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Blood Pressure Levels of Children 6-11 Years:

Relationship to Age, Sex, Race, and Socioeconomic Status

United States

Blood pressure measurements of children 6-11 years of age in the United States, 1963-65, are presented and discussed by age, sex, race, and socioeconomic status.

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BLOOD PRESSURE LEVELS OF CHILDREN 6-11 YEARS: RELATIONSHIP TO AGE, SEX, RACE, AND SOCIOECONOMIC STATUS

Noel S. Weiss, M.D., Dr. P.H.; Peter V. V. Hamill, M.D., M.P.H.; and Terence Drizd^a

INTRODUCTION

This report presents the distribution of blood pressure levels of U.S. children aged 6-11 years by age, sex, and race. Data were obtained in Cycle II of the Health Examination Survey (HES), which is one of the major programs of the National Center for Health Statistics (NCHS) concerned with assessing the health status of the U.S. population. The program consists of a series of surveys in which information is obtained on a probability sample of the U.S. population through examination, interview, measurement, and testing.

In Cycle II of the HES, a representative sample of all noninstitutionalized children 6-11 years of age in the United States was obtained. From July 1963 through December 1965, the survey staff examined 7,119 children, 96 per-

cent of the original sample of 7,417. A description of the sampling process, program operation, and response rates has been published previously.¹ The standardized examination, given during a single visit, was primarily concerned with assessing health factors related to growth and development. Additionally, measurements of visual and auditory acuity were made, and evidence of the presence of congenital abnormalities, ear-nose-throat conditions, heart disease, and neuromusculoskeletal abnormalities was sought.

BLOOD PRESSURE MEASUREMENT

The measurement of blood pressure was part of a general cardiovascular examination that, in addition to a medical history, included a pediatrician's examination, an electrocardiogram, a chest X-ray, and an exercise-tolerance test.

Blood pressure was measured indirectly with the use of a standard clinical sphygmomanometer, the instrument employed in all physicians' offices and in most surveys of blood pressure. This method is completely accepted by the children being examined, and it provides results comparable with clinical experience. The disadvantage

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of indirect blood pressure measurement is that the readings obtained in this way may differ from "true" values—i.e., from those obtained by direct (intra-arterial) measurement. The direct and indirect methods of measurement agree closely for systolic pressure if the blood pressure cuff size is appropriate to the examinee's height and arm girth.² For diastolic pressure, however, the agreement is not as good. In the HES, diastolic pressure was defined as the complete cessation of sounds. If the sounds failed to disappear, the pressure at which muffling occurred was used. The use of this criterion tends to underestimate intra-arterial diastolic blood pressure. The criterion not employed in the Survey of the muffling of sounds alone introduces approximately the same amount of bias in the opposite direction.²

Two measurements were obtained, one at the beginning of the physical examination and one after the electrocardiogram. During each one, the child was lying down. The four nurses who measured blood pressure observed the following guidelines:

1. The cuff should be at least 20 percent wider than the diameter of the arm or cover approximately two-thirds of the arm. (An adult 13-cm. cuff and a pediatric 9.5-cm. cuff were provided.)
2. The examiner should be at eye level with the manometer.
3. The meniscus should be checked weekly for zero calibration.
4. While measuring, the rate of fall should be approximately 2-3 mm. Hg per heartbeat.
5. Readings are to be made to the nearest 2 mm. Hg.

On the average, the first blood pressure measurement on an examinee was higher than the second (see appendix). Unless otherwise specified, the blood pressure values presented in this report are the average of the two measurements. Blood pressure readings were somewhat affected by the time of day and by the nurse who obtained the reading. These sources of bias are also discussed in the appendix.

DEFINITION OF OTHER VARIABLES

Age

The child's age was determined from the birth certificate in 95 percent of the cases and from the statement of a parent in the remainder. When used subsequently in this report, the term "age" will refer to the child's age at his last birthday.

Race

Three racial groups were defined: white (86.69 percent), Negro (13.87 percent), and other (0.45 percent). All three groups are included in references to all races, but separate data are presented for white and Negro children only.

Family Income and Parental Education

Annual family income and parental education were reported by one of the child's parents in a household interview before the examination; details of the interview have been described previously.¹ Annual family income is defined as the combined earnings of all members of the child's household, and parental education, as the highest grade level attained by either of the parents or guardian(s).

FINDINGS ON BLOOD PRESSURE LEVELS

Age

Systolic blood pressure among the children increased regularly by about 1.4 mm. Hg for each year of age (figure 1, table 1), from a median level of 105.5 mm. Hg at age 6 to 113.0 mm. Hg at age 11. This increase was present for both boys and girls and for both white and Negro children. Other percentiles rose with age approximately the same amount as did the median (figure 2, table 1). In contrast, diastolic blood pressure increased only about 0.3 mm. Hg per year

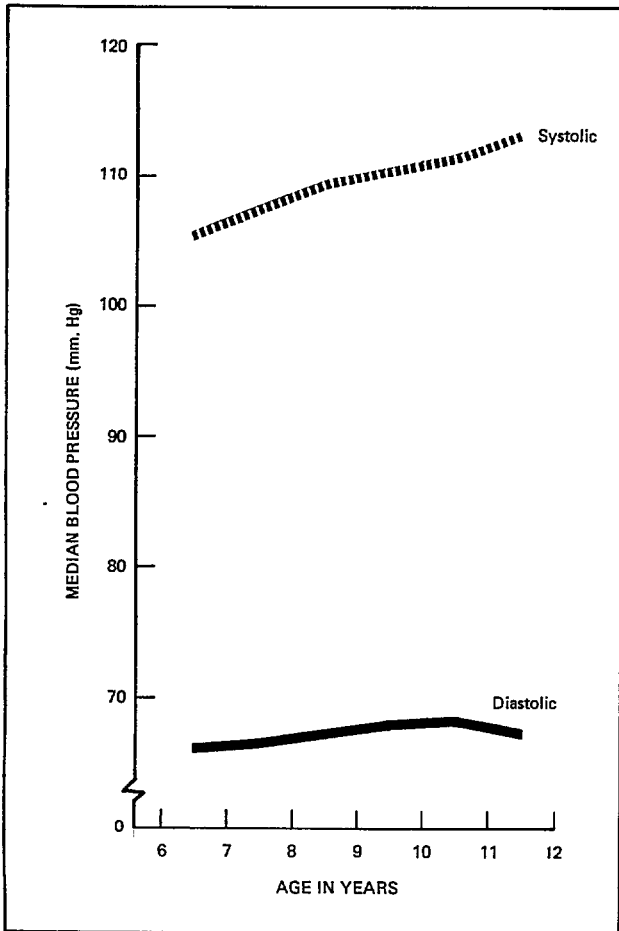


Figure 1. Median systolic and diastolic blood pressure of U.S. children 6-11 years of age by age.

of age and quite irregularly (figure 1, table 2). The median diastolic pressure was 66.1 mm. Hg for 6-year-olds; it rose to only 68.4 mm. Hg for 10-year-olds and fell to 67.2 mm. Hg for 11-year-olds. The pattern was similar for both sex and race groups (figure 3, table 2).

Sex

In general, the blood pressure of girls in the age group 6-11 years was higher than that of boys. For systolic pressure (figure 4, table 1), the boys' median exceeded the girls' only at age 6, and after age 8 the girls' excess increased steadily to a maximum difference of 2.6 mm. Hg at age 11. Diastolic blood pressure was higher

for girls at ages 7-10, but higher for boys at ages 6 and 11 (figure 5, table 2). The shape of the distributions of both systolic and diastolic pressure was nearly symmetrical for boys and girls (figures 2 and 3)—that for systolic skewed slightly toward higher values and that for diastolic skewed slightly toward lower values.

Race

The median systolic blood pressure of white children was lower than that of Negro children at age 6, about the same at ages 7 and 8, and greater at ages 9-11 (figure 6, table 1). Except at age 6, though, the differences were small, no greater than 1.5 mm. Hg. The median diastolic pressure of Negro children was higher than that of white children at each age (figure 7, table 2). The difference was about 2 mm. Hg at ages 6 and 11 and less at intermediate ages. Because the nurse who measured the blood pressure of a high percentage of Negro children also tended to measure diastolic pressure lower than the other three nurses, the true diastolic pressure differences between the races may be slightly larger than the ones shown here (see appendix). The blood pressure distributions for both white and Negro children were approximately symmetrical (figures 2 and 3).

Figures 8 and 9 show the relationship of blood pressure to age for each of the four race-sex groups. In general, white girls had the highest median systolic pressure, Negro boys the lowest. For most ages, the median diastolic pressure of girls of each race was higher than that of boys of the corresponding race, while the median diastolic pressure of Negro children of each sex was higher than that of white children of the corresponding sex.

