American Journal of Epidemiology
Copyright © 2000 by The Johns Hopkins University School of Hygiene and Public Health
All rights reserved

Vol. 151, No. 10
Printed in U.S.A.

Blood Pressure Differences between Blacks and Whites in Relation to Body Size among US Children and Adolescents

Bernard Rosner,[1] Ronald Prineas,[2] Stephen R. Daniels,[3] and Jennifer Loggie[3]

No large national studies of ethnic differences in blood pressure among children accounting for body size differences have been published, to the authors' knowledge. This report details the similarities and differences in systolic and diastolic blood pressures between Black children and White children in the United States and examines the effects of age, sex, and body size on ethnic differences in blood pressure levels. Standardized measurements of seated systolic and diastolic pressures from eight large epidemiologic studies published between 1978 and 1991 that included measurements of 47,196 children on 68,556 occasions for systolic pressure and for 38,184 children on 52,053 occasions for diastolic pressure were used; 51 percent (24,048 children) were boys and 37 percent (17,466 children) were Black. Overall, there appear to be few substantive ethnic differences in either systolic or diastolic pressure during childhood and adolescence. The differences that were observed were small, inconsistent, and often explained by differences in body size. There was an ethnic group-body mass index (BMI) interaction that resulted in these findings that at lower levels of BMI Blacks have higher blood pressure and more hypertension than do Whites, but that at the highest levels of BMI, Whites have more hypertension (systolic or diastolic pressure) than do Blacks. *Am J Epidemiol* 2000;151:1007–19.

blood pressure; body mass index; ethnic groups; hypertension

Elevated blood pressure has been established as a major risk factor for the development of cardiovascular disease (1). It is also clear that in the United States Black adults have a substantially higher prevalence of hypertension compared with White adults (2). For example, the estimated 3-year incidence of new diagnosis of hypertension was more than twice as high for Black women and three times higher for Black men compared with Whites in the Hypertension Detection and Follow-up Program (3). In addition, the CARDIA Study has documented significant differences in blood pressure between Blacks and Whites in the young adult age group (4).

The age at which racial differences in blood pressure emerge has not been clearly delineated. Studies of neonatal, infant, and preschool children in the United States have generally not found higher blood pressure in Black compared with White individuals (5–7). The results of studies of older children and adolescents have been mixed, with some showing no difference in blood pressure by race (8–12), others showing higher blood pressure in Black children (13, 14), and still others showing higher blood pressure in White children (15, 16). In many of these studies, the effects of covariates, such as body size, have not been extensively evaluated, and all have been of relatively small sample size.

The purpose of this analysis was to evaluate potential differences in blood pressure by ethnicity by combining data in 68,562 children-visits from eight large epidemiologic studies of cardiovascular risk factors in children and adolescents published between 1978 and 1991. In addition, we sought to determine the extent to which age, sex, and body size affect ethnic differences in blood pressure.

MATERIALS AND METHODS

Study populations were selected to match those used in the US Task Force Report on children's blood pressure (17). Of the eight populations included in this study, blood pressure measurement methods for six of the US population samples (18–24) (Lackland et al., unpublished manuscript, 1985) with both Black and White children at or above age 5 years are detailed in a previous publication (25). In addition, the Minnesota Prevention of High Blood Pressure in Children Program and the National Health and Nutrition Survey

Received for publication October 1, 1998, and accepted for publication July 23, 1999.

Abbreviations: BMI, body mass index; DBP5, fifth-phase diastolic blood pressure; NHANES, National Health and Nutrition Examination Survey.

[1] Channing Laboratory, Harvard University, Boston, MA.
[2] Department of Public Health Sciences, Wake Forest University School of Medicine, Winston-Salem, NC.
[3] Children's Hospital Medical Center and the University of Cincinnati, Cincinnati, OH.
Reprint requests to Dr. Bernard Rosner, Channing Laboratory, 181 Longwood Avenue, Boston, MA 02115 (e-mail: stbar@gauss.med.harvard.edu).

TABLE 1. Demographic data of study population, eight US study populations, 1979–1996

Source (reference and publication date)	Age (years)	No. of boys	No. of girls	No. Black	No. White	SBP* available		DBP5* available		Total	
						Persons†	Visits	Persons‡	Visits	Persons§	Visits
Bogalusa (18, 19) (1980)	5–17	3,671	3,513	2,424	4,760	7,184	14,663	0	0	7,184	14,663
Dallas (20, 21) (1983)	12–17	5,109	4,886	5,266	4,729	9,995	19,214	9,995	19,207	9,995	19,214
Houston (22) (1981)	5–17	559	565	514	610	1,124	1,124	0	0¶	1,124	1,124
Minnesota											
NaKS* (23) (1991)	10–15	7,618	7,124	3,422	11,320	14,472	14,742	14,588	14,588	14,742	14,742
PHPBC* (26) (1980)	12–18	584	499	374	709	1,083	5,751	1,081	5,738	1,083	5,751
NHANES III* (17) (1996)	5–17	1,500	1,589	1,766	1,323	3,089	3,088	2,639	2,639	3,089	3,089
NHES II* (24) (1979)	6–17	1,848	1,720	600	2,968	3,568	3,563	3,531	3,531	3,568	3,568
South Carolina# (1985)	5–17	3,159	3,252	3,100	3,311	6,411	6,411	6,350	6,350	6,411	6,411
Total		24,048	23,148	17,466	29,730	47,196	68,556	38,184	52,053	47,196	68,562
Percentage of total no. of children		51	49	37	63						

* SBP, systolic blood pressure; DBP5, fifth-phase diastolic blood pressure; NaKS, Sodium-Potassium Blood Pressure Trial in Children; PHPBC, Prevention of High Blood Pressure in Children Program; NHANES III, Third National Health and Nutrition Examination Survey; NHES II, Second National Health Examination Survey.

† Number of persons and visits for which SBP was available.

‡ Number of persons and visits for which DBP5 was available.

§ Number of persons and visits for which either SBP or DBP5 was available.

¶ Only fourth-phase Korotkoff sounds diastolic blood pressure was measured so no DBP5 measurement was available.

Lackland et al., unpublished manuscript, 1985.

(NHANES) III study data (17, 26) were added to those of the prior six studies. All studies were extant and national, community based and included Black and White children and were available with required databases in electronic form for use in this report. Briefly, a mercury sphygmomanometer was used in six studies, and a random-zero device was used in two. Only the first blood pressure measurement for each separate study visit was used for each subject aged 5–17 years in these analyses. Two studies (18, 19, 22) for which diastolic blood pressure was measured only at the onset of the fourth phase of Korotkoff sounds (muffling) contributed data only for systolic blood pressure measurements. Blood pressure levels measured at multiple visits for any subject were used only if they were made at different ages. Most studies based cuff size on the circumference of the upper arm; in all studies, blood pressure was measured in the seated position; fifth-phase diastolic blood pressure (the disappearance of sounds (DBP5)) was used to characterize diastolic pressure; and most blood pressure measurements were made in the nonfasting state, throughout the year, and throughout the day. Most measurements were made in the school setting or in special trailers. Height was measured without shoes in all studies, and weight was measured without heavy outer clothes on beam balance scales (27). None of the systematic differences in blood pressure measurements between studies affect Black/White comparisons because the studies are internally consistent.

