Blood Pressure in Adolescence

The United States Health Examination Survey

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SUMMARY A nationally representative sample of adolescents 12–17 years of age were examined in the U.S. Health Examination Survey and relationships between blood pressure and other variables were explored. During adolescence, blood pressure increases more rapidly in males than in females and only small racial differences are present. Weight has the strongest relationship to both systolic and diastolic pressure. Physiological maturation assessed by skeletal age and adiposity (skinfold thickness) are components of weight and each is also related to blood pressure. Although systolic murmurs are related to blood pressure at the time of examination, the murmurs are transitory and not predictive of future pressures. All factors were equally influential in each race-sex group. No significant relationships were found between geographic or demographic variables and blood pressure. These observations indicate the important relationships of physiological maturation and adiposity to adolescent blood pressure. (Hypertension 1: 566-571, 1979)

KEY WORDS • national representative population • epidemiology • blood pressure • adolescence • body mass • physiological maturation • systolic murmurs

FACTORS related to blood pressure in a nationally representative sample of children 6 to 11 years of age have been described.1 Skeletal age, body mass, adiposity (skinfold thickness), and pulse rate were found to be significantly related to blood pressure in this age range. It is reasonable to assume that some of these relationships reflect childhood growth and physiologic cardiovascular adaptation to an increasing body mass, while other relationships may not be physiologic and may presage elevated pressures later in life. In addition, some variables may relate to blood pressure only at the time of evaluation and have no prognostic importance for later pressures. To sort out these possibilities, we analyzed blood pressures and related variables in a representative sample of 6768 adolescents aged 12 to 17 years. The findings in this group are compared to those in the younger group and, through follow-up review of a subsample, the relationship of systolic murmurs to systolic blood pressure was clarified.

Population and Methods

Data were analyzed from the U.S. Health Examination Survey, Cycle III (HES III). This survey, completed between March, 1966 and March, 1970, comprised a national sample of the 22,700,000 non-institutionalized children aged 12 to 17 years. The sample is representative of adolescent youths with respect to age, sex, race, and geographic region. The design sampling and response rates are given in a monograph.2 Ninety percent (6768) of the 7514 children selected for the sample were interviewed and examined. Details of the survey plan, design of the sample, examination content, methodology, and operation of the survey were similar to those of HES II and have been reported in previous publications.3-4 The sample of adolescents examined in this survey (HES III) contained a subsample of 2200 youths examined 3 or 4 years earlier in HES II. This subsample permitted a longitudinal assessment of the persistence of systolic murmurs through time and their relationship to blood pressure.

Three blood pressure measurements were obtained by appropriately trained nurses. Two were taken in the supine position, one at the beginning and another at the conclusion of the physical examination. A third reading was obtained with the youth sitting after the second supine reading. A mercury sphygmomanometer was used and both a pediatric 9.5-cm cuff and a 13-cm adult cuff were available. Cuff size was selected to be at least 20% wider than the arm diameter or to cover approximately two-thirds of the arm. Readings were made to the nearest 2 mm Hg and cessation of sound (fifth Korotkoff phase) was taken as diastolic pressure. In the unusual instance when there was no loss of sound, the point of muffling (fourth Korotkoff phase) was recorded.
The National Center for Health Statistics (NCHS) has been concerned that the mean levels of systolic blood pressure recorded in this survey do not afford a continuum with the levels reported in the previous NCHS survey of children 6 to 11 years of age. However, the lack of conformity is related only to the first of the three recordings. The last two recorded pressures are lower than the first, and the entire distribution is shifted downward for the last two pressures. The averages for the third blood pressure measurements are similar to those reported for these ages from other studies. The initial pressures and the subsequent decrease may relate to the youths' anxiety on arrival at the examination site because they had been informed that a blood sample would be obtained. Blood pressures in a cohort examined in HES II and reexamined in HES III were slightly, but not significantly, lower than in the entire population of HES III. For the present analysis, we used the third (sitting) readings, which have means and distributions similar to those currently accepted as national standards.

The other aspects of the examination, including the structured questionnaires and general examination, were conducted in similar manner to HES II with measurement of: height, weight, skinfold thickness, other anthropometric measurements, and skeletal age. Skeletal age was based on a radiographic assessment of epiphyseal or carpal ossification using modified radiographic standards of Gruelich and Pyle. There were two additions to the examination of adolescents. Each youth was graded for sexual maturity using Tanner staging and blood was obtained for hematocrit and cholesterol measurement. Pulse rate was not recorded during the examination. The strategy for data analysis was similar to that used in the previous report.