Socioeconomic Status

There was no relationship of a child's systolic or diastolic blood pressure to his family's annual income (table 3). Systolic blood pressure tended to decrease with increasing parental education (table 4), but in neither white nor Negro children was this trend steady or of great magnitude. The largest difference, 1.8 mm. Hg, was that between the lowest and highest education

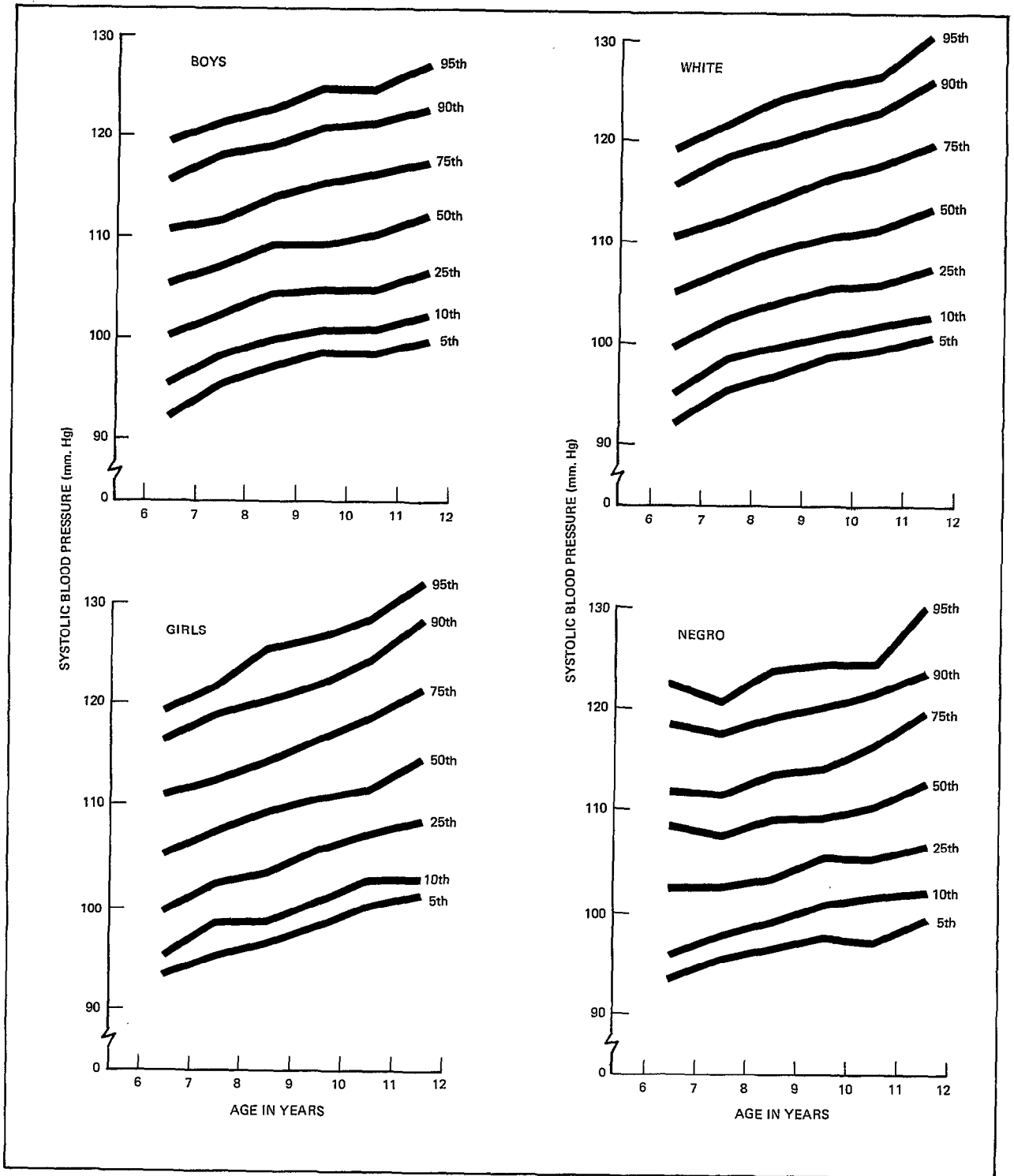


Figure 2. Percentile distribution of systolic blood pressure of U.S. children by age, sex, and race.

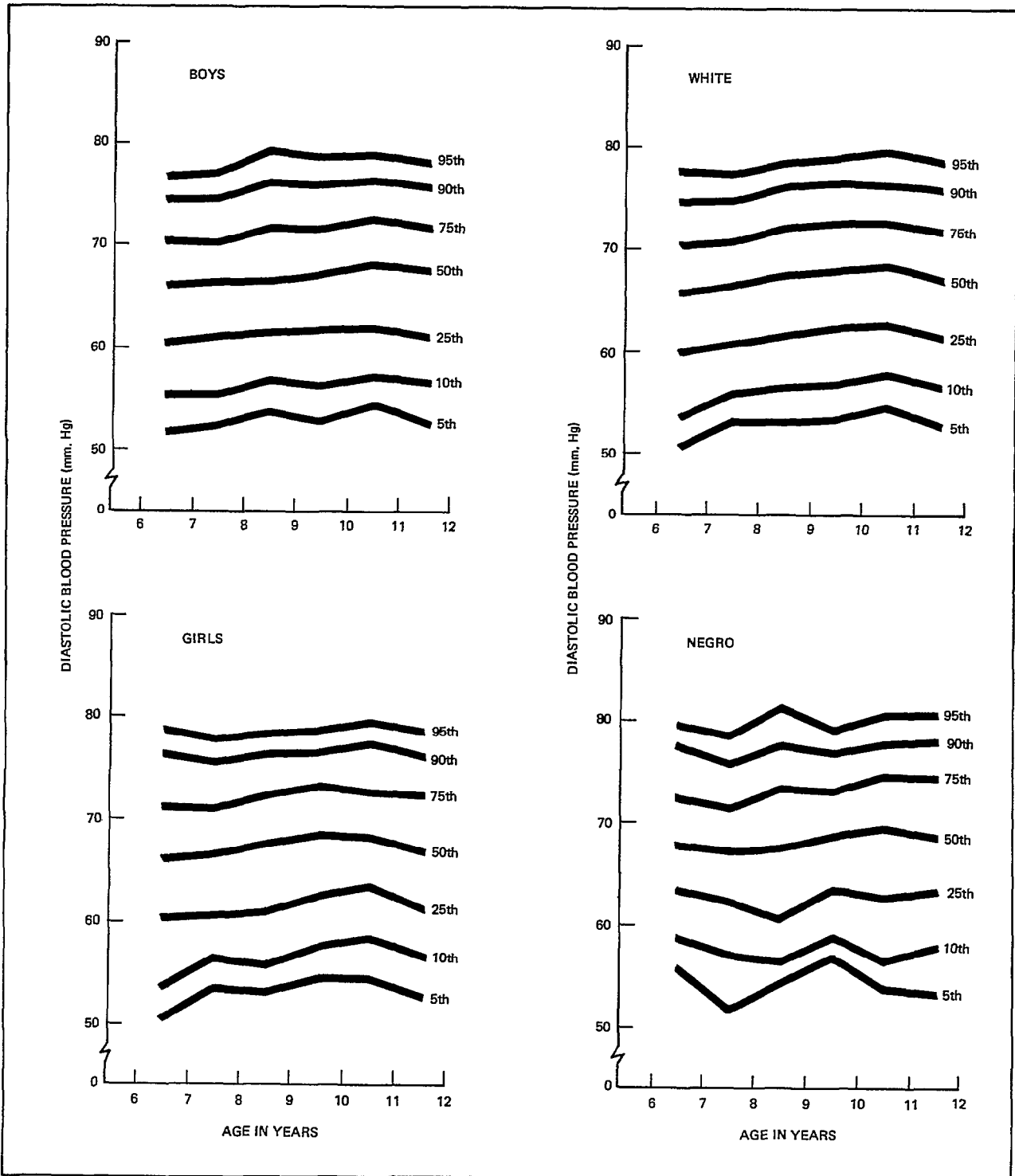


Figure 3. Percentile distribution of diastolic blood pressure of U.S. children by age, sex, and race.

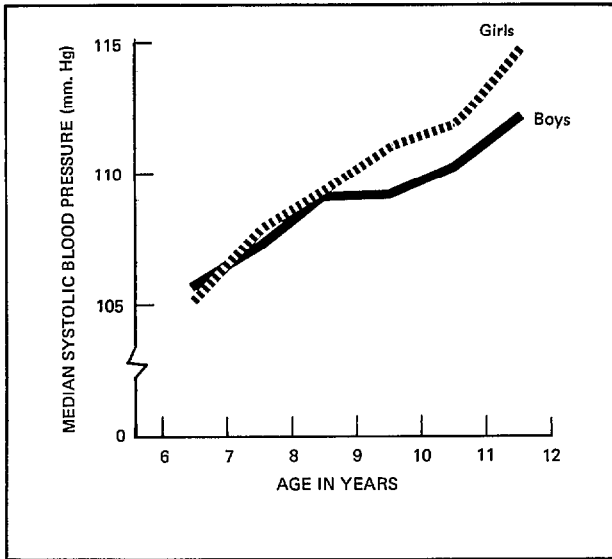


Figure 4. Median systolic blood pressure of U.S. children by age and sex.

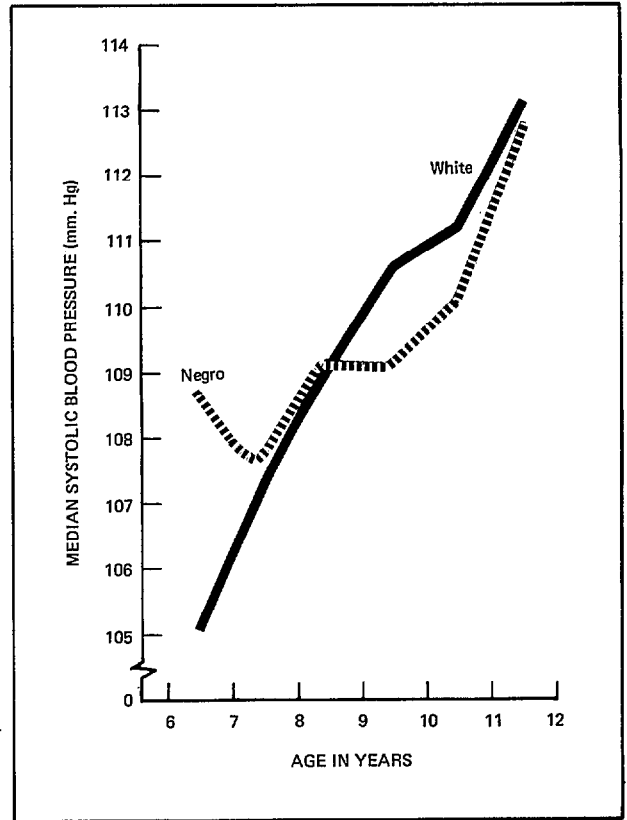


Figure 6. Median systolic blood pressure of U.S. children by age and race.

