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

BLOOD PRESSURE ADJUSTMENT TECHNIQUES*

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Abstract—This fourth article, in a series of five, reports on the statistical adjustments useful in analyzing blood pressure data from family sets. Blood pressure level has been associated with numerous demographic, physiologic, medical history, socioeconomic, temporal and genetic characteristics. To assess the effect of a subset of these characteristics on blood pressure, it is necessary to control for the remaining variables. Statistical methods, including categorization, standardization and regression, are presented as approaches toward adjusting blood pressure readings for sources of variation deemed concomitant. The ultimate, long-range purpose of these procedures is to separate genetic from environmental components of blood pressure.

INTRODUCTION

IT HAS been frequently observed that blood pressure is associated with a host of concomitant factors as attested in several excellent reviews, e.g. Pickering [1], Stamler [2]. Such concomitant factors are: demographic characteristics (sex, race, and age), physical measurements (overweight and skinfolds), medical history (childhood conditions and diseases of the kidney), socioeconomic variables (income and education), psychologic indices (personal stress), time measures (time of day, day of the week, season of the year, and time since last meal), and finally a heritability component. Clearly, then, to investigate blood pressure in conjunction with specified factors, e.g. the genetic contribution to blood pressure variability, a prior assessment of the other variables related to blood pressure must be made. The aims of this paper are twofold: (1) To explore and discuss a variety of techniques

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useful in adjusting blood pressure readings for extraneous or concomitant variables; and, (2) to explain the method of adjustment used in other papers [3, 4] in this series where the genetic component in variation of blood pressure is examined.

DATA

The data used in this paper were collected in the City of Detroit in 1968–1969 to allow consideration of stress, race and genetic aspects of blood pressure. This study has been thoroughly described elsewhere [5–7]. In summary, Detroit was divided into sets of contiguous census tracts inhabited predominantly by whites or blacks. These areas were scored and ordered based on socioecologic stress, measured by rates such as family stability, crime, education and income [6]. Four areas were chosen for study and were labelled: high stress black, high stress white, low stress black and low stress white. Within each area approximately 115 family sets were studied, each evolving from a randomly selected index case, who was married, aged 30–55 and possessing a sibling and a first cousin each within 6 yr of the age of the index and living in Detroit. Each family set was composed of five individuals: (1) index, (2) sibling, (3) cousin, (4) the spouse of the index, and (5) an unrelated individual matched with the index by being of the same sex, race, within 5 yr of the age of the index and residing in the same area. From each individual (461 family sets, 2305 persons) an interview and five blood pressure readings were obtained. In this and subsequent papers analyses are based on a blood pressure mean computed for the first three readings taken during the interview. The spouse has been deleted from the family set from all computations presented in this paper for reasons discussed elsewhere [8] and to make these computations consistent with those of the other presentations. Thus a total of 1844 subjects contribute data for analysis in this paper.

Since investigations of differences in blood pressure level related to race and socioecological stress subgroups are of primary importance in this series of papers, statistical analyses will take cognizance of these subgroups. Recall that family sets are controlled so that the sex of the index and unrelated person are the same; however, the other set members, sibling and first cousin, may be of the opposite sex. Thus adjustment for sex differences is required since differences in blood pressure by sex are well-established, e.g. [10]. In that stress is of focal importance in this study—both personal and socioecologic assessment of this characteristic should be made in the statistical analyses. Personal stress was measured via indices of: (1) marital tension, (2) financial burden, (3) residential stress or personal assessment of neighborhood safety, and two measures of coping with anger by use of suppressed hostility, (4) anger-in and (5) guilt about anger (see Appendix A).

Further, as was noted in an earlier article [8] age and per cent overweight were the factors most associated with blood pressure across all race–sex subgroups.

Therefore methods of adjusting blood pressure data and the results found by such adjustment will be developed and illustrated starting with the following variables: race, sex, socioecological stress, age, percent overweight, and personal stress variables. Other factors less strongly associated with blood pressure will not be pursued in this paper, but the methods could be applied to them.

The variables considered are of two types: (1) *qualitative nominal*—sex, race and ecologic stress and (2) *quantitative*, both *discrete*—personal stress indices and *continuous*—age, per cent overweight and the blood pressure readings.