Descriptive data are provided of systolic and diastolic pressures by 1-year age groups, sex, and ethnicity (Black/White) as well as by age for children (aged 5–12 years) and adolescents (aged 13–17 years). In addition, linear regression models were fit to control for 1) study, 2) study and height (z score), and 3) study, height (z score), and weight (z score) to address the possible mediating effects of height and weight on differences found between ethnic groups. The z scores were obtained from NHANES III on the basis of age-sex percentile charts of height and weight (17). To standardize height and weight for age and sex, we computed age- and sex-specific height and weight percentiles and the corresponding z scores on the basis of standard growth charts (28) using software (EPINUT program) distributed for this purpose by the Centers of Disease Control and Prevention, Atlanta, Georgia. Survey weights were not used for NHANES and the National Health Examination Survey so as to make the treatment of these studies comparable with the other studies in our dataset. Some previous studies have also investigated ethnic effects on extreme levels of blood pressure (e.g., more than the 95th percentile). Hence, we performed ethnic-specific logistic regressions of elevated blood pressure, defined as above the 95th percentile for a given age and height (17) on body mass index (BMI) and consider interaction effects of ethnicity and BMI using the model :

$$ln\,[p/(1-p)] = \alpha + \beta_1\,\text{ethnicity} + \beta_2\,\text{ethnicity} \times (\text{BMI} - 20) + \beta_3\,\text{BMI} + \beta_4(\text{age} - 10)(\text{BMI} - 20) + \beta_5(\text{age} - 10) + \beta_6\,\text{height}.$$

where p is the probability of being above the 95th percentile for a given age and height.

Furthermore, because there was a significant interaction effect of ethnicity and BMI on the prevalence of elevated diastolic pressure, we compared the proportion of Black versus White children with elevated blood pressure stratified by age group (ages 5–12 vs. 13–17 years), sex (male vs. female), and BMI (nonobese (first to fourth BMI quintiles) vs. obese (fifth BMI quintile)) using chi-square analysis. BMI quintiles were defined within specific years of age to avoid an age effect. We also compared the prevalence of elevated blood pressure by ethnic group while controlling for age group and sex by using the Mantel-Haenszel test.

The purpose of using (BMI – 20) and (age – 10) is to allow the main effect of ethnicity (measured by β_1) to be interpretable as the effect of ethnicity on the probability of having elevated blood pressure (≥95th percentile) for children of a roughly average age in the dataset (age 10 years) and a roughly average BMI in the dataset (20 kg/m^2).

RESULTS

The demographics of the study population are given in table 1. For systolic pressure, the study sample included 68,556 visits for 47,196 children and for DBP5 there were 52,053 visits for 38,184 children. The sample included 24,048 (51 percent) boys and 23,148 (49 percent) girls. Thirty-seven percent (n = 17,466) were Black, and 63 percent (n = 29,730) were White. The number of blood pressure visits available by each year of age from ages 5–17 years and by each of the eight studies contributing data to our analyses are given in table 2. The contribution of data by age group varied by study, with two studies providing all or most of the data for adolescents only. However, for the study sample as a whole, no single-year age group had fewer than 2,100 visits from which to contribute blood pressure measurements for analysis.

Comparison of blood pressure levels between Blacks and Whites, graphed in figures 1 and 2, was made by first presenting mean levels by age group for each year of age. Second, comparison was made after adjustment for study group alone; third, it was made separately, after adjustment for study and height z score; and finally, after adjustment for study, height z score, and weight z score. Table 3 shows all of these comparisons for systolic pressure among boys, and table 4 shows them for systolic pressure among girls. White boys had marginally higher systolic pressures than did Black boys for all age groups except age 12 years. The mean difference was 0.4 mmHg for children aged 5–12 years and 0.9 mmHg for adolescents aged 13–17 years. Adjustment for study and for height (as a measure of maturity) made only minor changes to these estimates of difference.

TABLE 2. Number of blood pressure visits by age distribution and study, eight US study populations, 1979–1996

Study (reference)	Age (years)													Total
	5	6	7	8	9	10	11	12	13	14	15	16	17	
Bogalusa (17, 18)	1,200	1,242	1,247	1,204	1,205	1,307	1,250	1,322	1,256	1,143	867	740	680	14,663
Dallas (19, 20)	0	0	0	0	0	0	0	0	4,897	3,333	4,810	2,470	3,704	19,214
Houston (21)	151	130	108	99	76	77	79	86	81	83	72	52	30	1,124
Minnesota														
NaKS* (22)	0	0	0	0	5	1,673	3,228	3,614	3,961	2,024	230	7	0	14,742
PHPBC* (26)	0	0	0	0	0	0	2	547	1,348	1,612	1,233	1,006	3	5,751
NHANES III* (17)	272	146	152	271	339	335	306	252	215	231	226	234	110	3,089
NHES II* (23)	0	227	292	260	287	286	287	282	312	361	322	342	310	3,568
South Carolina (24)	512	497	503	613	555	621	498	465	440	402	402	477	426	6,411
Total	2,135	2,242	2,302	2,447	2,467	4,299	5,650	6,568	12,510	9,189	8,162	5,328	5,263	68,562

* NaKS, Sodium-Potassium Blood Pressure Trial in Children; PHPBC, Prevention of High Blood Pressure in Children Program; NHANES III, Third National Health and Nutrition Examination Survey; NHES II, Second National Health Examination Survey.

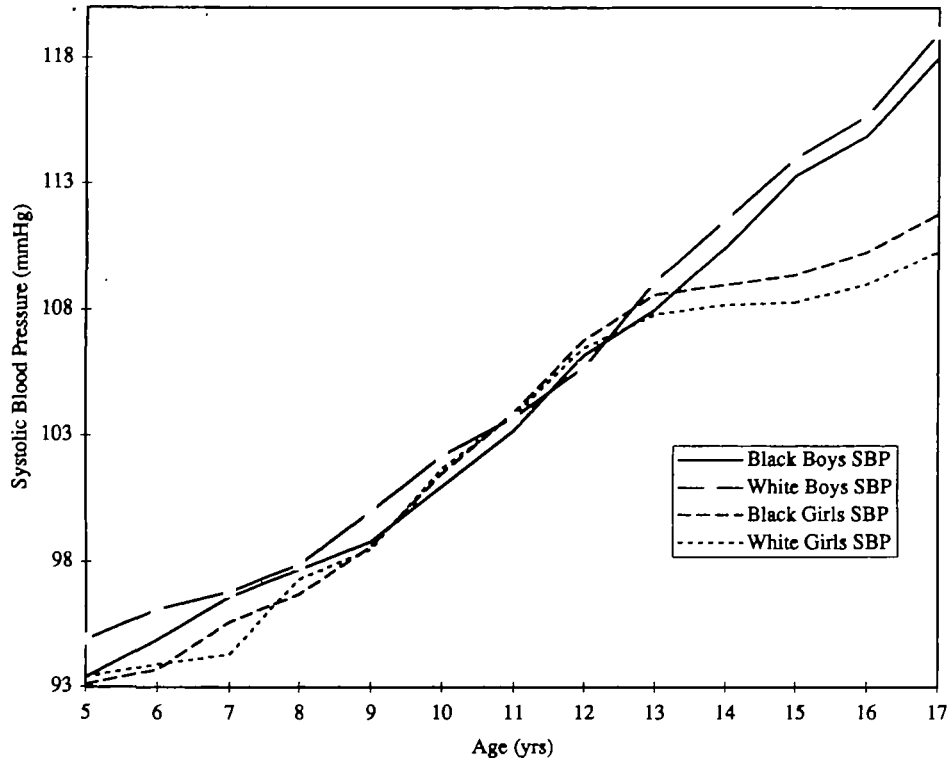

FIGURE 1. Means of systolic pressure levels of both Black and White boys and girls aged 5–17 years, eight US study populations, 1979–1996.