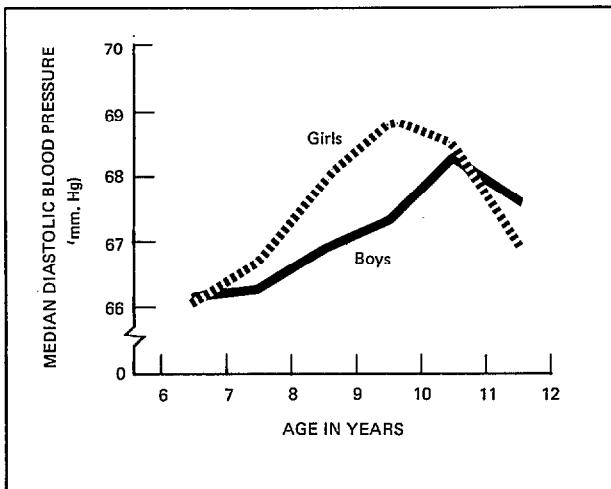


Figure 5. Median diastolic blood pressure of U.S. children by age and sex.

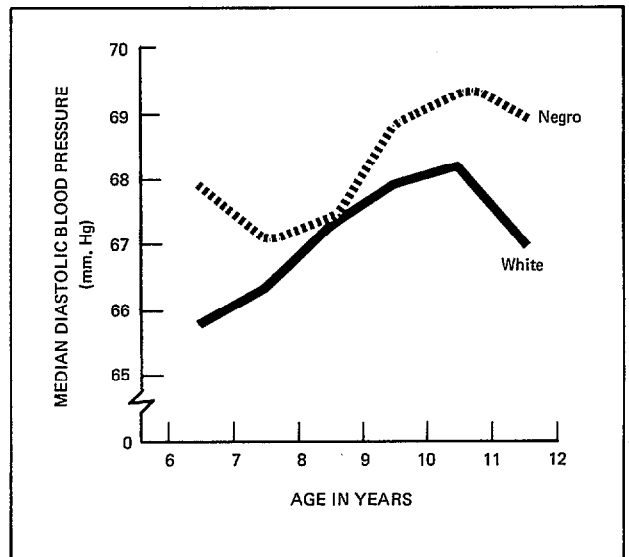


Figure 7. Median diastolic blood pressure of U.S. children by age and race.

groups among white children. This inverse relationship with parental education was also true for diastolic pressure in white children, with a difference of 2.2 mm. Hg between the lowest and highest education groups. In Negro children, there was no appreciable variation of diastolic pressure with parental education.

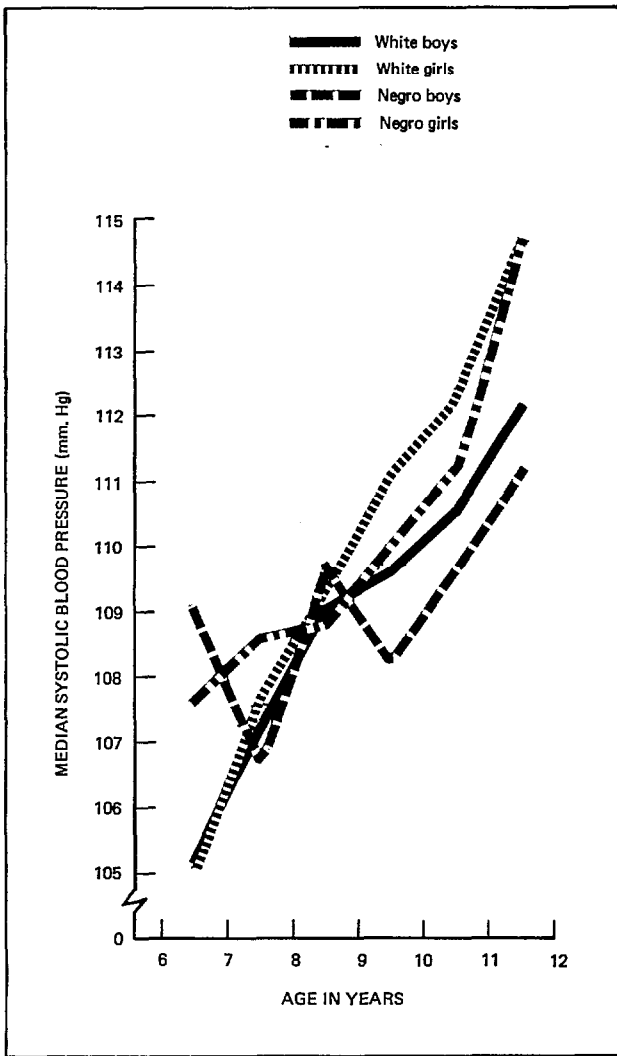


Figure 8. Median systolic blood pressure of U.S. children by age, race, and sex.

COMPARISON OF BLOOD PRESSURE LEVEL FINDINGS

Children and Adults

An adult's blood pressure is an important predictor of his health. Not only can death result from hypertensive disease per se, but blood pressure elevation is associated with arteriosclerosis in coronary, cerebral, and peripheral vessels.³⁻⁵ There is increasing evidence that this association may be a causal one.⁶ Age, sex, and race are all related to adult blood pressure levels.^{7,8} Thus, it is of interest to study blood pressure in children

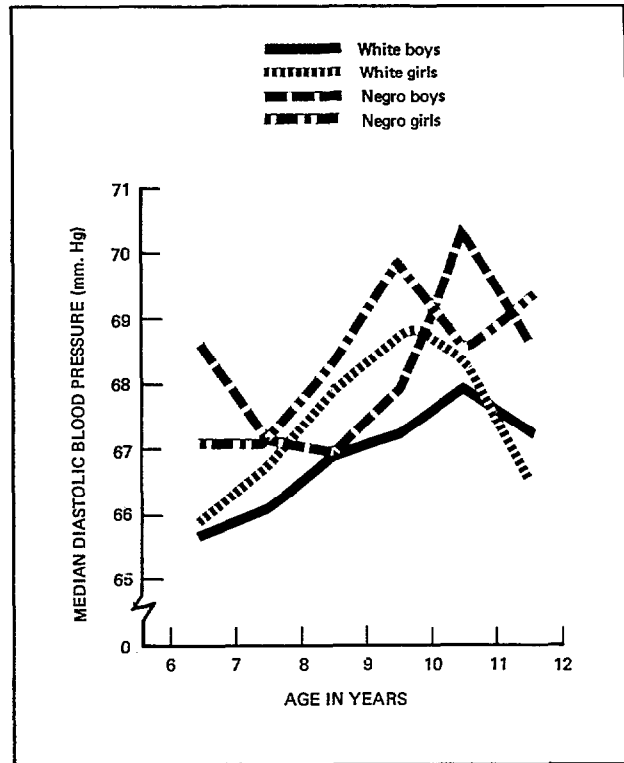


Figure 9. Median diastolic blood pressure of U.S. children by age, race, and sex.

and teenagers in an attempt to find out when these age, sex, and race differences become manifest, which in turn might suggest reasons for their occurrence.

As is well known, the blood pressure of children is lower than that of adults. Table A compares the mean systolic and diastolic blood pressures of children aged 6-11 years examined during 1963-65 with those of the 1960-62 HES sample of adults. The children's systolic and diastolic pressures are lower than those of the age group 18-24 years, the age group of the adults with the lowest blood pressure levels. Within the 6-11-year age group itself, there is a consistent increase in blood pressure with increasing age, with the exception of diastolic pressure among 11-year-olds. This increase in blood pressure levels with age may result partially from differences in arm girth, since arm girth increases with age among children and arm girth is smaller in children than it is in adults. The blood pressure increase may be caused by one or more normal processes of maturation, e.g., hormonal changes. Finally, as is probably true for adults, the age

Table A. Mean blood pressure in children aged 6-11 years and adults aged 18-74 years: United States, 1963-65 (children) and 1960-62 (adults)

Age	Mean blood pressure	
	Systolic	Diastolic
mm. Hg		
<u>Children</u>		
6-11 years	109.9	66.6
<u>Adults</u>		
18-24 years	116.4	70.4
25-34 years	119.9	74.6
35-44 years	125.6	79.3
45-54 years	133.8	82.6
55-64 years	143.6	84.0
65-74 years	154.8	82.5

increase may be a result of increased peripheral resistance in sclerotic arteries caused by wear and tear over the passage of time. A subsequent report in this series, in an attempt to distinguish between some of these factors, will consider more closely the relationship of blood pressure with arm girth, body mass, skeletal age, and chronological age.

The distributions of both systolic and diastolic blood pressure in adults become progressively more skewed to the right with increasing age. The blood pressure distributions for ages 6-11 years are consistent with this trend, being skewed even less than those of young adults, and are indeed almost symmetrical (figure 10). There was, however, a slight skew to the *left* (lower values) for the diastolic blood pressure distribution among the children, best seen in figure 3. This is probably due to the presence of children whose arterial sounds never disappeared, and in whom "muffling" of the sounds was heard only at a low pressure.

It has been claimed by some that the skewing to the right of the adult blood pressure distribution represents the superimposition of two distributions, one for normal persons and another for those who are pathologically hypertensive.⁹ If this hypothesis is accurate (and it is by no means universally accepted¹⁰), there would seem to be but a very few children aged

6-11 years who fall into the second, abnormal distribution.