1. *Standardization*

Adjustment of blood pressure for the qualitative nominal variables is formulated in light of the observation that blood pressure means and standard deviations differ by race and by sex. Table 1 summarizes the appropriate statistics. These means and standard deviations reflect the 'raw' data, i.e. values without any adjustment or standardization. Perusal of this table indicates that blacks and males have higher mean systolic and diastolic blood pressure than whites and females, respectively. For each family set member (index, sibling, first cousin and unrelated person) and combining all family set members, there are statistically significant differences in means across the four race–sex subgroups. Further, for most subcomparisons, a significant ($P < 0.05$) difference emerges between races and sexes. Also significant race–sex interactions were found overall and for many subcomparisons, particularly for diastolic blood pressure.

These significant differences require standardization at the outset of the analyses since comparisons were sought within and across family sets, which differed by sex and race. This emphasis on comparison necessitated several versions of the standardization procedure—of pivotal substantive importance is that by race–sex subgroup. This standardization is accomplished by transforming individual blood pressures about a new mean of zero and a new standard deviation of one. The subgroup mean is subtracted from each subject's blood pressure in a given subgroup and this difference is divided by the subgroup standard deviation, i.e. $Z = (X - \bar{X})S$, where Z is the standardized blood pressure, X is the original blood pressure, $\bar{X}$ is the subgroup mean and S is the standard deviation. It is noted that the standardized values, Z, are unit free. For these data, each subject's blood pressure was standardized relative to the appropriate race–sex subgroup. While this standardization necessitates that each race–sex subgroup have standardized mean of zero and standard deviation of one, it does not perforce make these statistics zero and one, respectively, for each family set member (index, sibling, cousin and unrelated). Table 2 summarizes the effect of standardization on various subsets of respondents.

Note that this process has removed significant differences in means among the four race–sex groups, between races, between sexes and interaction effects. It should be recalled that the major purpose of the analyses is to assess genetic and environment components on blood pressure. Comparisons therefore within and among certain subgroups delineated by race, sex, ecologic stress or other factors must be investigated. The standardization as illustrated above has removed differences between certain subgroups, but only with respect to *mean* differences and then only for the subgroups as a whole, *not* for individual family sets. The analyses are designed to assess differences in *variance* remaining after the standardization. Furthermore, certain analyses will be completed *within* subgroups. Comparisons then, among subgroups will consider how the within subgroup analyses are similar or different. Finally, the genetic effect on a population can result from two mechanisms—gene frequency and gene action. This investigation is interested in

TABLE 1. BLOOD PRESSURE MEANS AND STANDARD DEVIATIONS OVERALL AND BY RACE–SEX SUBGROUPS BY FAMILY SET MEMBER

Family set member		Black male (N)	Black male $\bar{X}$	Black male (S.D.)	Black female (N)	Black female ($\bar{X}$)	Black female (S.D.)	White male (N)	White male ($\bar{X}$)	White male (S.D.)	White female (N)	White female ($\bar{X}$)	White female (S.D.)	P-values: Across the 4 subgroups	P-values: Black vs white	P-values: Male vs female	Interaction Sex × Race
Index	Sys.	118	129.3	17.8	111	123.6	20.8	113	127.6	14.7	119	123.7	18.7	0.04	0.60	0.005	0.60
	Dias.		83.9	10.7		80.2	12.8		81.3	10.5		78.7	11.2	0.005	0.05	0.003	0.60
Sibling	Sys.	111	130.1	19.3	118	127.3	20.8	127	129.9	17.5	105	121.4	20.8	0.003	0.10	0.002	0.11
	Dias.		84.1	11.4		83.4	12.7		82.6	11.5		77.9	12.2	0.0005	0.002	0.02	0.07
First	Sys.	110	132.2	23.7	119	126.6	18.9	117	128.1	16.4	115	119.9	19.7	0.0001	0.004	0.0002	0.50
Cousin	Dias.		85.6	13.1		83.1	12.3		83.1	10.3		76.4	10.9	0.0001	0.0001	0.0001	0.06
Unrelated	Sys.	118	127.2	15.7	111	129.9	23.6	113	126.1	15.8	119	119.6	19.5	0.0004	0.001	0.30	0.01
	Dias.		84.2	19.5		82.9	13.5		81.8	11.4		76.6	11.2	0.0001	0.0001	0.003	0.07
Total	Sys.	457	129.6	19.3	459	126.8	21.1	470	128.0	16.2	458	121.2	19.6	0.0001	0.0001	0.0001	0.02
	Dias.		84.4	11.4		82.4	12.9		82.2	10.9		77.4	11.4	0.003	0.0001	0.0001	0.009

