National High Blood Pressure Education Program

# Update on the Task Force Report (1987) on High Blood Pressure in Children and Adolescents:

## A Working Group Report from the National High Blood Pressure Education Program

NATIONAL INSTITUTES OF HEALTH
NATIONAL HEART, LUNG, AND BLOOD INSTITUTE

# Update on the Task Force Report (1987) on High Blood Pressure in Children and Adolescents: A Working Group Report From the National High Blood Pressure Education Program

*NIH Publication*

*No. 96-3790*

*September 1996*

*National Institutes of Health*

*National Heart, Lung, and Blood Institute*

# National High Blood Pressure Education Program Working Group on Hypertension Control in Children and Adolescents


Working Group Members

Bonita Falkner, M.D., Chair
Professor of Medicine and Pediatrics
Allegheny University of the Health Sciences
Philadelphia, Pennsylvania

Stephen R. Daniels, M.D., Ph.D.
Professor of Pediatrics and Cardiology
University of Cincinnati
Children's Hospital Medical Center
Cincinnati, Ohio

Michael J. Horan, M.D., Sc.M.
Director, Division of Heart and Vascular Diseases
National Heart, Lung, and Blood Institute
Bethesda, Maryland

Jennifer M.H. Loggie, M.D.
Professor of Pediatrics
University of Cincinnati
Children's Hospital Medical Center
Cincinnati, Ohio

Ronald J. Prineas, M.D., Ph.D.
Professor and Chair of Epidemiology and Public Health
University of Miami School of Medicine
Miami, Florida

Bernard Rosner, Ph.D.
Professor of Medicine (Biostatistics)
Channing Laboratory
Harvard Medical School
Boston, Massachusetts

Alan R. Sinaiko, M.D.
Professor of Pediatrics
Department of Pediatrics
University of Minnesota Medical School
Minneapolis, Minnesota

NHLBI Resource Staff

Edward J. Roccella, Ph.D., M.P.H.
Coordinator
National High Blood Pressure Education Program
National Heart, Lung, and Blood Institute
Bethesda, Maryland

Darrell E. Anderson, M.S.
Program Manager
National High Blood Pressure Education Program
R.O.W. Sciences, Inc.
Rockville, Maryland

# Acknowledgments

The NHBPEP would like to acknowledge the following reviewers:

Barry L. Carter, Pharm.D.
Professor and Chair
Department of Pharmacy Practice
School of Pharmacy, UCHSC
University of Colorado
Denver, Colorado

Rae-Ellen W. Kavey, M.D.
Professor of Pediatrics and Preventive Medicine
Division of Pediatric Cardiology
State University of New York
Health Science Center
College of Medicine
Syracuse, New York

Lindsey Lane, M.D.
Assistant Professor of Pediatrics
Director of Pediatric Clerkship, East Falls
Allegheny University of the Health Sciences
Hanemann School of Medicine
Philadelphia, Pennsylvania

Gerald R. Marx, M.D.
Associate Chief
Division of Pediatric Cardiology
Director, Non-Invasive Laboratory
Tuffs University School of Medicine
Associate Professor
New England Medical Center
Boston, Massachusetts

Bruce Z. Morgenstern, M.D.
Pediatric Nephrology Consultant
Section of Pediatric Nephrology
Mayo Clinic Rochester
Rochester, Minnesota

Marvin Moser, M.D.
Clinical Professor of Medicine
Yale University School of Medicine
New Haven, Connecticut

Sheldon G. Sheps, M.D.
Professor of Medicine
Mayo Medical School and Clinic
Rochester, Minnesota

Douglas W. Teske, M.D.
Pediatric Cardiology
Children's Hospital
Columbus, Ohio

Mary C. Winston, Ed.D., R.D.
Senior Science Consultant
Science and Medicine Division
Office of Scientific Affairs
American Heart Association
Dallas, Texas

We wish to acknowledge the contributions of the Centers for Disease Control and Prevention, National Center for Health Statistics.

# National High Blood Pressure Education Program Coordinating Committee Member Organizations

Agency for Health Care Policy and Research
American Academy of Family Physicians
American Academy of Insurance Medicine
American Academy of Neurology
American Academy of Ophthalmology
American Academy of Physician Assistants
American Association of Occupational Health Nurses
American College of Cardiology
American College of Chest Physicians
American College of Occupational and Environmental Medicine
American College of Physicians
American College of Preventive Medicine
American Dental Association
American Diabetes Association, Inc.
American Dietetic Association
American Heart Association
American Hospital Association
American Medical Association
American Nurses' Association, Inc.
American Optometric Association
American Osteopathic Association
American Pharmaceutical Association
American Podiatric Medical Association
American Public Health Association
American Red Cross
American Society of Health-System Pharmacists
American Society of Hypertension
Association of Black Cardiologists
Citizens for Public Action on High Blood Pressure and Cholesterol, Inc.
Council on Geriatric Cardiology
Department of Veterans Affairs
Health Care Financing Administration
Health Resources and Services Administration
International Society on Hypertension in Blacks
National Black Nurses' Association, Inc.
National Center for Health Statistics, Centers for Disease Control
National Heart, Lung, and Blood Institute
National Heart, Lung, and Blood Institute Ad Hoc Committee on Minority Populations
National Hypertension Association, Inc.
National Institute of Diabetes and Digestive and Kidney Diseases
National Kidney Foundation, Inc.
National Medical Association
National Optometric Association
National Stroke Association
Society for Nutrition Education

# Foreword

Since the publication of the Report of the Second Task Force on Blood Pressure Control in Children—1987 (*Pediatrics.* 1987;79:1-25), new information has become available to assist pediatricians in identifying, preventing, and treating high blood pressure in children. Although hypertension generally was treated as an indication of a secondary medical problem in the past, it is now known that elevated blood pressure in many young persons may be the first sign of future adult essential hypertension.