As determined in the 1960-62 survey of adults (Cycle I of the HES), the blood pressure level of men is greater than that of women until ages 50-60 years. After these ages the blood pressure level of women is greater.⁷ Among those aged 6-11 years, however, girls' blood pressure is generally higher than boys, particularly for systolic pressure. In all likelihood, during puberty the blood pressure of boys increases faster than that of girls and exceeds it by the time they reach adulthood. An unlikely alternative is that some characteristic of this particular birth cohort of girls may predispose them to higher blood pressure than that of boys, and the difference between them will persist through life. The correct choice between these two hypotheses could be made by blood pressure measurements at subsequent points in time among representatives of this birth cohort. To a limited extent, such measurements have already been made: a sample of teenagers from the older half of this same birth cohort was examined during 1966-70 as part of Cycle III of the HES. These results will be published in a subsequent report.

As with the sexes, the relationship between the blood pressure levels of whites and Negroes is somewhat different in children than in adults. Among the adults measured by the HES, for all age and sex groups other than men aged 18-24 years, both systolic and diastolic pressure were higher in Negroes than in whites.⁸ Among children aged 6-11 years, although the diastolic blood pressure at each age was higher in Negroes, there was no consistent difference in systolic pressure. The white-Negro difference in systolic pressure that was seen at individual years of age was not large and could be explained by sampling variability (for standard errors, see tables 1 and 2). At least for diastolic blood pressure, however, the data presented here provide a basis for the conclusion that the difference between whites and Negroes begins early in life.

Cycle I of the HES found that adults with little education had a greater prevalence of hypertension than expected; the relationship of income level to hypertension was unclear.¹¹ In children, blood pressure tended to be inversely

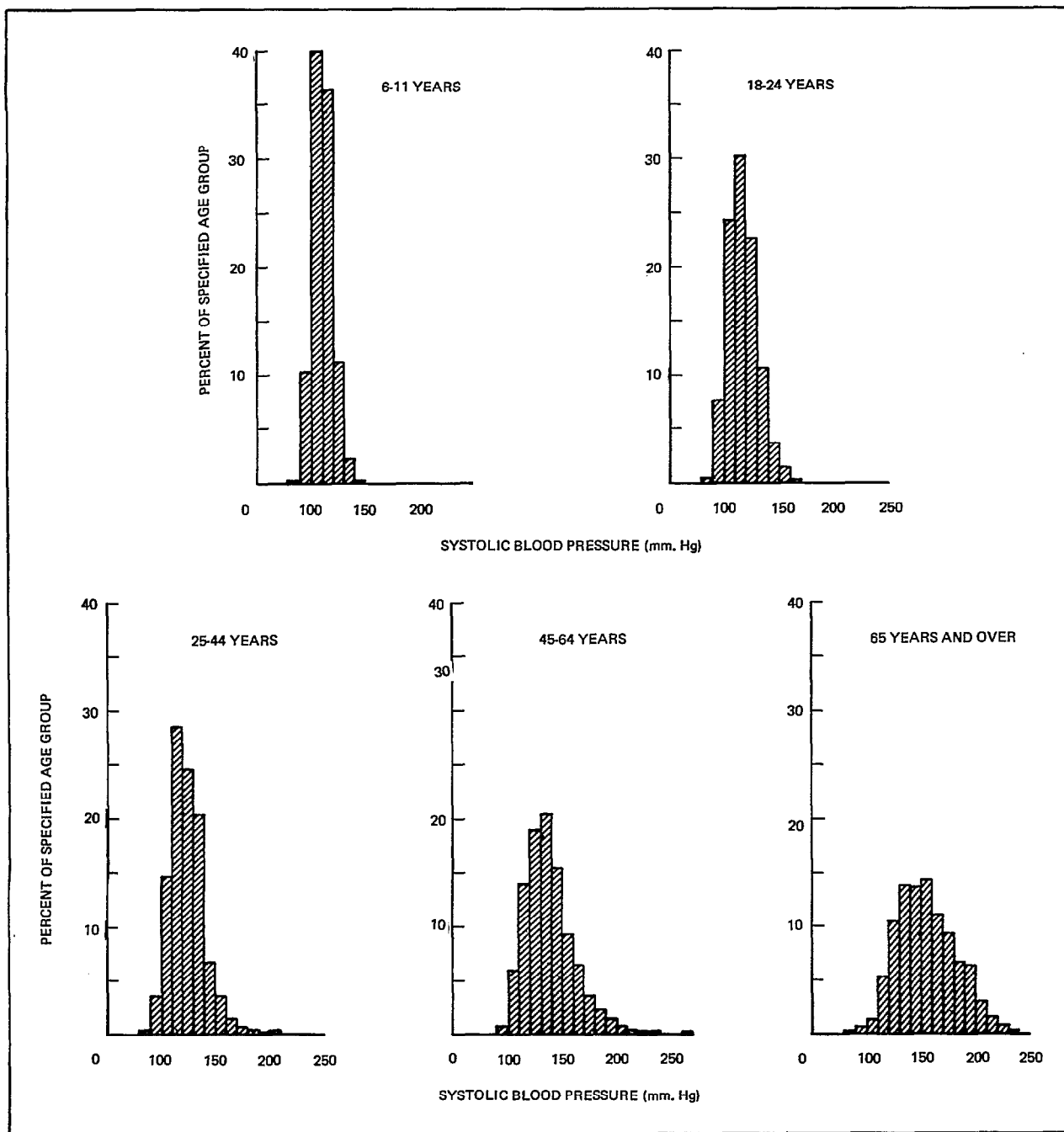


Figure 10. Comparison of frequency distribution of systolic pressure by increasing age: United States, 1963-65 (children) and 1960-62 (adults).

related to parental education, but the association was weak and probably of no importance.

There was no relationship between a child's blood pressure and his family's annual income.

HES Examinees and Children in Other Studies

Data from four studies of blood pressure in childhood have been selected for comparison with those presented here. Only one study, that reported by Johnson et al.¹² on the children of Tecumseh, Michigan, chose subjects that were representative of a well-defined population group, and none had the demographic breadth of the HES sample. Nonetheless, in each of the four studies blood pressure was measured in a standardized manner, and in each one a sufficient number of children were examined so that the sample estimates were reasonably stable. A summary of these and other design characteristics is presented in table B.

Theoretically, a comparison of a number of studies of children can demonstrate how a particular characteristic, e.g., height or blood type, is related to the place or the point in time in which they live. However, because the measurement of blood pressure is so readily affected by the examiner, the equipment, and the conditions of examination, the presence of small differences in the absolute levels of blood pressure observed in the various studies is probably of little significance. But, as can be seen in figures 11-13, some between-study differences were

quite large. For systolic pressure, the means observed by Faber and James¹³ and by Graham et al.¹⁴ for 6-year-old children were, respectively, 12 and 6 mm. Hg lower than those observed by the HES. In 11-year-old children the differences between studies were smaller, due to the fact that the increase in systolic pressure with age was less in the HES than in these other studies. Overall, the HES figures were considerably more in agreement with the more recent data of Johnson et al.¹² and Londe.¹⁵ Since these latter studies and the HES took place at a later time, there possibly has been an increase in the systolic blood pressure levels among U.S. children over the past 50 years. However, because the samples of children drawn by each of the studies were so dissimilar, and because of the sources of measurement variation mentioned previously, such a conclusion cannot be made with much confidence. A subsequent report will explore in more detail the possibility of a secular trend in blood pressure levels of children.

The diastolic blood pressure levels observed in the various studies differed little (figures 12, 13), with the exception of those of Graham et al.¹⁴ That study used disappearance of sounds as the criterion for diastolic pressure, as did all others except one (table B). Even with the use

Table B. Design characteristics of HES and four other selected studies of blood pressure in children

Author	Time of study	Examinees		Method of measurement
		Source	Number (6-11 years)	
Faber and James (ref. 13)	Before 1920	School children, California	570	Two examiners, child sitting, diastolic=muffling
Graham et al. (ref. 14)	1926-40	School children, Minnesota	3,500 (9,901 measurements)	One examiner, child sitting, diastolic=disappearance
Johnson et al. (ref. 12)	1960	Children of Tecumseh, Mich.	1,325	49 examiners, child sitting, diastolic=disappearance
Londe (ref. 15)	Not stated (published in 1966)	Healthy children seen in physician's office and clinic, St. Louis	824	One examiner, child supine, diastolic=disappearance
Health Examination Survey, Cycle II	1963-65	U.S. population sample	7,119	Four examiners, child supine, diastolic=disappearance