TABLE 2. RACE–SEX STANDARDIZED BLOOD PRESSURE MEANS AND STANDARD DEVIATIONS OVERALL AND BY RACE–SEX SUBGROUPS OF FAMILY SET MEMBER

Family set member		Black male (N)	Black male ($\bar{X}$)	Black male (S.D.)	Black female (N)	Black female ($\bar{X}$)	Black female (S.D.)	White male (N)	White male ($\bar{X}$)	White male (S.D.)	White female (N)	White female ($\bar{X}$)	White female (S.D.)	P-values: Across 4 race–sex groups	P-values: Black vs white	P-values: Male vs female	Interactions Race × Sex
Index	Sys.	118	−0.019	0.925	111	−0.153	0.985	113	−0.026	0.907	119	0.129	0.950	0.16	0.12	0.90	0.10
	Dias.		−0.046	0.938		−0.170	0.999		−0.082	0.957		0.117	0.988	0.15	0.16	0.68	0.07
Sibling	Sys.	111	0.021	0.998	118	0.021	0.986	127	0.120	1.081	105	0.001	1.060	0.82	0.65	0.56	0.57
	Dias.		−0.029	0.996		0.077	0.984		0.035	1.053		0.042	1.074	0.89	0.88	0.56	0.60
First	Sys.	110	0.134	1.230	119	−0.011	0.897	117	0.004	1.013	115	−0.062	1.002	0.54	0.35	0.28	0.69
Cousin	Dias.		0.103	1.147		0.049	0.959		0.079	0.943		−0.084	0.957	0.50	0.40	0.25	0.56
Unrelated	Sys.	118	−0.125	0.814	111	0.143	1.118	113	−0.114	0.978	119	−0.077	0.991	0.14	0.25	0.10	0.20
	Dias.		−0.023	0.920		0.036	1.053		−0.039	1.043		−0.072	0.983	0.87	0.50	0.89	0.62
Total	Sys.	457	0.0	1.0	459	0.0	1.0	470	0.0	1.0	458	0.0	1.0				
	Dias.		0.0	1.0		0.0	1.0		0.0	1.0		0.0	1.0				

gene action; adjustment, therefore, for possible varying gene frequency among the subpopulations is essential. Thus, the standardization is completed *within* subpopulations since, (1) this adjustment still allows assessment of variability *among* family sets, (2) analyses *within* subpopulations are unaffected in both mean and variance, and (3) gene frequencies may differ among subpopulations.

2. *Regression techniques—General*

Once all data have been standardized by race–sex subgroups, the second step is to adjust these standardized scores for independent variables that effect blood pressure, e.g. age, per cent overweight and personal stress. All of these variables are quantitative, suggesting a regression framework. Pickering [1 pp. 203–208], has presented a method of adjusting blood pressure for sex and age simultaneously allowing for different variability in blood pressure. This method is based on grouping and standardizing at different ages. It is our persuasion that a regression of one continuous variable (blood pressure, standardized for race and sex) on other quantitative variables (age, per cent overweight, personal stress indices) is a statistically more sensitive measure. Multiple linear regressions of standardized blood pressures, using separate analyses for systolic and diastolic, on age per cent overweight, and the five indices of personal stress were computed for the four race–sex, the four race–ecological stress subgroups and for the total data set. These analyses uniformly indicated that age and per cent overweight were statistically significant ($P < 0.001$) and that the two coping indices of suppressed hostility, 'anger-in' and 'guilt regarding anger' were frequently significant ($P < 0.05$). However, the indices measuring perceived residential, marital and financial stress were not significant contributors to the regressions. Thus, subsequent analyses use age, per cent overweight, anger-in and guilt about anger as the independent variables for purposes of adjusting blood pressure levels.

Prior to developing these regression equations, the investigator still must resolve the dilemma of simplicity of *linear* regression on the one hand and the possibility that the assumption of linearity is untenable on the other. Clearly, adjustment for concomitant variation should be performed using the most appropriate functional relationship. For these data it was judged that a linear regression was reasonable for blood pressure on age, per cent overweight and the personal stress indices. This belief is supported for age by several references [1 (pp. 204–205, 246–248), 9, 10] where graphical representation of blood pressure on age for males, females, blacks and whites indicate that a linear fit should be adequate between ages 25 and 60. These references suggest that beyond these ages, linearity deteriorates. Concerning per cent overweight, Pickering [4], on page 215, states that there is a definite correlation of blood pressure and the relation of body weight to height and indicates that blood pressure increases linearly with increasing weight.