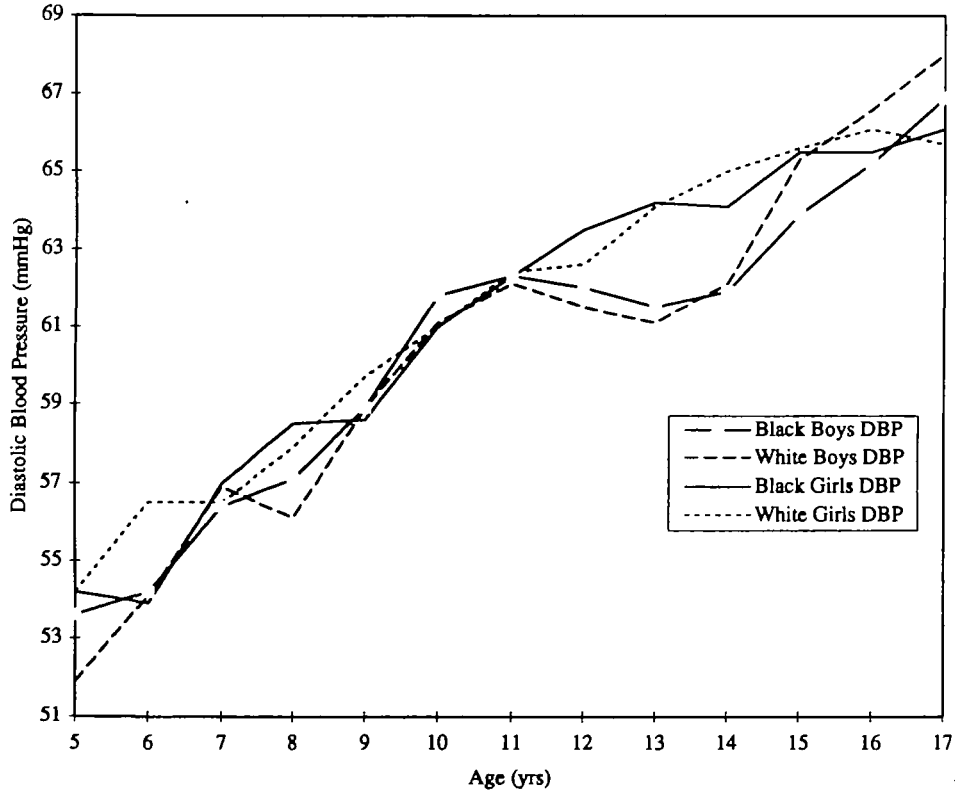

FIGURE 2. Means of diastolic pressure levels of both Black and White boys and girls aged 5–17 years, eight US study populations, 1979–1996.

TABLE 3. Distribution of systolic blood pressure by ethnicity in boys aged 5–17 years, eight US study populations, 1979–1996

Age (years)	Black			White			Black-White differences								
							Adjusted for study			Adjusted for study and height			Adjusted for study, height, and weight		
	Mean	(SD*)	No.	Mean	(SD)	No.	Mean	95% CI*	*p* value	Mean	95% CI	*p* value	Mean	95% CI	*p* value
5	93.4	(9.7)	425	94.9	(9.9)	579	−1.5	−2.7, −0.3	0.016	−2.1	−3.3, −0.9	<0.001	−2.0	−3.1, −0.8	0.001
6	94.9	(10.1)	465	96.1	(9.7)	682	−1.2	−2.3, 0.0	0.046	−1.9	−3.0, −0.7	0.001	−1.7	−2.8, −0.5	0.004
7	96.6	(10.1)	434	96.8	(10.0)	694	−0.2	−1.4, 1.0	0.74	−1.0	−2.2, 0.2	0.089	−0.7	−1.9, 0.4	0.21
8	97.7	(10.2)	475	97.9	(10.1)	769	−0.2	−1.4, 0.9	0.70	−1.0	−2.2, 0.1	0.065	−0.7	−1.7, 0.4	0.22
9	99.8	(10.1)	473	100.0	(10.1)	759	−0.2	−1.4, 0.9	0.71	−0.5	−1.6, 0.6	0.35	−0.2	−1.3, 0.8	0.65
10	101.0	(9.9)	652	102.2	(10.1)	1,501	−1.2	−2.1, −0.3	0.01	−1.8	−2.7, −0.9	<0.001	−1.4	−2.3, −0.5	0.001
11	103.2	(10.1)	844	103.7	(9.9)	2,011	−0.6	−1.4, 0.2	0.16	−0.9	−1.7, −0.1	0.029	−0.6	−1.3, 0.2	0.14
12	106.2	(10.3)	985	105.7	(10.0)	2,378	0.6	−0.2, 1.3	0.15	0 4	−0.4, 1.1	0.32	0.6	−0.1, 1.3	0.098
5–12							0.4	−0.8, −0.1	0.014	−0.9	−1.3, −0.6	<0.001	−0.7	−1.0, −0.3	<0.001
13	108.0	(11.9)	2,336	109.1	(11.3)	3,913	−1.1	−1.7, −0.5	<0.001	−0.9	−1.5, −0.4	0.001	−0.7	−1.3, −0.2	0.007
14	110.5	(12.3)	1,978	111.6	(11.8)	2,944	−1.0	−1.7, −0.3	0.004	−0.4	−1.1, 0.2	0.21	−0.3	−1.0, 0.4	0.29
15	113.3	(12.0)	1,843	114.0	12.1)	2,220	−0.7	−1.4, 0.1	0.083	−0.2	−0.9, 0.5	0.59	−0.3	−1.0, 0.4	0.35
16	114.9	(12.3)	1,234	115.7	(11.7)	1,562	−0.8	−1.7, 0.1	0.079	−0.4	−1.2, 0.5	0.44	−0.3	−1.1, 0.6	0.50
17	118.0	(12.2)	1,292	119	(12.1)	1,285	−1.0	−1.9, 0.0	0.043	−0.7	−1.6, 0.3	0.16	−0.9	−1.8, 0.0	0.05
13–17							−0.9	−1.3, −0.6	<0.001	−0.5	−0.8, −0.2	0.002	−0.5	−0.8, −0.2	0.001

* SD, standard deviation; CI, confidence interval.

TABLE 4. Distribution of systolic blood pressure by ethnicity in girls aged 5–17 years, eight US study populations, 1979–1996