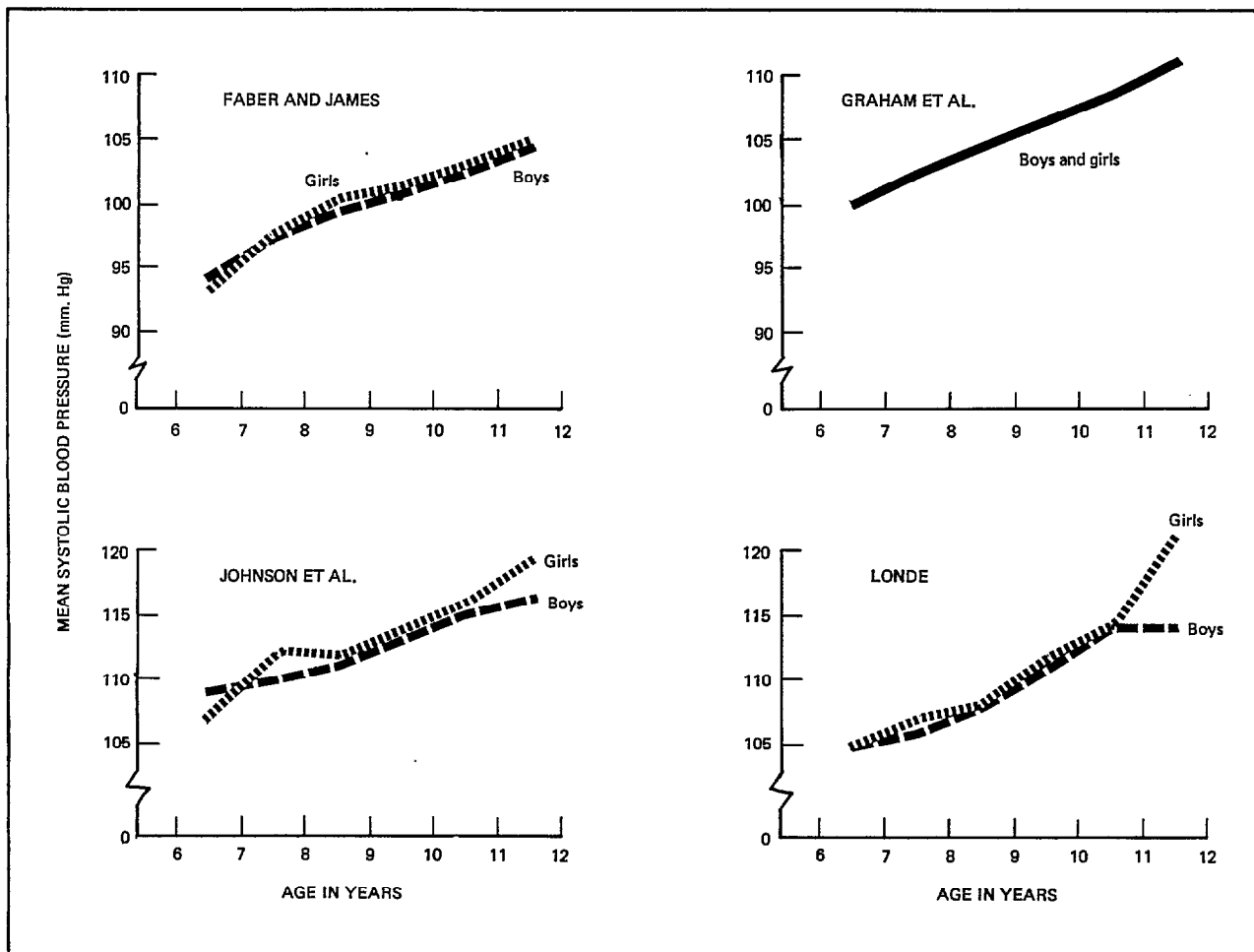


Figure 11. Mean systolic blood pressure of children by age and sex: Four prior studies.

of the same criterion, however, diastolic pressure is particularly susceptible to observer variability; therefore, probably no further meaning should be attached to the difference between that study and the others.

No matter what ambiguities exist in interpreting differences in absolute levels, it is nonetheless valid to compare the relationships between blood pressure distributions among groups of children, e.g., age or race groups, that are observed within each of the studies, to see how these relationships vary or how widely they can be generalized. Figure 11 shows that in all four previous studies systolic blood pressure increased in a nearly linear way with age. Diastolic blood pressure increased with age as well (figure 12), though compared to systolic pressure it in-

creased neither as much nor as regularly. These findings are quite similar to those of the HES.

Three of the four studies provided mean blood pressure values by sex as well as by age. At age 6, systolic pressure in boys was found to be greater than or equal to that in girls; at ages 7-11, the girls' systolic pressure tended to be higher (figure 11). For diastolic pressure, Faber and James¹³ found girls' levels to be higher, the difference between the sexes increasing with age (figure 12). Londe¹⁵ observed the girls' diastolic pressure to be higher than boys, except at age 10. Among the children of Tecumseh, Michigan, Johnson et al.¹² found no consistent difference. Again, the HES data are reasonably in accord with these earlier findings: systolic pressure was higher for girls after age 6 and particularly at

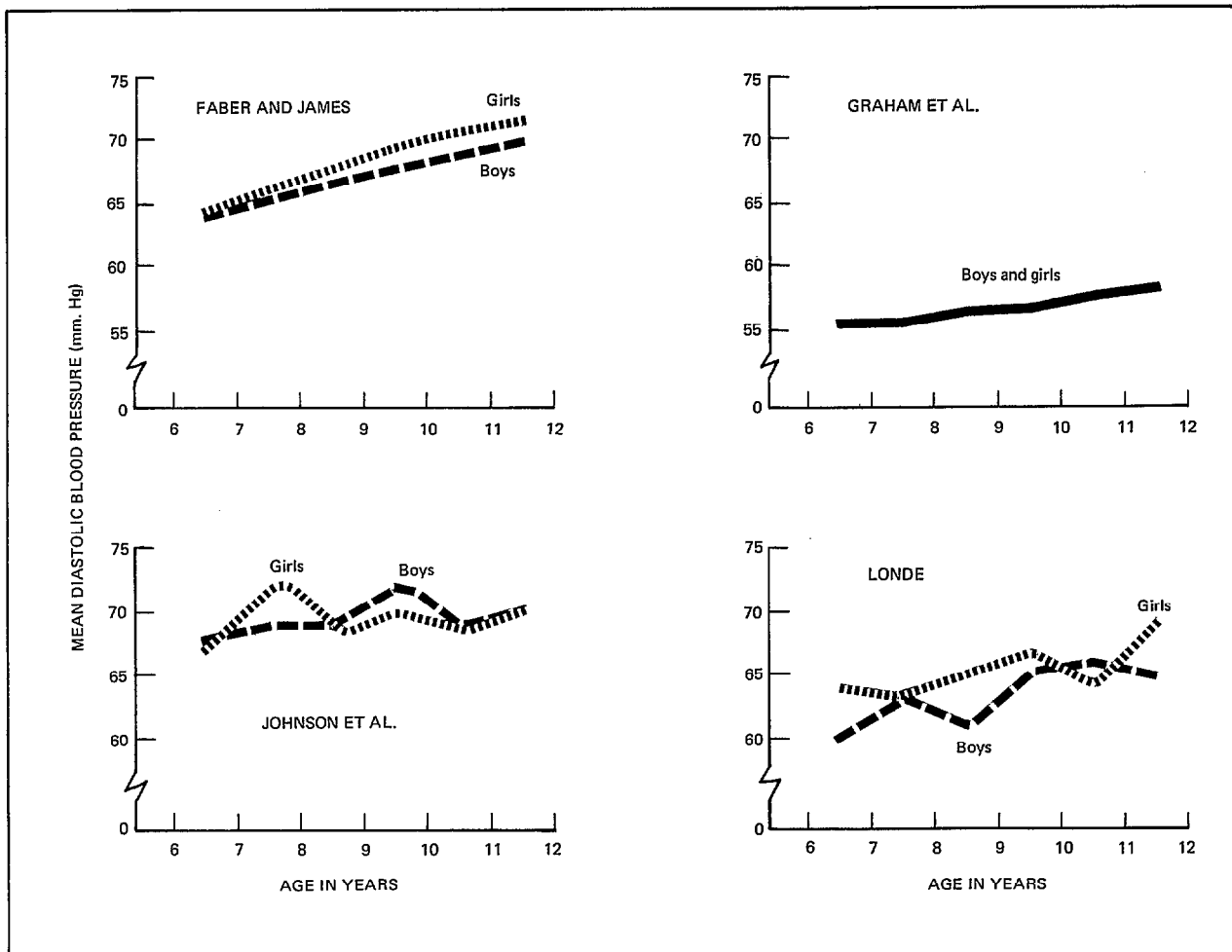


Figure 12. Mean diastolic blood pressure of children by age and sex: Four prior studies.

ages 9-11, while diastolic pressure was generally higher for girls, but not uniformly so.

None of these four studies, nor any others encountered, had sufficiently large numbers of Negro children to allow comparisons with the racial differences presented in this report.

SUMMARY

This report presents national estimates of blood pressure levels of children aged 6-11 years, based on findings of the Health Examination Survey of 1963-65.

In the HES, a nationwide probability sample of 7,417 children was selected to represent the approximately 24 million noninstitutionalized children 6-11 years of age in the United States.

Of those selected, 7,119 children (96 percent) were examined.

Two measurements were obtained on each child with the use of a sphygmomanometer. A standard set of procedures was followed by each of the four nurses responsible for the measurements.

The children's blood pressure levels were found to be lower than those of adults examined in the HES of 1960-62. Among the children, systolic blood pressure was higher in each successive age group, while diastolic blood pressure showed a less striking and more irregular increase.

