forehead between the eyes as the target skin area. In each field study, Pilot and Major, the four points showed a symmetrical distribution. As to validity, a genetic distance scale was significantly related to ratings of skin color for blacks in both the pilot and major study [11, 3]. Skin color was also related to blood pressure and areas of residence [12].

Stressor conditions were measured through both objective and subjective methods. The presence of *objective* stressor conditions was measured by residence in high and low stress areas selected by factor analysis of census tract rates indicating degree of social disorganization [5, 6]. The degree of individually *perceived* stressor conditions was measured through standard interview reports on perceptions and evaluations of the residential (stress area) environment [13], indicators of mental health and tension [14], marital dissatisfaction [14], and financial burdens. Finally, measures of a coping style called suppressed hostility [15] were also obtained. Descriptions of the variables used to measure these concepts will be presented in conjunction with their analyses in a later article of this series [2].

Sample used for this analysis

The sample used in this article includes all family sets but excludes the spouse; specifically, each set only contains an index, sib, first cousin and the matched unrelated person. We have excluded the spouse from the set in this and subsequent analyses in which family set data as a unit are used, for several reasons: (1) As described in the first article of this series, the index and unrelated persons are from a population of potential index cases. After the index is randomly selected, an unrelated person from the same pool of persons is then matched on sex, race, area, age and marital status with the selected index. Spouses, however, both differ and resemble the index in certain traits. The spouse of course differs in sex, and there are age differences with the index which vary by race and social class. Conversely, martial selection yields positive correlations between index and spouse on such traits as height, weight, skin color, and so forth. Given such contingencies therefore, exclusion of the spouse from the set makes for tighter control of between member comparisons within each family set for purposes of genetic analyses. (2) The spouse and the unrelated are each considered to be 100% distant in genetic origin from the index, and each therefore should be interchangeable in so far as genetic relationship is concerned. Data presented elsewhere [16] show that separate regressions of such traits as height, skin color, blood pressure, and pulse rate on a genetic scale have only negligible differences when the spouse was included or excluded from analysis after adjusting for sex differences.

The exclusion of the spouse, and therefore of index–spouse associations, from the family set sample allows a fair test of the assumption that set members can be viewed as 'subsamples of individuals,' e.g. if all siblings are compared to all first cousins regardless of their common relation to an index case, then there should be no significant differences on a variety of traits. Each distribution of traits for siblings or cousins, for example, would then each be considered to be a random subsample of individuals regardless of common origin. Using four set members as factors (index, sib, first cousin, unrelated), tests of the distribution of given traits by a one-way analysis of variance (data not shown) indicate that, indeed, the null hypothesis of no differences among set members is supported. Within each of four race–sex groups, 12 variables were separately analyzed. Of the 48 tests, only three show significant differences. These tests add strength to results emerging when family sets are later treated as statistical units, and also justify the present grouping of *individuals* across sets, excluding the spouse, for analyses of blood pressure distribution.

Because of the above reasons for excluding the spouse, this article and those which follow in this series use a variant of the family set, here called the Genetic Sample, meaning without spouse; all results of blood pressure will be presented in this article using this same population ($N = 1844$). Finally, because prior articles have already analyzed blood pressure difference among stress areas [6], perceptions of stress or conditions [13, 14] and coping [15], the focus here will be on age, overweight, race and sex, and systolic and diastolic blood pressure levels and categories.

RESULTS

First, the issue of excessive variability of error in measuring blood pressure requires scrutiny. We have already discussed the thorough training of the nurse-observers, the quality control of their daily instrument checking, and the relatively low percentage of digit preference bias compared to other studies, i.e. about 26–29% use of zeros, compared to higher percentages reported elsewhere (e.g. Ref. [17]). It has been established that besides digit preference, other factors in the local environment at time of reading have been related to variability. We therefore measured time of day, seasonal changes, number of hours since last meal, day of week, and rated tension at time of first reading. Multiple regression of these variables to predict to systolic and diastolic levels within race–sex groups ($N = 450+$) reveals (data not shown) that *no more than* 2% of the variance could be accounted for by all these factors when entered with age and overweight in the equation. For further details concerning the relationship of some of these variables to blood pressure, see [12]. However, even these factors, which contribute little toward explaining variance in blood pressure can be adjusted for in the genetic analyses.