Results

The trends in mean systolic and diastolic pressures are illustrated by age for each race and sex group (fig. 1). Only small differences in mean systolic and diastolic blood pressure are present between white and black groups. The pressures for males of both races are significantly higher at each age and there is a greater increase with age for males than for females. Blood pressure variance increases with age for all race-sex groups.

Blood pressure is closely related to physiological maturity in adolescence as in childhood. To discriminate between physiological maturity and chronological age, we used the difference between skeletal age and chronological age (fig. 2). With this relative scale of maturity, higher systolic pressures were found for youths 12 to 14 years of age who have greater physiological maturity, i.e., the difference between skeletal age and chronological age is positive: the standard error of the mean is less than 0.5 mm Hg for each group and, therefore, the differences between bars are statistically significant. For older adolescents (aged 15-17 years), the findings are somewhat different. For older adolescent males, physiological age is still related to blood pressure. However, for 15- to 17-year-old females, this relationship no longer holds. Skeletal age is more advanced for females than males of the same age, and many of the 15- to 17-year-old females have completed skeletal development. Therefore, the relationship between physiologic maturity and blood pressure is blunted in older adolescent females. Although the relationships with systolic pressure are illustrated, similar statistically significant relationships with diastolic pressures are present. There are no important racial differences.

Skinfold thickness has a positive relationship to blood pressure (fig. 3). With increasing thickness of the subscapular skinfolds ("fatfolds"), there is a significant increase in blood pressures for each race-sex group. This relationship is illustrated for systolic pressure, and a similar significant relationship holds true for diastolic pressure. Weight/height also has a relationship to blood pressure because of the strong correlation between skinfold thickness and weight/height in children 6-17 years of age.

In HES III, as in HES II, the presence of systolic murmur, regardless of intensity, was associated with higher systolic pressures. The persistence of such murmurs and their prognostic significance for blood pressure were assessed in the subsample of youths examined in both surveys separated by an interval of 3 or 4 years (table 1). The presence and intensity of systolic murmurs observed during each examination are shown in the columns (HES III) and rows (HES II). Two numbers appear in each cell. The number of youths classified by murmurs on each examination is given in parentheses in each cell and the mean systolic blood pressure on the second examination (HES III)
FIGURE 2. Relationship between systolic blood pressure and physiological maturity for youths 12-14 years of age (upper) and 15-17 years of age (lower). The difference between skeletal age and chronological age is used as a surrogate measure of physiological advancement. The asterisk indicates that only one (at > 2) or two (at -2 to -1) subjects were present in this class.

FIGURE 3. Relationship between diastolic blood pressure and subscapular skinfold thickness. There is a significant relationship between body fatness (skinfold thickness) and blood pressure for each age-sex-race group.
for these individuals is the other number in the cell. The evanescent nature of these murmurs is clear. Only 32% (139 of 441) of children found to have a murmur, either "possibly significant" or "innocent," on the first examination were so classified on the second assessment. The recording of a murmur on the first examination (HES II) did not predict higher pressures on the second examination. "Totals" in the right-hand column are not significantly different (p > 0.1). Although a systolic murmur is associated with a higher systolic pressure at the time of examination, it has no prognostic significance in children progressing to adolescence.

Multiple stepwise regression models were developed for both systolic and diastolic pressures as a means of defining which variables make significant independent contributions to explanation of blood pressure variance (tables 2–5). Regressions were developed using all variables found to have a statistically significant correlation with blood pressure (tables 2 and 3). As in the analysis for childhood blood pressure, weight was deleted when developing a second model because of its colinearity with both adiposity and physiological maturity (tables 4 and 5). This permits an assessment of the potential contributions of each variable to explanation of variance.

When all variables were included, weight was consistently selected as the variable explaining the major portion of variance for systolic and diastolic pressure (tables 2 and 3). Other variables (systolic murmur, skinfold thickness, and cigarette smoking history) added to the explanation of variance.

When weight was deleted from the analysis, skinfold thickness and skeletal age were the most important and consistent variables in the models. Skinfold thickness (body fatness) was important in all race-sex groups and weight/height² was found to substitute for skinfolds with respect to the sequence of selection and the strength of association. Skeletal age was an important predictor of blood pressure in males only; this contrasts with the study of children in which it was a predictor for males and females.¹ Sexual maturation was a significant predictor of blood pressure only if weight and skeletal age were deleted from the analysis. An inverse relationship between cigarette smoking and blood pressure was found for females only. This relationship was confirmed in univariate analysis and was independent of weight.

The population was classified by several social and demographic variables, but no significant relationships were found between blood pressure and socioeconomic status, or geographic region, or parent educational attainment.