Age (years)	Black			White			Black-White differences								
							Adjusted for study			Adjusted for study and height			Adjusted for study, height, and weight		
	Mean	(SD*)	No.	Mean	(SD)	No.	Mean	95% CI*	*p* value	Mean	95% CI	*p* value	Mean	95% CI	*p* value
5	93.1	(11.0)	456	93.4	(9.8)	671	−0.3	−1.5, 1.0	0.68	−1.2	−2.5, 0.0	0.048	−1.1	−2.4, 0.1	0.067
6	93.7	(10.3)	454	93.9	(10.1)	634	−0.1	−1.4, 1.1	0.83	−0.9	−2.1, 0.3	0.14	−0.7	−1.9, 0.5	0.25
7	95.6	(10.0)	453	94.3	(10.0)	714	1.4	0.2, 2.6	0.022	−0.1	−1.2, 1.1	0.90	0.3	−0.8, 1.5	0.54
8	96.7	(10.3)	458	97.3	(10.5)	742	−0.6	−1.8, 0.6	0.36	−1.8	−3.0, −0.6	0.003	−1.5	−2.6, −0.3	0.012
9	98.6	(10.3)	487	98.5	(11.2)	747	0.1	−1.1, 1.4	0.85	−1.5	−2.7, −0.2	0.019	−1.4	−2.6, −0.3	0.014
10	101.5	(10.3)	689	101.7	(10.3)	1,456	−0.2	−1.2, 0.7	0.61	−1.5	−2.4, −0.5	0.002	−1.5	−2.4, −0.6	<0.001
11	103.9	(10.3)	822	103.8	(10.2)	1,967	0.1	−0.7, 0.9	0.84	−1.0	−1.8, −0.2	0.018	−1.0	−1.8, −0.2	0.011
12	106.8	(10.4)	976	106.5	(10.2)	2,197	0.3	−0.5, 1.0	0.52	−0.4	−1.1, 0.4	0.32	−0.7	−1.5, 0.0	0.052
5–12							0.1	−0.3, 0.4	0.66	−1.0	−1.3, −0.6	<0.001	−1.0	−1.3, −0.6	<0.001
13	108.6	(11.6)	2,413	107.8	(10.8)	3,774	0.8	0.2, 1.3	0.007	0.7	0.1, 1.2	0.02	0.0	−0.5, 0.6	0.93
14	109	(11.3)	1,744	108.2	(10.6)	2,456	0.9	0.2, 1.5	0.013	0.9	0.2, 1.6	0.007	0.4	−0.2, 1.1	0.20
15	109.4	(11.0)	1,881	108.3	(10.7)	2,156	1.1	0 4, 1.8	0.001	1.2	0.6, 1.9	<0.001	0.4	−0.3, 1.0	0.28
16	110.3	(10.5)	1,186	109	(10.7)	1,296	1.3	0.4, 2.1	0.003	1.4	0.6, 2.2	<0.001	0.9	0.1, 1.7	0.034
17	111.8	(11.0)	1,361	110.3	(10.7)	1,324	1.6	0.8, 2.4	<0.001	1.8	1.0, 2.6	<0.001	0.8	0.0, 1.5	0.053
13–17							1.0	0.7, 1.3	<0.001	1.1	0.8, 1.4	<0.001	0.4	0.1, 0.7	0.006

* SD, standard deviation; CI, confidence interval.

TABLE 5. Distribution of diastolic blood pressure by ethnicity in boys aged 5–17 years, eight US study populations, 1979–1996

Age (years)	Black			White			Black-White differences								
							Adjusted for study			Adjusted for study and height			Adjusted for study, height, and weight		
	Mean	(SD*)	No.	Mean	(SD)	No.	Mean	95% CI*	*p* value	Mean	95% CI	*p* value	Mean	95% CI	*p* value
5	53.6	(10.5)	162	51.9	(10.4)	161	1.7	−0.6, 3.9	0.16	1.0	−1.2, 3.3	0.37	1.1	−1.1, 3.4	0.33
6	54.2	(12.2)	205	54.1	(11.0)	213	0.0	−2.2, 2.3	0.97	−0.1	−2.3, 2.1	0.93	−0.1	−2.3, 2.1	0.92
7	56.4	(11.0)	197	56.9	(9.9)	256	−0.5	−2.5, 1.4	0.59	−0.8	−2.7, 1.2	0.45	−0.3	−2.2, 1.6	0.75
8	57.1	(11.8)	227	56.1	(11.0)	336	1.0	−0.9, 2.9	0.32	0.2	−1.7, 2.1	0.83	0.2	−1.7, 2.1	0.84
9	58.9	(11.7)	216	58.9	(10.2)	324	0.0	−1.9, 1.8	0.97	0.0	−1.9, 1.8	0.97	0.1	−1.7, 1.9	0.90
10	61.8	(11.6)	397	61.1	(11.4)	1,002	0.7	−0.6, 2.1	0.29	0.4	−0.9, 1.8	0.52	0.5	−0.9, 1.8	0.49
11	62.3	(11.8)	566	62.1	(11.0)	1,566	0.2	−0.9, 1.3	0.73	0.1	−1.0, 1.2	0.87	0.2	−0.9, 1.3	0.75
12	62	(12.1)	690	61.5	(11.9)	1,896	0.6	−0.5, 1.6	0.30	0.5	−0.5, 1.6	0.34	0.6	−0.5, 1.6	0.27
5–12							0.4	−0.1, 1.0	0.11	0.3	−0.3, 0.8	0.35	0.3	−0.2, 0.8	0.29
13	61.5	(12.0)	2,079	61.1	(12.2)	3,423	0.4	−0.3, 1.0	0.26	0.5	−0.2, 1.1	0.14	0.5	−0.1, 1.2	0.11
14	61.9	(12.4)	1,695	62.1	(12.5)	2,537	−0.2	−1.0, 0.5	0.54	0.1	−0.6, 0.9	0.72	0.1	−0.6, 0.9	0.78
15	63.9	(11.7)	1,646	65.3	(11.5)	1,924	−1.4	−2.2, −0.6	<0.001	−1 0	−1.7, −0.2	0.011	−1.0	−1.8, −0.3	0.007
16	65.2	(11.7)	1,072	66.6	(11.5)	1,309	−1.4	−2.3, −0.5	0.003	−1.0	−2.0, −0.1	0.032	−1.0	−1.9, −0.1	0.033
17	66.9	(11.3)	1,147	68	(10.4)	1,069	−1.1	−2.0, −0.2	0.02	−0.8	−1.7, 0.1	0.1	−0.8	−1.7, 0.1	0.071
13–17							−0.6	−0.9, −0.2	0.002	−0.3	−0.6, 0.1	0.15	−0.3	−0.6, 0.1	0.11

* SD, standard deviation; CI, confidence interval.

TABLE 6. Distribution of diastolic blood pressure by ethnicity in girls aged 5–17 years, eight US study populations, 1979–1996

Age (years)	Black			White			Black-White differences								
							Adjusted for study			Adjusted for study and height			Adjusted for study, height, and weight		
	Mean	(SD*)	No.	Mean	(SD)	No.	Mean	95% CI*	*p* value	Mean	95% CI	*p* value	Mean	95% CI	*p* value
5	54.2	(11.4)	207	54.2	(10.6)	198	−0.0	−2.2, 2.2	1.0	−0.8	−3.0, 1.3	0.45	−1.0	−3.1, 1.1	0.35
6	53.9	(11.7)	194	56.5	(10.4)	217	−2.5	−4.7, −0 4	0.021	−3.1	−5.2, −1.0	0.005	−3.0	−5.1, −0.9	0.001
7	57.0	(11.6)	194	56.6	(11.2)	256	0.5	−1.7, 2.6	0.68	−0.6	−2.8, 1.6	0.59	−0.3	−2.5, 1.8	0.75
8	58.5	(10.2)	218	57.9	(9.8)	287	0.5	−1.2, 2.3	0.54	0.4	−1.4, 2.2	0.65	0.5	−1.2, 2.3	0.55
9	58.6	(12.0)	240	59.7	(12.0)	332	−1.2	−3.2, 0.8	0.25	−2.2	−4.2, −0.2	0.035	−1.9	−3.9, 0.1	0.05
10	61.0	(11.7)	432	61.0	(11.0)	1,003	−0.0	−1.3, 1.3	0.98	−0.4	−1.7, 0.9	0.51	−0.5	−1.7, 0.8	0.48
11	62.3	(11.5)	576	62.4	(11.2)	1,535	−0.1	−1.2, 1 0	0.83	−0.8	−1.9, 0.3	0.17	−0.8	−1.9, 0.3	0.17
12	63.5	(11.4)	697	62.6	(11.8)	1,767	0.9	−0.2, 1.9	0.97	0.6	−0.4, 1.6	0.26	0.4	−0.6, 1.4	0.43
5–12							0.0	−0.5, 0.6	0.87	−0.5	−1.0, 0.1	0.081	−0 6	−1.1, 0.0	0.037
13	64.2	(11.9)	2,149	64.1	(11.3)	3,377	0.1	−0.6, 0.7	0.83	0.0	−0.6, 0 6	0.97	−0.3	−0.9, 0.3	0.36
14	64.1	(11.3)	1,499	65	(10.8)	2,102	−1.0	−1.7, −0.2	0.009	−0.9	−1.7, −0.2	0.012	−1.1	−1.9, −0.4	0.002
15	65.5	(10.3)	1,690	65.6	(9.9)	1,879	−0.2	−0.8, 0.5	0.63	−0.1	−0.7, 0.6	0.8	−0.5	−1.1, 0.2	0.16
16	65.5	(10.4)	1,011	66.1	(9.7)	1,078	−0.6	−1.5, 0.3	0.17	−0.5	−1.3, 0.4	0.29	−0.8	−1.6, 0.1	0.076
17	66.1	(10.1)	1,204	65.7	(9.7)	1,120	0.4	−0.4, 1.2	0.31	0.6	−0.2, 1.4	0.13	0.0	−0.8, 0.8	0.98
13–17							−0.2	−0.6, 0.1	0.16	−0.2	−0.5, 0.2	0.30	−0.5	−0.8, −0.2	0.002

* SD, standard deviation; CI, confidence interval.