Tables 2 and 3 describe the means and standard deviations and relations of the mean systolic and diastolic blood pressure with age and percent overweight within sex–race groups for the genetic sample. Table 2 shows the steady, expected rise in pressure with increasing age for all groups [18] with a slight decrease in the 50–59 male groups. Black pressure levels are also consistently higher than white levels with a few exceptions [19]. Because of the restricted age range perhaps, the 'cross-over' effect for females after menopause age does not appear (e.g. Ref. [20]). Table 3 shows sex–race means and standard deviations of pressure, linearly adjusted for age by a standard multiple regression technique, by categories of per cent overweight. Overall, there is a rise of levels with increasing per cent overweight for all groups with a few minor inconsistencies [21]. It can be noted, however, that for males in the subgroup of >40% overweight, both systolic and

TABLE 2. MEANS AND STANDARD DEVIATIONS OF SYSTOLIC AND DIASTOLIC BLOOD PRESSURES, BY AGE, SEX AND RACE

Age group	Males						Females					
	Black (N = 457)			White (N = 470)			Black (N = 459)			White (N = 458)		
(yr)	(N)	Mean	SD	(N)	Mean	SD	(N)	Mean	SD	(N)	Mean	SD
					Systolic							
25–29	(39)	122.1	13.8	(33)	120.4	11.0	(31)	118.6	17.5	(28)	111.6	13.1
30–34	(90)	123.5	13.0	(69)	122.9	12.4	(87)	116.7	13.9	(61)	110.4	11.2
35–39	(105)	126.5	19.0	(87)	126.6	14.7	(89)	123.6	17.6	(89)	114.8	11.9
40–44	(80)	128.4	17.5	(103)	128.1	14.9	(102)	129.2	20.9	(82)	122.6	22.6
45–49	(78)	138.3	22.9	(95)	132.3	17.5	(80)	130.4	21.8	(95)	124.4	20.5
50–59	(65)	138.9	20.6	(83)	131.7	19.7	(70)	139.7	25.1	(103)	131.6	21.2
					Diastolic							
25–29	(39)	78.7	8.8	(33)	76.2	8.8	(31)	77.6	12.4	(28)	74.3	8.8
30–34	(90)	81.0	9.6	(69)	78.6	8.7	(87)	77.4	11.2	(61)	70.9	8.3
35–39	(105)	83.3	9.8	(87)	82.3	10.5	(89)	80.9	10.3	(89)	74.3	7.5
40–44	(80)	84.4	11.9	(103)	83.1	11.2	(102)	83.8	11.8	(82)	80.6	14.3
45–49	(78)	89.4	12.8	(95)	85.0	11.9	(80)	85.4	14.1	(95)	79.4	11.2
50–59	(65)	88.5	11.8	(83)	83.2	10.9	(70)	87.3	14.9	(103)	80.3	11.6

TABLE 3. MEANS AND STANDARD DEVIATIONS OF SYSTOLIC AND DIASTOLIC BLOOD PRESSURES, BY PER CENT OVERWEIGHT AND RACE–SEX GROUPS, ADJUSTED FOR AGE WITHIN RACE–SEX GROUPS