Discussion

This national survey of adolescents extends and expands the observations of blood pressure relationships described in the earlier survey of children aged 6–11 years. Despite the cross-sectional nature of the study, inferences about changes with age are justified because of the relatively unbiased sampling, high participation

<table>
<thead>
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<th>Variable</th>
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<tr>
<td>White males</td>
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<tr>
<td>Systolic murmur</td>
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Forward stepwise regression analysis used to select independent variables until p < 0.05 was exceeded. Only variables adding 0.9% or more to explanation of variance are included and all inclusions are significant at the p < 0.001 level.
When blood pressure associations are assessed from childhood through adolescence, interesting trends become apparent. Systolic and diastolic pressures increase with age, and in adolescents the increase in males is more marked than in females, particularly with respect to systolic pressure. The differences between sexes exceed the small differences between races and, in fact, there are only minor racial differences in pressures through 17 years of age. The trends in blood pressure during childhood and adolescence differ for boys and girls. In girls, blood pressures increase more during late childhood and pubescence than in boys. A plausible explanation of these differing trends in each sex during childhood adolescence is that this reflects a cardiovascular adaptation to growth. Girls experience a prepubescent growth spurt at 10 to 11 years of age, and after menarche little additional growth of lean body mass (skeletal and muscle tissue) occurs. In contrast, boys have a gradual increase in lean body mass from pubescence through 18 years of age. The trends in blood pressure for each sex parallel these growth patterns.

Weight has the strongest relationship to blood pressure in these surveys of childhood and adolescence and this relationship remains robust through adult life. In the growing individual, weight reflects both an increase in lean body components (bone and muscle) and often in adipose tissue. The availability of independent measures of physiological maturity (skeletal age) and of adiposity (skinfold thickness) permitted us to sort out the contributions of each. Both are related to blood pressure in adolescents, but the prognostic importance for subsequent pressure differs.
In these analyses, we used a surrogate measure of physiologic advancement, the difference between skeletal age and chronological age. Another measure of maturation, development of secondary sexual characteristics (Tanner sexual staging), is also related to blood pressure, but not as closely as skeletal age. Therefore, both the indirect evidence, trends in blood pressure in the two sexes, and the direct evidence, physiologic advancement, are compatible with the concept that increasing blood pressure in growing children reflects physiological maturation.

Comparison of this sample of U.S. youths with studies from primitive societies is interesting. In the few studies of noninstitutionalized populations following a primitive life style, blood pressure increases with age during childhood and early adolescence. However, in most of these groups, blood pressure does not increase during adult life, in contrast to the gradual rise in blood pressure during adulthood in industrialized societies. These comparisons support the concept that some of the increase in blood pressure during the growth period is a universal phenomena which is “physiologic.”

However, another component of weight, adiposity, is also related to blood pressure, and this relationship may have importance for the pathogenesis of high blood pressure. Skinfold thickness as a measure of relative fatness is related to systolic and diastolic pressures in childhood and adolescence and is characteristic of all race-sex groups in the United States. A similar relationship is present in adults, and the degree of adiposity directly related to systolic and diastolic pressures. In childhood and adolescence, this association has important implications for prevention of high blood pressure. An additional observation on childhood obesity adds a further dimension. Longitudinal studies in children clearly establish that relative body fatness is a persistent characteristic in the same individual from childhood to adolescence, and the “tracking” correlation for fatness \((r = 0.73)\) approaches that of height \((r = 0.84)\). Because the fat child is very likely to become a fat adolescent and obesity is associated with higher blood pressure, the importance of identification and intervention on obesity is strengthened. Weight reduction in childhood may provide safe and effective prevention of adult hypertension.

The previous cross-sectional survey of children disclosed a relationship between systolic murmurs and blood pressure, and this correlation was confirmed in this survey of adolescents. Both surveys were cross-sectional, however, and do not disclose whether the relationship is present only during the examination or whether it is persistent. The cohort examined in both surveys provides an answer. Systolic murmurs did not persist on the follow-up examination and did not predict subsequent blood pressure levels. One may speculate that many of these are systolic ejection murmurs that result from transient increases in cardiac output and higher systolic pressures during the examination. This relationship has no prognostic importance and deserves attention primarily to alert the physician to the benign nature of this association.

As noted in the survey of children, the national probability sampling permitted evaluation of the potential influence of many demographic factors on blood pressure. Geographic region, urban/rural residence, socioeconomic status, and educational attainment of parents were examined for a relationship to blood pressure. No significant relationships were found. Thus, in these surveys two major predictors of blood pressure were found — growth and adiposity — and one of these, adiposity, can have important implications for development of high blood pressure.

References

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