Comparisons of systolic pressures between Black girls and White girls revealed more complex results than did those for boys. Unlike that for boys, Black girls' systolic pressure was higher (mean, 1 mmHg) than that of White girls for adolescents aged 13–17 years. These differences remained and were significant after adjustment by study. However, after adjustment by height and weight, the difference was reduced by more than 50 percent, although it was still significant, at 0.4 mmHg higher systolic pressure among Black than among White female adolescents. Like boys, among younger girls (aged 5–12 years), after adjustment for study, height, and weight, White girls as a group had higher adjusted (1 mmHg) systolic pressure than did Black girls.

Table 5 shows the comparisons of mean levels of DBP5 by age and race for boys adjusted for study group alone, for study group and height, and for study group, height, and weight. There were no significant differences between ethnic groups among boys for DBP5 for children aged 5–12 years or for adolescents aged 13–17 years after adjustment for study, height, and weight.

Girls showed fewer differences between Blacks and Whites for DBP5 (table 6) than for systolic pressure. Diastolic pressure for both young girls aged 5 and 12 years and adolescents aged 13–17 years were significantly lower by about half a mmHg for Blacks than for Whites.

Figure 3 shows the greater BMI for Black girls at all ages after 8 years compared with the other age-sex groups. Further analysis for ethnic group by BMI interactions were explored to determine whether age- and sex-adjusted body size is related to blood pressure levels differently among the two ethnic groups. The results of these analyses are shown in table 7. First, the odds of elevated blood pressure was significantly higher for the upper versus the lower decile of BMI for both sexes, ethnic groups, and age groups. The only significant differences in the influence of BMI on blood pressure between ethnic groups was for systolic pressure among adolescent males (aged 13–17 years old), in which systolic pressure was significantly more influenced by BMI for Whites than for Blacks (odds ratio for occurrence of elevated blood pressure for upper vs. lower decile of BMI, 2.7 vs. 1.5, respectively)

The effect of the interaction of ethnicity and BMI on the frequency of elevated blood pressure is further explicated in table 8. Table 8 shows that, regardless of BMI quintile, the odds ratio for elevated systolic pressure is generally lower for Blacks than for Whites except for older (aged 13–17 years) girls, where the reverse is true. However, the odds ratio of elevated diastolic pressure among Blacks (odds ratio = 1.17, 95 percent confidence interval: 1.04, 1.33) is greater than for Whites for the lower quintiles of BMI, and the

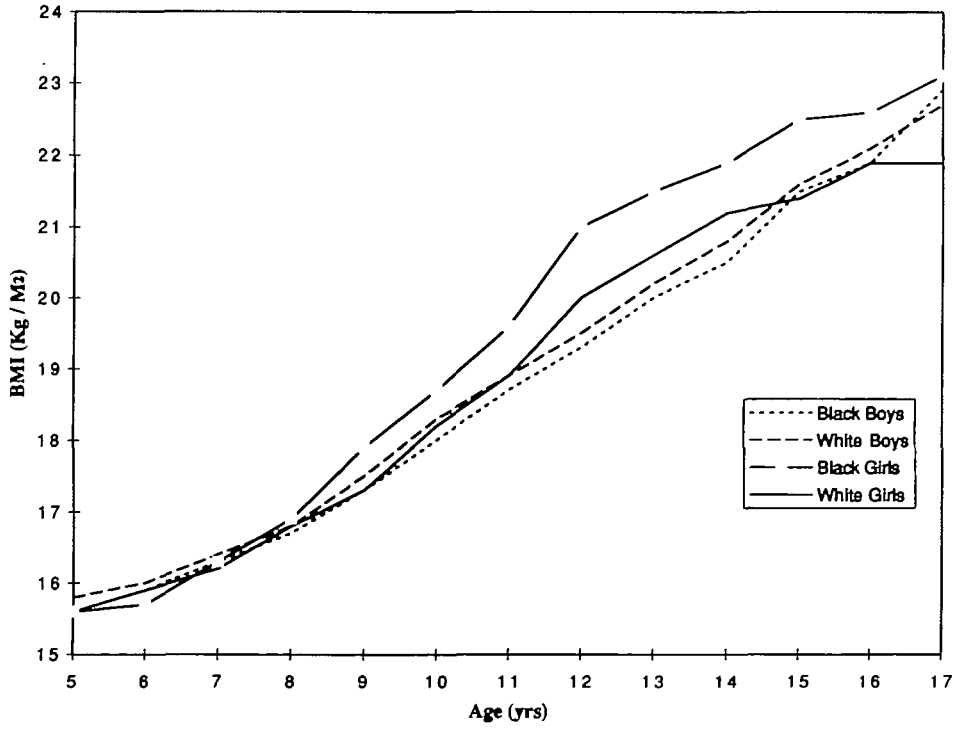

FIGURE 3. Means of BMI of both Black and White boys and girls aged 5–17 years, eight US study populations, 1979–1996.

TABLE 7. Odds ratios for children and adolescents with elevated blood pressure (above the 95th percentile for age and height*) comparing upper and lower deciles of BMI† stratified by age groups and ethnicity, eight US study populations, 1979–1996

Blood pressure level, sex, and age group (years)	BMI†			Black				White				Interaction effect of ethnicity × BMI‡ (*p* value)
	10th percentile	90th percentile	Difference	OR†	95% CI†	No.	No. above 95th percentile	OR	95% CI	No.	No. above 95th percentile	
SBP†												
Male												
5–12	14.8	22.3	7.5	2.9	2.3, 3.6	4,753	137	3.4	2.8, 4.1	9,373	302	0.20
13–17	17.3	25.7	8.4	2.8	2.4, 3.2	8,683	457	3.3	2.9, 3.8	11,924	686	0.096
DBP†												
Male												
5–12	14.8	22.3	7.5	1.6	1.1, 2.4	2,660	73	2.1	1.6, 2.8	5,754	169	0.16
13–17	17.3	25.7	8.4	1.5	1.2, 1.9	7,639	247	2.7	2.3, 3.3	10,262	314	<0.001
SBP												
Female												
5–12	14.4	23.1	8.7	2.5	2.0, 3.3	4,794	160	2.5	2.0, 3.1	9,128	358	0.96
13–17	17.4	27.0	9.6	3.6	3.1, 4.2	8,585	470	3.7	3.1, 4.3	11,006	460	0.71
DBP												
Female												
5–12	14.4	23.1	8.7	1.7	1.3, 2.4	2,758	104	2.4	1.8, 3.2	5,595	105	0.071
13–17	17.4	27.0	9.6	2.3	2.0, 2.8	7,553	306	2.9	2.4, 3.5	9,556	348	0.062

* National High Blood Pressure Education Program Working Group Report on Hypertension Control in Children and Adolescents (27).
† BMI, body mass index; OR, odds ratio; CI, confidence interval; SBP, systolic blood pressure; DBP, diastolic blood pressure.
‡ Log $P/1-P = \alpha + \beta_1$ethnicity $+ \beta_2$ethnicity $\times$ (BMI $- 20$) $+ \beta_3$ BMI $+ \beta_4$(age $- 10$)(BMI $- 20$) $+ \beta_5$(age $- 10$) $+ \beta_6$height.