With respect to the personal stress indices and to further investigate the assumption that a multiple linear regression of blood pressure on age and per cent overweight is appropriate for our data, several approaches were considered. First, the graphs referred to previously suggest that if a linear fit on age is not adequate, a quadratic fit would be the most likely to improve the relationship. Multiple regressions of blood pressure on age, per cent overweight, and personal stress indices ('linear fit') and on age, $(\text{age})^2$, per cent overweight, $(\text{per cent overweight})^2$,

TABLE 3. REGRESSION COEFFICIENTS AND SQUARED MULTIPLE CORRELATION COEFFICIENTS (R^2) OF BLOOD PRESSURES FOR *linear* FIT ON AGE, PER CENT OVERWEIGHT, ANGER-IN AND GUILT ABOUT ANGER AND QUADRATIC FIT ON AGE, $(\text{AGE})^2$, PER CENT OVERWEIGHT, $(\text{PER CENT OVERWEIGHT})^2$, ANGER-IN, $(\text{ANGER-IN})^2$, GUILT ABOUT ANGER AND $(\text{GUILT ABOUT ANGER})^2$ FOR ALL SUBJECTS (N = 1844)

	Systolic blood pressure		Diastolic blood pressure	
Variable	Linear	Quadratic	Linear	Quadratic
1. Age	0.0339**	0.0128**	0.0263**	0.0910**
2. $(\text{Age})^2$		0.0003		−0.0008*
3. Per cent overweight	0.0125**	0.0138	0.0125**	0.0145**
4. $(\text{Per cent overweight})^2$		−0.0000		−0.0000
5. Anger-in	0.0029**	0.0028	0.0021**	0.0027
6. $(\text{Anger-in})^2$		0.0000		−0.0000
7. Guilt about anger	0.0009	−0.0066*	0.0023*	−0.0040
8. $(\text{Guilt about anger})^2$		0.0001**		0.0001*
R^2	0.168**	0.173**	0.132**	0.139**

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

anger-in, $(\text{anger-in})^2$, guilt about anger and $(\text{guilt about anger})^2$ ('quadratic fit') were computed across all subjects.

The results are summarized in Table 3. It is notable that for *both* systolic and diastolic 'linear' regressions, the regression coefficients for age, per cent overweight and anger-in are significantly different from zero. For the 'quadratic' regressions, the squared terms add little for systolic blood pressure, except guilt about anger and $(\text{guilt about anger})^2$ are significant along with age, and results for per cent overweight are not statistically significant. For diastolic blood pressure, the 'quadratic' regression coefficients for $(\text{age})^2$ and $(\text{guilt about anger})^2$ are significant. It is most important to note that the squared multiple correlation coefficient (R^2), which represents the per cent of the variability in the blood pressure ascribable to the terms of the regression, increases minimally when the quadratic terms are added.

A second consideration of the acceptability of linear regressions used subgroups of subjects categorized by the age of the index case: <35, 35–39, 40–44, 45–49, 50–59. Recall that the study design required the sibling, first cousin and unrelated subject to be within approx 5 yr of the age of the index case. Classifying each subject into the appropriate subgroup based on the age of the index case of that family set focuses on the acceptability of the assumption of linearity on age within a tighter age constraint on the subjects.

The results summarized in Table 4 indicate that the multiple linear regressions of race–sex standardized systolic pressure have similar regression coefficients on age, per cent overweight, anger-in, and guilt about anger across these age categories (P = 0.15). The test hypothesis is that the *set* of four coefficients (age, per cent overweight, anger-in and guilt about anger) is equal across the age subgroups being compared. This test does not consider each independent variable singly, e.g. age, but tests for all four simultaneously. Thus, assuming a multiple regression of blood pressure on the four independent variables, the question is: must separate equations be generated for each subgroup? The answer is 'no' for systolic blood pressure, since the P-value is relatively large. However, for diastolic pressure the