Differences between the blood pressure levels of boys and girls were small. After age 6, girls generally had a higher systolic pressure, the

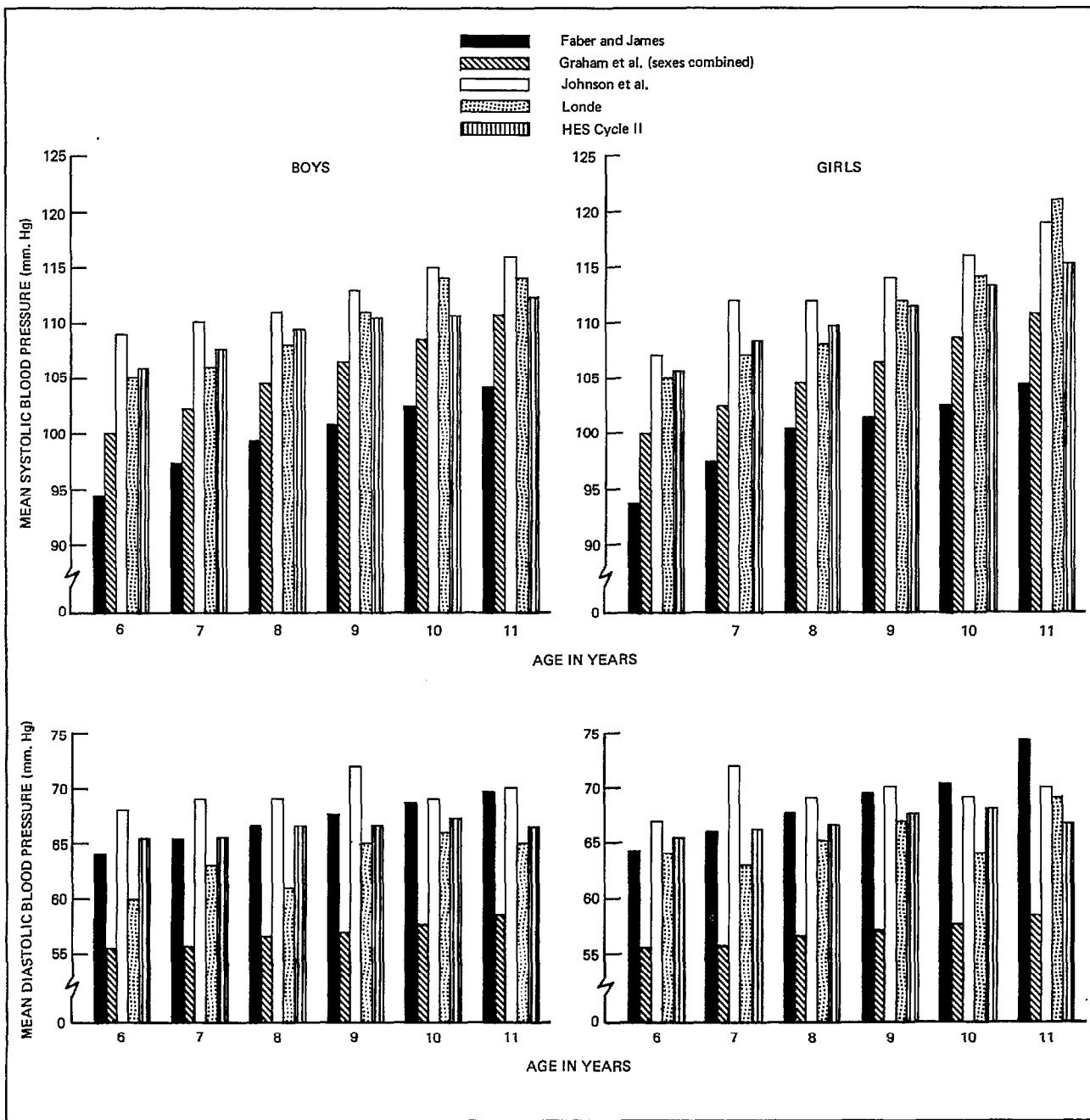


Figure 13. Comparison of mean systolic and diastolic blood pressure of children in HES and four selected studies by age and sex.

largest difference of 2.6 mm. Hg occurring at ages 10-11. Diastolic pressure tended to be higher in girls as well, but the sex differences were neither as large nor as consistent across each year of age as those for systolic pressure. Negro children had consistently higher levels of diastolic pressure than did white children, the largest difference being about 2 mm. Hg. For systolic pressure there was little difference between races.

The children's blood pressure showed a weak

inverse relationship to parental education and no relationship to annual family income.

The relationship of blood pressure to age and sex observed in the HES data is quite similar to that observed in earlier studies of blood pressure of children in the United States. Though there is a discrepancy between the absolute blood pressure levels obtained in the HES and in studies conducted several decades ago, the levels in the Survey are in close agreement with those obtained in more recent studies.

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Table 1. Systolic blood pressure of children by race, sex, and age at last birthday: Selected percentiles, standard error of the median, sample sizes, and mean, United States, 1963-65

Race, sex, and age	Percentile							s_{50th}	n	N	\bar{X}
	5th	10th	25th	50th	75th	90th	95th				
<u>All races</u>	mm. Hg										
Both sexes, 6-11 years . . .	96.6	99.3	103.9	109.4	115.2	121.2	125.4	0.30	7,119	23,784	109.9
6 years	92.8	95.3	100.1	105.5	111.1	115.9	119.7	.54	1,111	4,098	105.9
7 years	95.6	98.4	102.3	107.3	112.2	118.5	121.5	.43	1,241	4,084	108.0
8 years	97.0	99.5	104.0	109.1	114.2	119.8	124.0	.31	1,231	3,986	109.5
9 years	98.6	100.9	105.3	110.2	116.1	121.1	125.3	.46	1,184	3,957	110.9
10 years	99.1	101.8	105.8	111.1	117.7	122.8	126.3	.23	1,160	3,867	111.9
11 years	100.6	102.6	107.2	113.0	119.4	125.6	130.1	.44	1,192	3,792	113.7
Boys, 6-11 years	96.5	99.3	103.8	108.9	114.4	120.1	123.8	0.32	3,632	12,081	109.4
6 years	92.4	95.6	100.3	105.7	111.0	115.6	119.8	.84	575	2,082	106.0
7 years	95.7	98.2	102.3	107.1	111.9	118.0	121.2	.52	632	2,074	107.8
8 years	97.4	99.9	104.2	109.1	114.0	119.0	122.8	.34	618	2,026	109.4
9 years	98.9	100.9	104.9	109.3	115.2	120.8	124.6	.49	603	2,012	110.3
10 years	98.6	101.0	105.0	110.2	116.3	121.2	124.3	.29	576	1,963	110.8
11 years	99.5	102.1	106.7	112.0	117.3	122.6	126.9	.50	628	1,924	112.4
Girls, 6-11 years	96.6	99.3	104.1	109.9	116.1	122.3	126.8	0.31	3,487	11,703	110.5
6 years	93.3	95.1	99.9	105.2	111.1	116.3	119.4	.52	536	2,016	105.8
7 years	95.4	98.6	102.5	107.7	112.8	119.0	121.9	.53	609	2,010	108.2
8 years	96.7	98.8	103.6	109.2	114.3	120.4	125.5	.40	613	1,960	109.6
9 years	98.1	100.9	105.9	110.9	116.8	122.0	126.9	.55	581	1,945	111.5
10 years	100.2	102.8	107.1	111.9	118.8	124.3	128.3	.41	584	1,904	113.1
11 years	101.1	103.0	108.3	114.6	121.4	128.1	131.8	.62	564	1,868	115.1
<u>White</u>											
Both sexes, 6-11 years . . .	96.6	99.3	103.9	109.4	115.4	121.3	125.6	0.30	6,100	20,403	109.9
6 years	92.4	95.2	99.9	105.1	110.9	115.3	119.1	.47	950	3,509	105.6
7 years	95.6	98.6	102.3	107.3	112.3	118.7	121.8	.38	1,063	3,497	108.0
8 years	97.0	99.6	104.0	109.1	114.2	119.9	124.1	.31	1,035	3,413	109.6
9 years	98.8	100.9	105.3	110.6	116.3	121.3	125.6	.53	1,019	3,393	111.0
10 years	99.2	101.8	105.9	111.2	117.8	123.0	126.4	.30	1,014	3,324	112.1
11 years	100.7	102.6	107.4	113.1	119.4	125.7	130.2	.49	1,019	3,267	113.8
Boys, 6-11 years	96.6	99.2	103.8	108.9	114.6	120.2	123.9	0.30	3,153	10,391	109.4
6 years	92.2	95.3	99.9	105.2	110.8	115.1	118.3	.65	489	1,787	105.5
7 years	95.4	98.3	102.3	107.2	112.0	118.1	121.4	.46	551	1,781	107.8
8 years	97.1	100.0	104.3	109.0	114.0	119.3	123.0	.36	537	1,739	109.5
9 years	99.1	100.9	104.8	109.6	115.6	120.8	124.1	.65	525	1,730	110.4
10 years	98.7	100.9	105.0	110.5	116.3	121.6	124.7	.38	509	1,692	110.9
11 years	99.9	100.2	106.9	112.1	117.6	122.9	127.0	.52	542	1,662	112.6

NOTE: s_{50th} = standard error of the median, n = sample size, N = estimated number of children in population in thousands, \bar{X} = mean.

Table 1. Systolic blood pressure of children by race, sex, and age at last birthday: Selected percentiles, standard error of the median, sample sizes, and mean, United States, 1963-65—Con.