TABLE 8. Proportion of individuals with elevated blood pressure* by BMI† quintile, age, ethnicity, sex, and odds ratios for proportions with elevated blood pressure, Black versus White, eight US study populations, 1979–1996

Blood pressure level, BMI quintile, and age (years)	Sex	Black		White		χ^2	df	p value	OR†	95% CI†
		Total no.	% ≥95th percentile	Total no.	% ≥95th percentile					
SBP†										
1–4										
5–12	Male	3,856	2.0	7,443	2.1	0.08	1	0.78	0.95	0.72, 1.25
13–17	Male	7,096	3.9	9,391	4.2	0.69	1	0.41	0.93	0.80, 1.09
5–12	Female	3,733	2.4	7,409	3.1	4.10	1	0.043	0.77	0.60, 0.98
13–17	Female	6,530	3.7	9,144	2.9	7.08	1	0.008	1.28	1.07, 1.53
5–17						0.001	1	0.97	1.00	0.85, 1.18
5										
5–12	Male	897	6.6	1,930	7.5	0.59	1	0.04	0.87	0.64, 1.20
13–17	Male	1,587	11.2	2,533	11.5	0.08	1	0.78	0.97	0.80, 1.18
5–12	Female	1,061	6.8	1,719	7.7	0.64	1	0.42	0.88	0.65, 1.18
13–17	Female	2,055	11.2	1,862	10.5	0.44	1	0.51	1.08	0.88, 1.32
5–17						0.17	1	0.68	0.97	0.86, 1.11
DBP†										
1–4										
5–12	Male	2,100	2.6	4,540	2.4	0.06	1	0.81	1.07	0.77, 1.49
13–17	Male	6,197	3.0	8,087	2.4	5.15	1	0.023	1.27	1.04, 1.56
5–12	Female	2,099	3.2	4,505	2.6	1.65	1	0.20	1.23	0.91, 1.67
13–17	Female	5,709	3.0	7,895	2.8	0.87	1	0.35	1.11	0.90, 1.36
5–17						6.64	1	0.01	1.17	1.04, 1.33
5										
5–12	Male	560	3.4	1,214	4.9	1.81	1	0.18	0.68	0.40, 1.14
13–17	Male	1,442	4.2	2,175	5.6	3.30	1	0.069	0.74	0.54, 1.01
5–12	Female	659	5.5	1,090	7.0	1.32	1	0.25	0.77	0.51, 1.16
13–17	Female	1,844	7.2	1,661	7.8	0.47	1	0.49	0.91	0.71, 1.17
5–17						6.16	1	0.013	0.81	0.68, 0.96

* Above the 95th percentile for blood pressure after adjustment for age, height, and sex.
† BMI, body mass index; OR, odds ratio; CI, confidence interval; SBP, systolic blood pressure; DBP, diastolic blood pressure.

reverse is true for the highest quintile of BMI, in which the odds ratio among Blacks is lower than that for Whites (odds ratio = 0.81, 95 percent confidence interval: 0.68, 0.96).

Figures 4–7 reinforce the findings in tables 7 and 8 by showing that at lower levels of BMI, Blacks have a higher proportion of individuals above the 95th percentile of blood pressure, whereas for the highest quintile of BMI, Whites have a greater proportion of individuals above the 95th percentile of blood pressure.

DISCUSSION

There is a well-documented excess of hypertension among adult Blacks compared with Whites. Until these analyses, no substantial differences in blood pressure levels or the prevalence of hypertension have been found between Black and White children aged 12 years and younger in the United States. However, smaller studies, which did not adjust for differences in height and weight, have found conflicting evidence for differences in blood pressure levels between US adolescent Blacks and Whites, as noted in the introduction and as previously reviewed (29). A recent review (16) that attempted to summarize 29 previous studies of blood pressure that included both Black and White participants found that Black adolescent girls (aged 13–17 years) did have a greater mean systolic pressure (but not diastolic pressure) than did White adolescent girls. In the same review, Black boys were found to have a higher diastolic pressure (but no difference for systolic pressure) than White boys aged less than 13 years, but there was no adjustment for height or weight.

After data from 68,562 children-visits in eight US population or school-based studies were combined, differences in blood pressure between Black children and White children aged 5–17 years were detailed. Differences were found that were small, inconsistent by age group, and different for systolic and diastolic pressures and by sex. White boys had marginally higher systolic pressure than did Black boys for both young (aged 5–12 years) and older (aged 13–17 years) age groups. For diastolic pressure, there were no differences for male Blacks and Whites. Among girls,

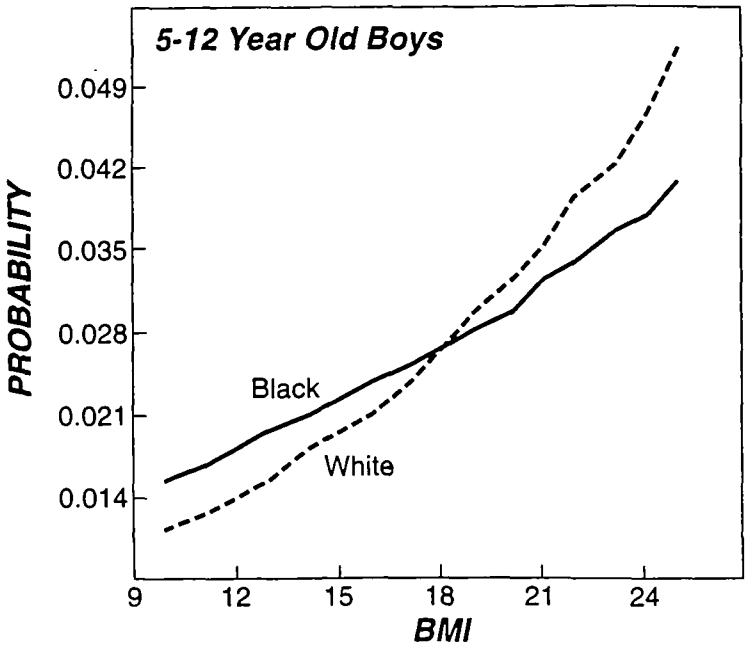

FIGURE 4. Probability of diastolic pressure over the 95th percentile versus BMI among boys aged 5–12 years by ethnic group, eight US study populations, 1979–1996.

diastolic pressure was marginally and significantly lower in Black girls than in White girls for both children and adolescents. This was also true since, for systolic pressure among children aged 5–12 years, White girls had a marginally higher blood pressure than did Black girls; however, for adolescents the reverse was true. The higher systolic pressure among adolescent Black compared with White girls was reduced 50 percent, to 0.4 mmHg, after adjustment for study height and weight.