TABLE 4. REGRESSION COEFFICIENTS FOR REGRESSIONS OF RACE–SEX STANDARDIZED BLOOD PRESSURES ON AGE, PER CENT OVERWEIGHT, ANGER-IN AND GUILT ABOUT ANGER FOR ALL SUBJECTS AND BY AGE CATEGORIES BASED ON THE AGE OF THE INDEX†

	For all Subjects	Age of index					Equality of coefficients
		<35	35–39	40–44	45–49	50–59	
N	1844	400	412	376	364	292	P-value
				Systolic			
Regression coefficient on:							
Age	0.0339**	0.0293**	0.0330**	0.0417**	0.0300**	0.0289	
% Overweight	0.0125**	0.0126**	0.0102**	0.0136**	0.0131**	0.0119**	
Anger-in	0.0029**	0.0005	0.0020	0.0042*	0.0018	0.0084**	0.15
Guilt about anger	0.0009	0.0022	0.0005	0.0031	−0.0048	0.0029	
R^2	0.168**	0.105**	0.097**	0.144**	0.083**	0.087**	
				Diastolic			
Regression coefficient on:							
Age	0.0263**	0.0375**	0.0242**	0.0420**	0.0141**	0.0116	
% Overweight	0.0125**	0.0138**	0.0099**	0.0144**	0.0149	0.0071*	
Anger-in	0.0021*	−0.0002	−0.0002	0.0029	0.0009	0.0070*	0.009
Guilt about anger	0.0023*	0.0013	0.0016	0.0070**	−0.0031	0.0055	
R^2	0.132**	0.111**	0.066**	0.152**	0.084**	0.067**	

*$P < 0.05$.
**$P < 0.01$.
†Each subject was classified into the appropriate subgroup based on the age of the index case of his or her family set.

answer is more tenuous ($P = 0.009$) as it appears that for the older ages (45–49 and 50–59) the relationship of diastolic blood pressure on age and per cent overweight has altered from that of the younger ages. When quadratic fits were applied to data in these subgroups, similar conclusions as noted previously across all subjects were observed, namely, marginal increase in R^2 and, in general, statistical significance only for the regression coefficient of per cent overweight. Based on the results of these several investigations it was concluded that a multiple linear regression of blood pressure on age, per cent overweight, anger-in and guilt about anger would suffice for subsequent analyses.

Aware that blood pressures were standarized *by* race–sex subgroups, we believed that linear adjustments on age, per cent overweight, anger-in, and guilt about anger might be more sensitive *within* race–sex subgroups than by a single regression across all subjects. Table 5 summarizes these regression equations as well as those for race–stress subgroups. Two characteristics of these regression coefficients are: (1) the adjustments yielded statistically significant ($P < 0.01$) coefficients for both age and per cent overweight; and (2) the sets of coefficients are generally consistent across race–sex subgroups (systolic: $P = 0.34$; diastolic: $P = 0.40$). For the race–stress subgroups there was no statistical significance between these groups for the systolic sets of regression coefficients ($P = 0.19$); however significance

TABLE 5. REGRESSION COEFFICIENTS AND INTERCEPTS FOR REGRESSIONS OF RACE–SEX STANDARDIZED BLOOD PRESSURES ON AGE, PER CENT OVERWEIGHT, ANGER-IN AND GUILT ABOUT ANGER ACROSS ALL SUBJECTS AND BY RACE–SEX AND RACE–STRESS SUBGROUPS

		Race–Sex					Race–Ecologic stress				
	Across all Subjects	Black males	Black females	White males	White females	Equality of coefficients (P-value)	Black high stress	Black low stress	White high stress	White low stress	Equality of coefficients (P-value)
N	1844	457	459	470	458		488	468	468	460	
						Systolic					
Regression coefficient on:											
Age	0.0339**	0.0344**	0.0323**	0.0277**	0.0423**	0.34	0.0315**	0.0363**	0.0408**	0.0325**	0.19
% Overweight	0.0125**	0.0121**	0.0111**	0.0140**	0.0138**		0.0098**	0.0116**	0.0111**	0.0177**	
Anger-in	0.0029**	0.0035	0.0037	0.0014	0.0031		0.0047*	0.0020	−0.0002	0.0040*	
Guilt about anger	0.0009	0.0014	−0.0040	0.0038	0.0017		−0.0009	−0.0020	0.0048*	−0.0000	
R^2	0.168**	0.149**	0.192**	0.117**	0.247**		0.157**	0.168**	0.164**.	0.211**	
						Diastolic					
Regression coefficient on:											
Age	0.0263**	0.0303**	0.0248**	0.0233**	0.0276**	0.40	0.0216**	0.0350**	0.0329**	0.0206**	0.02
% Overweight	0.0125**	0.0132**	0.0095**	0.0136**	0.0157**		0.0077**	0.0117**	0.0107**	0.0203**	
Anger-in	0.0021*	0.0032	0.0022	0.0019	0.0010		0.0035	0.0012	−0.0011	0.0037	
Guilt about anger	0.0023*	0.0032	−0.0016	0.0048	0.0019		0.0015	−0.0003	0.0036	0.0030	
R^2	0.132**	0.140**	0.120**	0.106**	0.190**		0.082**	0.170**	0.125**	0.191**	