Per cent overweight	Males						Females					
	Black (N = 457)			White (N = 470)			Black (N = 459)			White (N = 458)		
	(N)	Mean	SD	(N)	Mean	SD	(N)	Mean	SD	(N)	Mean	SD
(%)	Systolic											
≤−10%	(18)	124.8	19.1	(16)	121.3	14.0	(30)	119.0	11.4	(45)	111.3	13.6
−9–0	(69)	125.3	17.3	(61)	124.0	18.8	(71)	123.0	18.8	(94)	118.4	14.2
1–10	(120)	127.5	14.8	(134)	125.8	14.9	(95)	124.1	17.9	(106)	118.8	17.3
11–20	(122)	128.9	17.6	(121)	127.7	14.6	(83)	123.9	16.9	(83)	121.9	16.8
21–30	(72)	134.9	24.0	(75)	130.8	13.3	(69)	128.1	19.1	(45)	124.3	18.8
31–40	(33)	136.8	18.5	(38)	136.0	16.9	(37)	132.7	25.7	(31)	128.2	20.2
>40%	(23)	134.6	11.1	(25)	134.5	17.1	(74)	136.3	22.6	(54)	131.2	22.7
	Diastolic											
≤−10%	(18)	80.3	11.9	(16)	78.2	9.4	(30)	77.5	10.5	(45)	71.4	8.6
−9–0	(69)	81.5	9.8	(61)	78.1	10.6	(71)	80.5	10.2	(94)	75.3	8.9
1–10	(120)	83.9	10.4	(134)	80.5	10.3	(95)	81.1	11.8	(106)	75.9	9.7
11–20	(122)	83.4	11.2	(121)	82.6	10.3	(83)	80.8	11.5	(83)	78.1	10.3
21–30	(72)	86.9	10.3	(75)	84.7	10.2	(69)	83.9	11.6	(45)	78.7	10.7
31–40	(33)	90.2	12.7	(38)	88.6	11.5	(37)	86.6	17.0	(31)	81.4	12.2
>40%	(23)	88.4	7.5	(25)	84.5	10.1	(74)	86.3	13.4	(54)	84.4	14.1

diastolic pressures unexpectedly fall. The distribution of per cent overweight by frequency (N) appears normal for males; however, for females, there is a distinct rise in frequency in the 'tailend' for the >40% overweight class. This is especially strong for black females. Not shown is the fact that per cent overweight, on the average is highest for the black female group, whose mean is about 19%, compared to an average of about 13–14% in the other sex–race groups; this higher per cent comes from the working-class and not from the middle-class areas [6].

TABLE 4. CORRELATIONS AND SQUARED CORRELATIONS OF BLOOD PRESSURE WITH AGE AND PER CENT OVERWEIGHT BY RACE AND SEX (FAMILY SET SAMPLE, EXCLUDING SPOUSE)

	Black		White	
	Male (N = 457)	Female (N = 459)	Male (N = 470)	Female (N = 458)
	Systolic			
Age				
r	0.33	0.34	0.24	0.39
% σ^2 (r^2)	11.0	11.3	5.7	15.2
Per cent overweight				
r	0.22	0.34	0.24	0.34
% σ^2 (r^2)	4.9	11.3	5.6	11.7
	Diastolic			
Age				
r	0.31	0.26	0.21	0.27
% σ^2 (r^2)	9.3	6.8	4.3	7.4
Per cent overweight				
r	0.23	0.28	0.23	0.37
% σ^2 (r^2)	5.5	7.8	5.3	13.6

All r's on this table are significantly different from '0' with $P < 0.001$.

TABLE 5. DISTRIBUTION OF SYSTOLIC AND DIASTOLIC BLOOD PRESSURE CATEGORIES AND CHI SQUARE BY SEX, RACE, AND RACE–SEX GROUPS