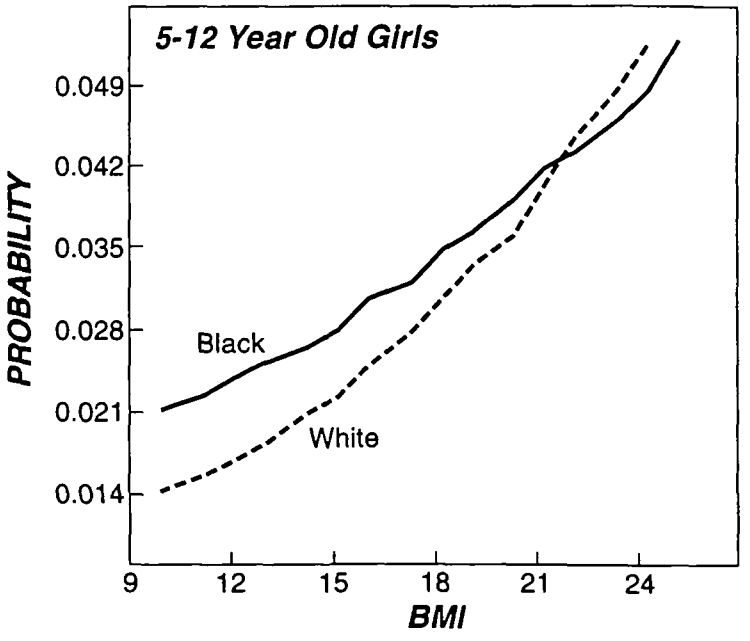

FIGURE 5. Probability of diastolic pressure over the 95th percentile versus BMI among girls aged 5–12 years by ethnic group, eight US study populations, 1979–1996.

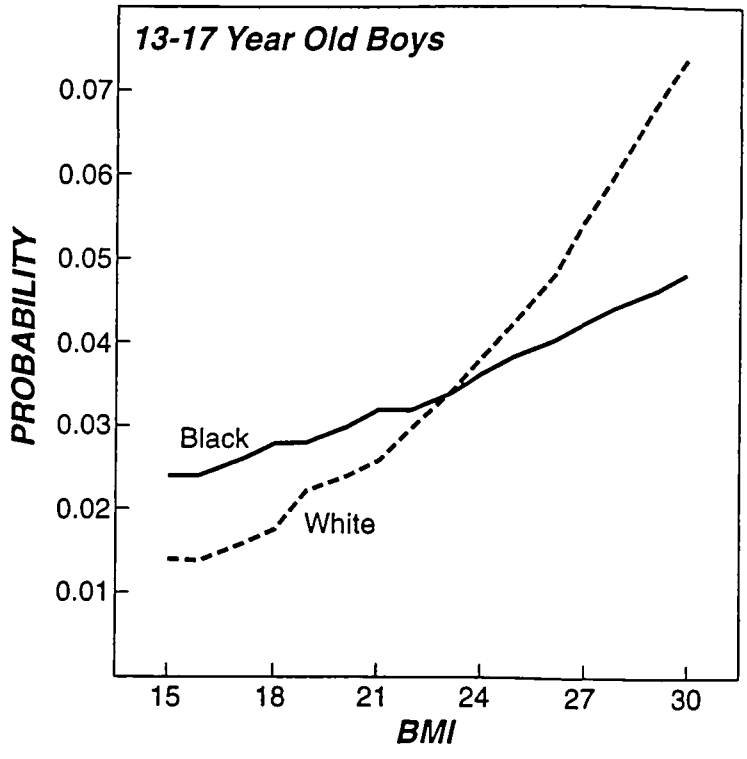

FIGURE 6. Probability of diastolic pressure over the 95th percentile versus BMI among boys aged 13–17 years by ethnic group, eight US study populations, 1979–1996.

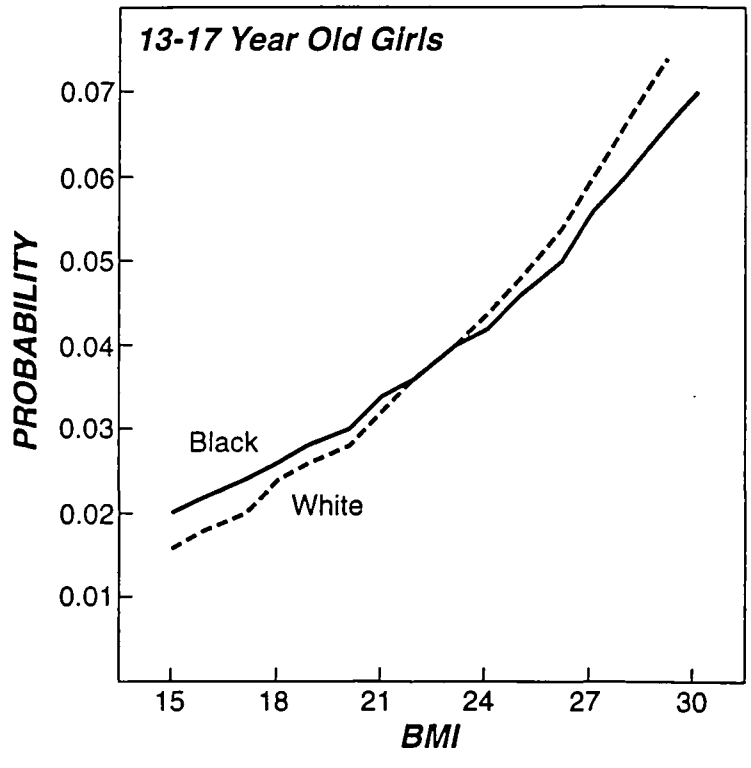

FIGURE 7. Probability of diastolic pressure over the 95th percentile versus BMI among girls aged 13–17 years by ethnic group, eight US study populations, 1979–1996.

White girls exhibit higher blood pressure than do Black girls before the approximate time of puberty (13 years), but this is reversed (for systolic pressure) among adolescents from age 13 years on. Pubertal maturation is an important determinant of weight, and weight is a determinant of blood pressure level. Assessment for pubertal maturation was not included in many of these studies, and so it was not possible to include it in the analysis. The differences in levels among adolescents are explained largely by differences in height and weight, whereas the differences in childhood are not. For boys aged 5–17 years, there are essentially no major differences in diastolic pressure level and only minor differences in systolic pressure after adjustment for height and weight.

The odds of elevated blood pressure increased for both age groups, sexes, and ethnic groups with increasing levels of BMI. However, generally, Blacks were less influenced by a BMI effect on their diastolic pressure level than were Whites. Furthermore, Blacks tended to have fewer elevated diastolic pressure readings at higher levels of BMI and more elevated blood pressure at lower levels of BMI than did Whites. These findings are consistent with the most recent studies of young adults. Some past studies of the relative contribution of obesity to high blood pressure have found, among adults, a lesser effect for Blacks than for Whites (30, 31), while others (32–34) have not found a difference between Blacks and Whites or have been equivocal (35). More recently (36), combined data from two large population studies found no significant differences in regression slopes of systolic pressure on the sum of triceps plus subscapular skinfold thickness between Blacks and Whites of either sex for those aged 18–30 years. For those aged 45–65 years, however, there was a significantly smaller regression coefficient for Black than for White women (0.07 mmHg per 1-mm increase in the sum of subscapular skinfold thickness for Black women versus 0.19 mmHg per 1-mmHg for White women). The significance of these past observations coupled with our analyses suggests that BMI may have a lesser effect on blood pressure levels in Black than in White females. Further, it may be that there is also a different effect of BMI on blood pressure depending on the degree of fatness. It was noted that the proportion of hypertensive individuals (greater than the 95th percentile of blood pressure) was greater among Blacks than among Whites for those in the lower percentiles of BMI, but was greater among Whites than among Blacks for those in the higher levels of BMI. Such variability may relate to hormonal differences associated with differing levels of fat deposit in the two ethnic groups. The mechanism underlying this difference will need further research.