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

($P = 0.02$) did emerge for diastolic coefficients. In the sequel to this paper [4], linear adjustment for age, per cent overweight and coping variables should be used—sometimes by race–sex and race–stress subgroups, sometimes for all subjects in one regression.

Once the 'best' regression form has been determined, the values used for blood pressure analysis are obtained by finding the difference between each subject's race–sex standardized blood pressure and the value predicted by the regression equation. This difference is the residual race–sex standardized blood pressure after removing the linear affect of age, per cent overweight, anger-in and guilt about anger. For the data at hand these residuals were computed in a variety of ways—always, however, assuming that race–sex standardized blood pressure is a *linear* function of age, per cent overweight, anger-in and guilt about anger. Residuals were generated for race–stress, race–sex subgroups and for all subjects. For subsequent analyses, use of these residuals insures that any linear relationship that age, per cent overweight, anger-in and guilt about anger have with the standardized blood pressure has been removed. It might be noted that in no case was an R^2 larger than 0.247, indicating that the linear effect of age, per cent overweight, and coping variables accounts for not more than 25% of the variance of the race–sex standardized systolic and diastolic blood pressure for these data.

3. *Regression techniques—Genetic analysis*

It should be emphasized that the standardization and linear adjustment of the blood pressures do not take cognizance of the family set structure of the data. Thus, in preparation for analysis of the heritability of blood pressure, assessment of the association of blood pressure between family set members was undertaken. The approach employed is developed fully in a later paper [4] in this series. The method will be briefly discussed here as a technique for adjusting a variable taking into account genetic relationships among persons.

The method used is a multiple linear regression of the value of the variable, X (here blood pressure), of the index case, X_I on the values of other members of the family set, X_C (first cousin), X_S (sibling) and X_U (randomly selected unrelated). Thus the form of this 'genetic' regression is: $X_I = \alpha + \beta_S X_S + \beta_C X_C + \beta_U X_U +$ error where α is a constant and β_S, β_C, and β_U are the regression coefficients for the sibling, cousin and randomly chosen individual. Clearly this regression can be computed for X's which are (1) Raw (unstandardized or unadjusted blood pressures), (2) Race–sex standardized blood pressures, (3) Residual (by linear multiple regression on age and per cent overweight) race–sex standardized blood pressures, where the residuals are found in a variety of ways, e.g. across all subjects, by race, by race–stress or by race–sex subgroups. Further, whether raw, standardized or residual blood pressures are used in the 'genetic' regression, *this* regression can be computed across all subjects or by race–sex, race–stress, etc. subgroups.

DISCUSSION

In an attempt to separate those relationships which blood pressure may have with a host of environmental factors, ranging from demographic, socioeconomic, medical history, psychological, and temporal from genetic factors, statistical techniques become imperative. The necessity of statistical control is more easily perceived than the form of the procedure. A multitude of statistical methods for assessing covariates of blood pressure level and variability can be proposed.

In this article we have considered two approaches: standardization for categorical factors and regression for the quantitative variables. Combinations of categorization, standardization and regression will probably increase the sensitivity of the adjusted blood pressures to other factors of interest (e.g. heritability) if the concomitants being adjusted for are truly associates of blood pressure. The purpose of all these techniques statistically is to reduce the variance in blood pressures. If the concomitants are adding variability to the blood pressure, removal of those sources of variation will make the blood pressures statistically more stable. As a corollary, then, differences in adjusted blood pressures between subgroups (e.g. race, sex or stress groups) will be more easily discerned and effects of yet other sources of blood pressure variation (e.g. genetic) will be more clearly perceived. The investigator has the task of checking whether a statistical technique is actually increasing sensitivity or merely adding random error. Tests of significance (e.g. are regression coefficients different from zero), magnitude of correlation coefficients, and reduction in variability of the adjusted blood pressures are ways to check the efficiency of the technique. Another problem is selecting the most appropriate *functional* relationship of concomitants to blood pressure. If the wrong function is developed, clouding rather than insight into assessing variability may result.