Race, sex, and age	Percentile							s_{50th}	n	N	\bar{X}
	5th	10th	25th	50th	75th	90th	95th				
<u>White—Con.</u>	mm. Hg										
Girls, 6-11 years	96.6	99.4	104.1	109.9	116.2	122.5	127.0	0.37	2,947	10,012	110.6
6 years	92.9	95.1	100.0	105.1	111.0	116.3	119.2	.48	461	1,722	105.7
7 years	95.8	98.7	102.5	107.6	112.9	119.0	122.1	.53	512	1,716	108.2
8 years	96.6	99.1	103.6	109.3	114.5	120.3	125.3	.53	498	1,674	109.7
9 years	98.2	101.0	106.0	111.1	116.9	122.8	127.6	.65	494	1,663	111.7
10 years	100.4	102.9	107.2	112.2	119.0	124.6	128.7	.54	505	1,632	113.3
11 years	101.1	103.0	108.5	114.6	121.6	128.3	131.8	.63	477	1,605	115.2
<u>Negro</u>											
Both sexes, 6-11 years . .	96.3	98.9	104.1	109.3	114.4	120.8	124.6	0.78	987	3,272	109.8
6 years	93.9	96.0	102.4	108.7	112.0	118.8	122.7	1.59	156	570	107.8
7 years	95.3	98.0	102.6	107.7	111.8	117.7	120.8	1.46	172	570	107.8
8 years	96.7	98.9	103.4	109.1	113.9	119.1	124.0	1.08	192	560	109.2
9 years	97.5	100.8	105.6	109.1	114.1	120.3	124.2	.92	158	534	110.1
10 years	97.1	101.6	105.3	110.1	116.7	121.3	124.4	.93	142	530	110.9
11 years	99.3	102.0	106.7	112.8	119.7	125.2	130.0	.98	167	507	113.3
Boys, 6-11 years	96.3	99.6	104.0	109.0	113.9	119.8	123.0	1.02	464	1,642	109.5
6 years	93.7	96.8	103.1	109.0	112.2	119.1	123.3	1.36	84	289	108.8
7 years	96.6	98.1	102.6	106.7	111.3	116.8	119.3	1.75	79	286	107.4
8 years	98.9	99.8	103.6	109.7	113.9	116.9	121.2	1.18	79	279	109.2
9 years	97.0	101.2	105.3	108.2	112.4	120.9	126.0	1.10	74	269	109.9
10 years	96.2	101.8	104.6	109.6	116.6	120.7	121.3	1.11	65	264	110.1
11 years	96.3	100.2	105.3	111.1	116.3	121.8	125.7	1.59	83	255	111.5
Girls, 6-11 years	96.3	98.3	104.4	109.7	115.2	121.7	125.7	0.71	523	1,629	110.1
6 years	93.9	95.3	100.0	107.6	111.4	116.9	121.9	2.08	72	281	106.7
7 years	94.6	97.7	102.7	108.6	112.7	118.7	121.2	1.34	93	284	108.2
8 years	96.0	97.0	103.2	108.8	113.9	121.6	126.1	1.24	113	281	109.1
9 years	97.8	99.3	105.7	110.0	115.6	120.2	122.1	.82	84	265	110.4
10 years	98.2	101.5	106.6	111.2	116.9	123.6	127.7	1.03	77	266	111.6
11 years	101.0	104.8	108.0	114.6	121.2	127.6	131.9	1.67	84	253	115.1

NOTE: s_{50th} = standard error of the median, n = sample size, N = estimated number of children in population in thousands, \bar{X} = mean.

Table 2. Diastolic blood pressure of children by race, sex, and age at last birthday: Selected percentiles, standard error of the median, sample sizes, and mean, United States, 1963-65

Race, sex, and age	Percentile							s_{50th}	n	N	\bar{X}
	5th	10th	25th	50th	75th	90th	95th				
<u>All races</u>											
mm. Hg											
Both sexes, 6-11 years	53.0	56.4	61.3	67.2	71.9	75.9	78.6	0.70	7,119	23,784	66.6
6 years	51.1	54.5	60.4	66.1	70.9	75.1	78.1	.81	1,111	4,098	65.5
7 years	52.9	56.1	60.9	66.6	70.9	75.1	77.3	.65	1,241	4,084	66.0
8 years	53.3	56.4	61.1	67.3	72.1	76.2	78.9	.92	1,231	3,986	66.8
9 years	53.7	56.9	62.2	68.0	72.3	76.3	78.7	.70	1,184	3,957	67.2
10 years	54.6	57.6	62.7	68.4	72.7	76.7	79.2	.72	1,160	3,867	67.6
11 years	52.8	56.6	61.2	67.2	72.2	76.2	78.4	.76	1,192	3,792	66.8
Boys, 6-11 years	52.9	56.6	61.1	67.0	71.4	75.6	78.2	0.72	3,632	12,081	66.4
6 years	51.9	55.7	60.6	66.2	70.4	74.2	76.9	.90	575	2,082	65.5
7 years	52.3	55.7	61.0	66.3	70.4	74.6	77.1	.77	632	2,074	65.7
8 years	53.7	57.0	61.2	66.9	71.9	76.1	79.3	.77	618	2,026	66.7
9 years	53.0	56.5	61.6	67.3	71.6	76.0	78.6	.66	603	2,012	66.7
10 years	54.6	57.2	61.7	68.3	72.6	76.3	78.8	1.06	576	1,963	67.2
11 years	52.7	56.6	61.0	67.6	71.8	76.0	78.1	.89	628	1,924	66.7
Girls, 6-11 years	53.0	56.2	61.6	67.4	72.2	76.2	78.8	0.73	3,487	11,703	66.9
6 years	50.7	53.8	60.3	66.1	71.3	76.2	78.6	.85	536	2,016	65.5
7 years	53.6	56.3	60.8	66.7	71.1	75.6	77.7	.59	609	2,010	66.2
8 years	53.1	55.6	61.0	67.9	72.3	76.2	78.3	1.18	613	1,960	66.8
9 years	54.6	57.7	62.8	68.8	73.2	76.6	78.8	.79	581	1,945	67.7
10 years	54.6	58.2	63.8	68.5	72.9	77.3	79.7	.57	584	1,904	68.1
11 years	52.9	56.7	61.3	67.0	72.7	76.4	78.9	.73	564	1,868	66.9
<u>White</u>											
Both sexes, 6-11 years	52.8	56.2	61.1	67.1	71.7	75.8	78.3	0.76	6,100	20,403	66.4
6 years	50.9	53.9	60.0	65.8	70.4	74.7	77.7	.90	950	3,509	65.1
7 years	53.2	56.0	60.8	66.3	70.8	74.9	77.1	.74	1,063	3,497	65.9
8 years	53.1	56.4	61.2	67.3	72.0	76.0	78.3	.95	1,035	3,413	66.7
9 years	53.2	56.7	62.1	67.9	72.3	76.3	78.7	.75	1,019	3,393	67.1
10 years	54.8	57.7	62.7	68.2	72.4	76.3	79.2	.70	1,014	3,324	67.5
11 years	52.7	56.3	61.1	67.0	71.9	75.9	78.2	.80	1,019	3,267	66.6
Boys, 6-11 years	52.7	56.2	60.8	66.9	71.1	75.2	78.0	0.79	3,153	10,391	66.2
6 years	51.3	54.6	60.0	65.7	69.9	73.9	75.9	.91	489	1,787	65.0
7 years	52.7	55.5	60.8	66.1	70.3	74.3	76.8	.91	551	1,781	65.6
8 years	53.0	57.1	61.1	66.9	71.7	75.9	78.7	.95	537	1,739	66.6
9 years	52.2	56.1	61.0	67.2	71.6	75.8	78.2	.81	525	1,730	66.5
10 years	54.6	57.2	61.3	67.9	71.9	75.8	78.8	1.13	509	1,692	66.8
11 years	52.8	56.4	61.1	67.3	71.4	75.7	78.2	.99	542	1,662	66.6

NOTE: s_{50th} = standard error of the median, n = sample size, N = estimated number of children in population in thousands, \bar{X} = mean.

Table 2. Diastolic blood pressure of children by race, sex, and age at last birthday: Selected percentiles, standard error of the median, sample sizes, and mean, United States, 1963-65—Con.

Race, sex, and age	Percentile							s _{50th}	n	N	X̄
	5th	10th	25th	50th	75th	90th	95th				
<u>White—Con.</u>											
mm. Hg											
Girls, 6-11 years	52.9	56.1	61.6	67.3	72.1	76.1	78.8	0.72	2,947	10,012	66.8
6 years	50.5	53.0	60.0	65.9	71.2	76.2	78.6	1.09	461	1,722	65.3
7 years	53.7	56.4	60.8	66.7	71.1	75.5	77.9	.64	512	1,716	66.2
8 years	53.2	55.9	61.3	67.9	72.1	76.1	78.1	1.17	498	1,674	66.9
9 years	53.9	57.4	62.9	68.7	73.2	76.7	79.0	.80	494	1,663	67.7
10 years	55.2	58.7	64.0	68.4	72.9	77.3	79.7	.56	505	1,632	68.3
11 years	52.3	56.3	61.1	66.6	72.3	76.1	78.4	.79	477	1,605	66.5
<u>Negro</u>											
Both sexes, 6-11 years	54.6	57.2	62.8	68.4	73.2	77.1	79.4	0.87	987	3,272	67.8
6 years	55.8	58.8	63.6	67.9	72.2	77.3	79.3	1.18	156	570	68.1
7 years	51.7	57.0	62.3	67.1	71.5	75.8	78.2	.65	172	570	66.7
8 years	54.5	56.2	60.3	67.4	73.4	77.7	81.3	1.45	192	560	67.2
9 years	56.7	58.9	63.8	68.8	73.0	76.6	78.9	.88	158	534	68.1
10 years	53.7	56.2	62.7	69.3	74.6	77.7	79.7	1.69	142	530	68.3
11 years	53.2	57.7	63.1	68.9	74.3	77.8	79.3	.86	167	507	68.3
Boys, 6-11 years	55.1	57.4	63.3	68.3	73.3	77.5	80.2	0.77	464	1,642	68.1
6 years	57.5	59.9	64.3	68.6	73.2	78.1	80.0	.99	84	289	69.0
7 years	50.2	57.8	62.9	67.1	71.1	75.8	80.6	.86	79	286	66.8
8 years	56.0	56.9	62.8	67.0	73.2	78.6	82.3	1.61	79	279	67.8
9 years	56.2	59.2	63.9	67.9	71.9	77.0	81.0	.74	74	269	67.9
10 years	54.4	57.1	64.6	70.3	75.3	77.8	79.7	2.12	65	264	69.4
11 years	51.7	56.8	60.2	68.7	74.0	77.0	78.1	1.38	83	255	67.7
Girls, 6-11 years	54.0	56.9	61.5	68.5	73.0	76.9	79.0	1.07	523	1,629	67.4
6 years	55.8	58.0	62.0	67.1	71.6	76.7	78.8	1.33	72	281	67.2
7 years	52.8	56.1	60.9	67.1	72.0	75.8	77.1	1.14	93	284	66.5
8 years	51.0	54.8	59.2	68.3	73.6	77.7	80.7	2.82	113	281	66.6
9 years	57.0	58.8	62.3	69.8	73.7	76.6	77.2	.70	84	265	68.3
10 years	53.1	54.8	60.6	68.6	72.6	77.3	79.7	1.73	77	266	67.1
11 years	56.3	59.0	64.3	69.3	74.7	78.7	80.0	.93	84	253	69.0

NOTE: s_{50th} = standard error of the median, n = sample size, N = estimated number of children in population in thousands, X̄ = mean.