Overall, there appear to be few substantive ethnic differences in either systolic or diastolic pressure during childhood and adolescence. The differences that were observed were small, inconsistent, and often explained by differences in body size. This suggests that important changes occur in the late teenage and early adult years, leading to higher blood pressure and a greater prevalence of hypertension in Black than in White adults or that the effects of important influences on blood pressure in childhood are delayed at least until young adulthood.

ACKNOWLEDGMENTS

Supported by National Institute of Health grant no. RO3-HL54319.

The authors thank the principal investigators and/or study liaisons of some of the studies used in this report—Dr. Gerald Berenson, Vicki Burt, and Drs. Terry Drizd, David Fixler, Margaret Gutgesell, Darwin Labarthe, Daniel Lackland, Alan Sinaiko, and Stephen Zinner—for providing the data tapes and a detailed description of the blood pressure, height, and weight measurement conditions.

REFERENCES

1. Gillum RF. Trends in acute myocardial infarction and coronary heart disease death in the United States. J Am Coll Cardiol 1994;23:1273–7.
2. Subcommittee on Definition and Prevalence of the 1984 Joint National Committee. Hypertension prevalence and the status of awareness, treatment and control in the United States. Hypertension 1984;7:457–68.
3. Hall WD, Saunders E, Schulman NB, eds. Hypertension in Blacks: epidemiology, pathophysiology and treatment. Chicago, IL: Yearbook Medical Publishers, 1985.
4. Liu K, Ballew C, Jacobs DR Jr, et al. Ethnic differences in blood pressure, pulse rate, and related characteristics in young adults: the CARDIA Study. Hypertension 1989;14:218–26.
5. Schachter J, Kuller LH, Perkins JM, et al. Infant blood pressure and heart rate: relation to ethnic group (Black or White), nutrition, and electrolyte intake. Am J Epidemiol 1979;110:205–18.
6. Schachter J, Kuller LH, Perfetti C. Blood pressure during the first five years of life: relation to ethnic group (Black or White) and to parental hypertension. Am J Epidemiol 1984;119:541–53.
7. Berenson GS, Foster TA, Frank GC, et al. Cardiovascular disease risk factor variables at the preschool age: the Bogalusa Heart Study. Circulation 1978;57:603–12.
8. Voors AW, Foster TA, Frerichs RR, et al. Studies of blood pressures in children, ages 5–14, in a total biracial community: the Bogalusa Heart Study. Circulation 1976;54:319–27.
9. Roberts J, Maurer K. Blood pressure levels of persons 6–74 years, United States, 1971–1974. (Vital and Health Statistics. Series 11, Series 203). (DHEW publication no. HRA 78–1648). Washington, DC: Department of Health, Education, and Welfare, 1978.
10. Goldring D, Londe S, Sivakoff M, et al. Blood pressure in a high school population. I. Standards for blood pressure and

the relation of age, sex, weight, height, and race to blood pressure in children 14 to 18 years of age. J Pediatr 1977;91: 884–9.
11. Londe S, Gollub SW, Goldring D. Blood pressure in Black and White children. J Pediatr 1977;90:93–5.
12. Morrison JA, Khoury P, Kelly K, et al. Studies of blood pressure in schoolchildren (ages 6–19) and their parents in an integrated suburban school district. Am J Epidemiol 1980;111: 156–65.
13. Liebman M, Chopin LF, Carter E, et al. Factors related to blood pressure in a biracial adolescent female population. Hypertension 1986;8:843–50.
14. Manatunga AK, Jones JJ, Pratt JH. Longitudinal assessment of blood pressure in Black and White children. Hypertension 1993;22:84–9.
15. Rowland M. Roberts J. Blood pressure levels and hypertension in persons aged 6–74 years: United States, 1976–80. Advance data. Hyattsville, MD: National Center for Health Statistics, 1982;84:1– 12.
16. Alpert BS, Fox ME. Racial aspects of blood pressure in children and adolescents. Pediatr Clin North Am 1993;40:13–22.
17. National High Blood Pressure Education Program Working Group Report on Hypertension Control in Children and Adolescents. Update on the 1987 Task Force Report on high blood pressure in children and adolescents: a working group report from the National High Blood Pressure Education Program. Pediatrics 1996;98:649–58.
18. Berenson GS, McMahan CA, Voors AW, et al. Cardiovascular risk factors in children: the early natural history of atherosclerosis and essential hypertension. New York, NY: Oxford University Press, 1980.
19. Berenson GS. Causation of cardiovascular risk factors in children: perspectives on cardiovascular risk in early life. New York, NY: Raven Press, 1986.
20. Fixler DE, Laird WP. Validity of mass blood pressure screening in children. Pediatrics 1983;72:459–63.
21. Baron AE, Freyer B, Fixler DE. Longitudinal blood pressure in blacks, whites and Mexican Americans during adolescence and early adulthood. Am J Epidemiol 1986;123:809–17.
22. Gutgesell M, Terrell G, Labarthe D. Pediatric blood pressure: ethnic comparison in a primary care center. Hypertension 1981;3:39–49.
23. Gomez O, Prineas RJ, Sinaiko AR. The Sodium-Potassium Blood Pressure Trial in Children. Design, recruitment, and randomization: the Children and Adolescent Blood Pressure Program. Control Clin Trials 1991;12:408–23.
24. Harlan WR, Cornoni-Huntley J, Leaverton PE. Blood pressure in childhood: the National Health Examination Survey. Hypertension 1979;1:559–65.
25. Rosner B, Prineas RJ, Loggie JMH, et al. Blood pressure nomograms for children and adolescents, by height, sex, and age in the United States. J Pediatr 1993;123:871–86.
26. Prineas RJ, Gillum RF, Horibe H, et al. The Minneapolis Children's Blood Pressure Study. Part I. Standards of measurement for children's blood pressure. Hypertension 1980;2 (Suppl. 1):18–24.
27. Rosner B, Prineas R, Loggie J, et al. Percentiles for body mass index in U.S. children 5 to 17 years of age. J Pediatr 1998; 132:211–22.
28. Hamill PVV, Drizd TA, Johnson CL, et al. Physical growth: National Center for Health Statistics percentiles. Am J Clin Nutr 1979;32:607–26.
29. Prineas RJ, Gillum R. U.S. epidemiology of hypertension in Blacks. In: Hall WD, Saunders E, Shulman NB, eds. Hypertension in Blacks. Chicago, IL: Yearbook Medical Publishers, 1985:17–36.
30. Van Itallie TB. Health implications of overweight and obesity in the United Sates. Ann Intern Med 1985;103:983–8.
31. Tyroler HA, Heyden S, Hames CG. Weight and hypertension: Evans County studies of blacks and whites. In: Paul O, ed. Epidemiology and control of hypertension. New York, NY: Stratton International Medical Book Corp., 1975:177–204.
32. Gillum RF. Pathophysiology of hypertension in blacks and whites. A review of the basis of racial blood pressure differences. Hypertension 1979;1:468–74.
33. Neser WB, Thomas J, Semenya K, et al. Obesity and the hypertension in a longitudinal study of black physicians: The Meharry Cohort Study. J Chronic Dis 1986;39:105–13.
34. Stamler J, Berkson DN, Dyer A, et al. Relationship of multiple variables to blood pressure findings from four Chicago epidemiologic studies. In Paul O, ed. Epidemiology and control of hypertension. New York, NY: Stratton International Medical Book Corp., 1975:307–56.
35. Blair D, Habicht JP, Sims EAH, et al. Evidence for an increased risk for hypertension with centrally located body fat and the effect of race and sex on this risk. Am J Epidemiol 1984;119:526–40.
36. Folsom AR, Burke GL, Byers CL, et al. Implications of obesity for cardiovascular disease in blacks: the CARDIA and ARIC studies. Am J Clin Nutr 1991;53:1604S–11S.