SUMMARY

Statistical methods for assessing effects of blood pressure have been presented. These include categorization, standardization and regression. The merits of various combinations of these techniques are considered. Finally the basic development of a regression model deemed appropriate for studying genetic effects in blood pressure is presented.

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APPENDIX A

The five psychosocial indices of personal stress and coping used for this analysis must here be treated briefly. The three personal stress indices of Financial Burden, Marital Tension, and Perceived Residential Stress were found unrelated to blood pressure levels; the interested reader is referred to [11] for details of the latter variables and their negligible correlations to pressure.

The two measures of coping by use of suppressed hostility are Anger-In and Guilt about Anger. The theory, its background, the framework of the measures, and two of the variables are described in detail elsewhere [7]. The Anger-In Index includes 14 items. Respondents were presented with seven hypothetical situations where someone important to them (spouse, policeman, mother, father, boss, houseowner, and employment agent) treated them unfairly (yelled at them for no reason, discriminated against them). For the first five persons listed, the respondent was asked the following set of items:

A. <u>ANGER-IN INDEX</u> (14 items)

1. IMAGINE (A POLICEMAN) GOT ANGRY OR BLEW UP AT YOU FOR SOMETHING THAT WASN'T YOUR FAULT, HOW WOULD YOU FEEL?

[1]	[2]	[3]	[4]
GET ANGRY OR MAD AND SHOW IT	GET ANNOYED AND SHOW IT	GET ANNOYED AND KEEP IT IN	GET ANGRY AND KEEP IT IN

2. IF (A POLICEMAN) REALLY DID GET ANGRY AT YOU FOR SOMETHING THAT WASN'T YOUR FAULT, WHAT WOULD YOU MOST LIKELY DO?

[1]	[2]	[3]	[4]
PROTEST STRONGLY	PROTEST A LITTLE	JUST LEAVE	JUST KEEP QUIET

For persons called 'houseowner' and 'employment agent' listed above, the respondent was asked to imagine that such perons discriminated against them by refusing them a house or job because of race, nationality or religion; they were then asked about their experinces of anger and their actions, using the same response categories as in A1 and A2.

During coding, the response categories were collapsed into 0/1 variables such that for Anger-In, a score of '0' was assigned to either showing anger or protesting, and '1' to either keeping anger in or leave/keep quiet responses. Adding these scores produced the Anger-In Index score.

The Guilt about Anger Index was composed of 9 items, referring again to the first five persons already listed above, reported in response to items immediately following the Anger-In set, and were in this format:

B. <u>GUILT ABOUT ANGER INDEX</u> (9 items)

1. SUPPOSE YOU GOT ANGRY OR MAD AT (THE POLICEMAN) AND SHOWED (HIM) THAT YOU FELT THIS WAY, HOW WOULD YOU FEEL ABOUT IT LATER?

[1]	[2]	[3]	[4]
NOT AT ALL GUILTY OR SORRY	A LITTLE GUILTY OR SORRY	SOMEWHAT GUILTY OR SORRY	VERY GUILTY OR SORRY

Four other items described the degree of guilt when punished by each of one's parents, and 2 other items describe the degree of selfblame for such punishment.

The Guilt about Anger Index then was a sum of recorded response categories illustrated by B1 above where '0' was assigned to 'not at all' and 'a little'; and depending on the frequency distribution, 'somewhat guilty' was either assigned '0' or '1'; and 'very guilty' was always assigned a '1'.

For both indices, among respondents who were not raised with their biological parents, the appropriate surrogate parents were used as references; among non-married respondents, a close friend of the opposite sex or lover was used instead of spouse; and for those who were not working, the 'boss' item was dropped from the Index. Scores for *both* indices were then computed as a proportion of the sum of '1's' to the total times reported by the respondent.

For the same set of items, two scales were also constructed using a Guttman–Lingoes scaling technique [12]. These two Guttmann–Lingoes scales, 'Anger-In' and 'Guilt about Anger' correlated 0.80 and 0.85 respectively with the two indices previously described.