	Sex				Race				Race–sex							
	Male		Female		Black		White		Black male		White male		Black female		White female	
Blood pressure	(%)	(*N*)	(%)	(*N*)	(%)	(*N*)	(%)	(*N*)	(%)	(*N*)	(%)	(*N*)	(%)	(*N*)	(%)	(*N*)
							Systolic									
Total	100.0	(927)	100.0	(917)	100.0	(916)	100.0	(928)	100.0	(457)	100.0	(470)	100.0	(459)	100.0	(458)
Normo ≤ 139 mm	77.7	(720)	79.4	(728)	76.5	(701)	80.5	(747)	76.6	(350)	78.7	(370)	76.5	(351)	82.3	(377)
Borderline 140–159 mm	16.6	(154)	14.4	(132)	15.9	(146)	15.1	(140)	16.2	(74)	17.0	(80)	15.7	(72)	13.1	(60)
Hypertensive 160 + mm	5.7	(53)	6.2	(57)	7.5	(69)	4.4	(41)	7.2	(33)	4.3	(20)	7.8	(36)	4.6	(21)
	$\chi^2_{(2)} = 1.83$				$\chi^2_{(2)} = 8.64$*						$\chi^2_{(6)} = 11.55$					
							Diastolic									
Total	100.0	(927)	100.0	(917)	100.0	(916)	100.0	(928)	100.0	(457)	100.0	(470)	100.0	(459)	100.0	(458)
Normo ≤ 89 mm	72.7	(674)	78.7	(722)	71.0	(650)	80.4	(746)	69.4	(317)	76.0	(357)	72.5	(333)	84.9	(389)
Borderline 90–94 mm	11.0	(102)	11.0	(101)	13.1	(120)	8.9	(83)	12.9	(59)	9.1	(43)	13.3	(61)	8.7	(40)
Hypertensive 95 + mm	16.3	(151)	10.3	(94)	15.9	(146)	10.7	(99)	17.7	(81)	14.9	(70)	14.2	(65)	6.3	(29)
	$\chi^2_{(2)} = 14.86$***				$\chi^2_{(2)} = 22.28$***						$\chi^2_{(6)} = 40.11$***					

* $P < 0.05$.
** $P < 0.01$.
*** $P < 0.001$.

Table 4 shows the results of regressing blood pressure on age and on per cent overweight. For age, more variance is accounted for in the systolic levels than for diastolic [22]; age appears more related to pressure for females than for males [23], except for the black female diastolic results. Age is related to levels more for black than for white males, while the converse is true for females. For overweight in Table 4, similar predictability appears for both systolic and diastolic pressures, within race–sex groups. Across all groups, females show more relationship of overweight by pressure levels than males, while race differences appear important only for diastolic levels for females.

Table 5 presents frequency analyses relating sex, race, and sex–race groups to conventional categories of blood pressure risk levels [24]. Males show a higher per cent of borderline and hypertensive readings than females, and the differences are most clear for the diastolic readings. By race, blacks have more elevated pressures than whites for both borderline and hypertensive categories, as expected. By race–sex, black males show a tendency to higher per cent hypertensives than white males, though not clearly significant; the same pattern shows for the females, though much more clearly for diastolic differences, again confirmed in other studies (e.g. Ref. [25]). In general, in this population, using these conventional categories, there is a higher percentage of diastolic than systolic hypertensive pressures in all race–sex groups.

DISCUSSION AND SUMMARY

The major results indicate that the distribution of blood pressure in the Family Set sample, when viewed as a group of individuals regardless of common origin, were related in similar directions to factors already well-studied. Negligible amounts of variance in the readings were related in predictable directions differentially across race–sex groups to such factors as time of day, day of week, season, time since last meal, and rated tension [26, 27]. Of interest, though the data are presented elsewhere [12], darker skin color for blacks was also found related to higher blood pressure independently of other variables.

Statistically significant and more universally known relations in American populations were obtained between elevated pressure, both systolic and diastolic, and race, age and per cent overweight [19]. Age and per cent overweight appear as the most consistent predictors of blood pressure variance across sex–race groups among all factors studied. In this population, there was a higher per cent of diastolic hypertensive pressures than systolic in all race–sex groups. These findings are important in establishing conformity of results with other studies, but more pertinent, the analyses describe certain critical influences on blood pressure which can be adjusted for or taken into account in estimating the influence of a genetic factor on blood pressure.

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