Table 3. Median systolic and diastolic blood pressure in children aged 6-11 years by annual family income and race of child: United States, 1963-65

Race	Annual family income		
	Less than \$3,000	\$3,000-\$9,999	\$10,000 or more
Median systolic blood pressure in mm. Hg			
Total	109.3	109.5	109.2
White	108.7	109.7	109.1
Negro	110.3	108.2	110.6
Median diastolic blood pressure in mm. Hg			
Total	67.8	67.0	67.1
White	67.6	66.9	67.1
Negro	68.1	68.5	71.5

Table 4. Median systolic and diastolic blood pressure in children aged 6-11 years by education of parent and race of child: United States, 1963-65

Race	Education of parent			
	Less than 5 years	5-8 years	9-12 years	13 years or more
Median systolic blood pressure in mm. Hg				
Total	110.4	109.3	109.6	108.8
White	110.6	109.2	109.7	108.8
Negro	110.2	110.0	108.6	109.1
Median diastolic blood pressure in mm. Hg				
Total	68.5	67.3	67.3	66.2
White	68.3	67.2	67.2	66.1
Negro	68.6	68.0	68.7	68.5

APPENDIX

SPECIAL SOURCES OF VARIATION IN THE MEASUREMENT OF BLOOD PRESSURE

Time of Examination

In the HES survey of adults, it was observed that blood pressure measurements tended to be slightly higher in the afternoon than in the morning.⁷ Table I shows that this held true in children for systolic pressure, but not for diastolic pressure. As in the survey of adults, the magnitude of the morning-afternoon difference was small enough that it could be ignored in other analyses of these data.

Comparisons among the morning or afternoon times were hindered in that the large majority of exams started at about the same time, 9-9:59 a.m. and 1-1:59 p.m.

Order of Measurement

The examinee's first blood pressure determination was made before the physical exam; the second was made some time later, after the electrocardiogram. On the average, the first measurement was higher than the second, both for

systolic and for diastolic pressure (table II). The difference between the medians was 3.6 mm. Hg for systolic and 1.7 mm. Hg for diastolic and was of approximately the same magnitude for the higher and lower percentiles as well. In view of the effect of apprehension on blood pressure level, it was to be expected that measurements early in the course of the exam would be higher than later ones. A similar phenomenon was observed in the HES survey of adults.⁷

Examiner Variability

The blood pressure measurements in this survey were obtained by four nurses. In general, only one was assigned to work at any particular location of the examining caravan. The percent distribution of examinees by age, sex, race, and examining nurse is shown in table III. Among the nurses there were small differences in the distribution of examinees by age and sex and larger differences by race. The median systolic

Table I. Median blood pressure and number of examinees by beginning time of examination

Median blood pressure and number of examinees	Beginning time of examination							
	a.m.				p.m.			
	8-10:59	8-8:59	9-9:59	10-10:59	12-2:59	12-12:59	1-1:59	2-2:59
Total examinees	3,736	144	3,516	76	3,343	271	2,271	801
Systolic pressure (mm. Hg)	109.0	111.1	108.9	109.4	110.2	109.6	110.1	110.5
Diastolic pressure (mm. Hg)	67.0	67.4	67.0	68.4	67.1	64.5	67.8	66.1

Table II. Blood pressure of children by order of measurement, selected percentiles^a

Blood pressure (mm. Hg)	Percentile				
	10th	25th	50th	75th	90th
Systolic I	100.0	104.4	111.6	117.8	123.8
Systolic II	97.9	102.1	108.0	113.8	120.0
Diastolic I	56.2	61.6	68.0	72.4	78.0
Diastolic II	55.5	60.0	66.3	70.6	75.9

^aSample weights are not taken into account in this table; the figures presented do not represent estimates for the U.S. population.

and diastolic blood pressure of the children examined at those locations where each nurse worked are shown in table IV. The values have been adjusted to account for differences in the age, sex, and race composition of the examinees in the four groups. For the purpose of this analysis, values for examinees at locations where more than one nurse was employed have been excluded.

The differences in the median systolic blood pressure obtained by each nurse were relatively small, the largest being 2.8 mm. Hg. Diastolic pressure variation between them, however, was greater; the largest difference was 8.8 mm. Hg. The fact that diastolic pressure was measured

Table III. Number and percent distribution of examinees by age, sex, race, and examining nurse

Age, sex, and race of examinees	Examining nurse			
	1	2	3	4
	Number			
Total examinees ^a	1,465	2,960	732	1,123
	Percent distribution			
<u>Age</u>				
6-11 years	100.0	100.0	100.0	100.1
6-7 years	33.0	32.9	32.9	32.7
8-9 years	34.1	33.6	32.7	35.4
10-11 years	32.9	33.5	34.4	32.0
<u>Sex</u>				
Both sexes	100.0	100.0	100.0	100.0
Male	50.6	52.3	49.2	50.4
Female	49.4	47.7	50.8	49.6
<u>Race</u>				
Total	100.0	100.0	100.0	100.0
White	79.8	89.7	94.8	84.8
Negro	20.2	10.3	5.2	15.2

^aExcludes 839 children who were examined at locations where there was more than 1 examining nurse.

Table IV. Number of examinees and median systolic and diastolic blood pressure of children by examining nurse^a

Median blood pressure and number of examinees	Examining nurse			
	1	2	3	4
Total examinees ^b	1,465	2,960	732	1,123
Systolic blood pressure (mm. Hg) ^c	110.2	108.4	111.2	110.4
Diastolic blood pressure (mm. Hg) ^c	60.5	69.3	64.9	66.6

^aSample weights are not taken into account in this table; the figures presented do not represent estimates for the U.S. population.

^bExcludes 839 children who were examined at locations where there was more than one examining nurse.

^cAdjusted to the racial distribution of all examinees.

less uniformly than systolic pressure is not surprising since the end point for diastolic (disappearance of sounds) is usually less clear cut than that for systolic (initiation of sounds) and would be more susceptible to differences in the auditory thresholds of the nurses.

This discrepancy among the nurses in the measurement of diastolic blood pressure has not affected the analysis of diastolic pressure variation by age or sex since each of the four nurses examined about the same proportion of children in the various age and sex groups (table III). It has affected the diastolic pressure difference between the races by understating the difference. Nurse 1, who, of the four nurses, measured the highest percentage of Negro children, tended to measure diastolic pressure lower than the others. Thus, since the Negro children were observed as having a higher diastolic pressure, if the variability among nurses had been taken into account, the difference between Negro and white children would have been slightly greater still.

Subsequent reports concerning the relationship of diastolic blood pressure and some other characteristic, if each of the nurses has not examined the same proportion of persons with this characteristic, will have to take these examiner differences into account.

End-Digit Preference

Table V shows the distribution of the final digit of the first and second blood pressure measurements and of the average of the two measurements. Despite instructions to record blood pressure to the nearest 2 mm. Hg, the nurses recorded several odd end digits. Among

the even digits there was more variation than would have been expected by chance, with "0" recorded the most frequently, "6" the least. This digit preference was far less, however, than that shown by the physicians who measured blood pressure in the HES survey of adults.⁷ Once the two measurements were averaged, the digit preference was obscured (table V).

Parameter and Variance Estimation

All estimates of parameters presented in this report are weighted estimates, taking into account the statistical weights that were assigned to each of the 7,119 examined children so that they might very closely represent the 6-11-year-old noninstitutionalized population of the United States in 1963-65. Because of the complex design of the HES, which has been described elsewhere,¹ a half-sample replication technique¹⁶ developed by the U.S. Bureau of the Census was used to produce variance estimates for sample statistics. These estimates are based on 20 balanced half-samples created by orthogonally selecting one from each of the 20 pairs of primary sampling units employed in the HES. The desired statistic is calculated for each half-sample and for the total sample. The variance (in this report, the variance of distribution of medians of the half-samples) is then computed by the usual mean-squared deviation formula (with 20 degrees of freedom), and the standard error is simply the square root of this value. This approach compensates for the effects of clustering, stratification, ratio estimation, and poststratification, all of which are part of the sampling procedure of the HES.

Table V. Distribution of end digits on blood pressure measurement by order of measurement

End digit	Systolic I	Diastolic II	Avg. systolic II	Avg. diastolic II	Avg. systolic	Avg. diastolic
	Number of examinees					
0	1,759	1,756	1,724	1,856	772	897
1	-	-	3	2	749	712
2	1,442	1,319	1,375	1,240	815	630
3	-	2	3	12	695	646
4	1,534	1,216	1,490	1,212	630	671
5	6	5	9	9	697	687
6	1,047	954	1,071	1,049	679	656
7	1	1	2	13	685	708
8	1,321	1,860	1,405	1,705	658	688
9	3	-	10	3	736	821
Missing	6	6	17	18	3	3

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