This report was produced by a working group appointed by the National High Blood Pressure Education Program (NHBPEP) under the capable leadership of Dr. Bonita Falkner. The report drew upon the combined knowledge and experience of pediatricians, pediatric cardiologists, clinicians, epidemiologists, and public health specialists.

This report updates the 1987 report and includes the following new information.

- New data, such as results from the 1988-91 National Health and Nutrition Examination Survey, have been included to develop revised normative blood pressure tables, which now include height percentiles, age, and gender.
- The normative blood pressure tables use the fifth Korotkoff sound for the definition of diastolic blood pressure for all age groups except infants younger than 1 year of age.
- New charts have been developed to guide practicing clinicians in selecting antihypertensive drug therapy. These include newer classes of drugs not available at the time of the last report.
- A public health statement encourages health professionals to promote healthy lifestyles in all children and adolescents.
- Easy-to-use physician education charts provide a quick reference tool for clinicians.

Dr. Falkner and the members of the working group are to be congratulated for developing this important document. Pediatric care must be a priority if our efforts to solve important public health problems through prevention and treatment of hypertension are to be successful.

Claude Lenfant, M.D.
Director
National Heart, Lung, and Blood Institute
National Institutes of Health
and
Chair
NHBPEP Coordinating Committee

# Table of Contents



**FIGURES**



**TABLES**

# INTRODUCTION

The relevance of childhood blood pressure (BP) measurement to pediatric health care and the development of adult essential hypertension has undergone substantial conceptual change during the past 2 decades. The original orientation of physicians with regard to BP in children and adolescents was toward identification and treatment of secondary forms of hypertension, such as renal parenchymal disease and renal artery stenosis. The incorporation of BP measurement into the routine pediatric examination as well as the publication of national norms for BP in children[1-3] not only enabled detection of significant asymptomatic hypertension secondary to a previously undetected disorder but also confirmed that mild elevations in BP during childhood were more common than previously recognized, particularly in adolescents. It is now understood that hypertension detected in some children may be a sign of an underlying disease such as renal parenchymal disease, whereas in other cases the elevated BP may represent the early onset of essential hypertension.

Since publication of the 1977 task force report,[2] new and more extensive epidemiologic data on normal BP distributions and the natural history of BP throughout the pediatric age range have been published. These data, as well as advances in diagnosis of and therapy for hypertension, prompted publication of the *Report of the Second Task Force on Blood Pressure Control in Children—1987*.[3] From the expanded body of knowledge on hypertension in the young, several sources are now available that provide detailed guidelines for clinical evaluation and treatment of children and adolescents with hypertension.[4-6] The purpose of this report is to update practitioners on new data on BP in children and to call attention to modifications that are recommended for the diagnosis, treatment, and prevention of hypertension in children.

# DEFINITION OF HYPERTENSION

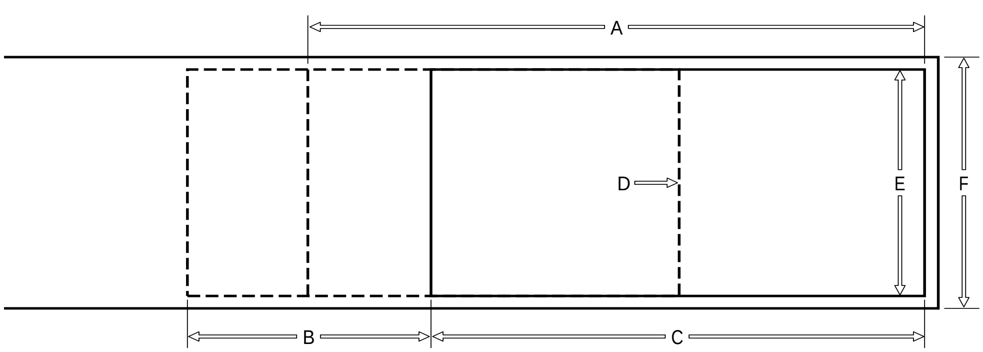
Although clinical hypertension occurs less frequently in children than in adults,[7-9] ample evidence now supports the concept that the roots of essential hypertension extend back to childhood. Familial patterns for BP have been established from early infancy,[10,11] and children with BP in the higher distributional percentiles are more likely to come from families with a history of hypertension.[12,13] Although it is generally agreed that early essential hypertension poses little immediate risk to most children, evidence from preliminary studies of children and adolescents has shown cardiac ventricular and hemodynamic changes consistent with an adverse effect of mild hypertension prior to the third decade of life.[14-19] Of particular importance is the documentation that elevated BP in childhood often correlates with hypertension in early adulthood, thereby supporting the need to track BP in children.[20]

BP varies widely throughout the day in children, as well as in adults, due to normal diurnal fluctuation and changes in physical activity, emotional stress, or other factors. This variability can make the diagnosis of hypertension in children a difficult task. The second National Heart, Lung, and Blood Institute (NHLBI) task force developed definitions based on the distribution of BP in normal children as well as clinical experience and consensus.[3] **Normal** BP is defined as systolic and diastolic BP below the 90th percentile for age and sex. **High-normal** BP is defined as average systolic or diastolic BP greater than or equal to the 90th percentile but less than the 95th percentile. **Hypertension** is defined as average systolic or diastolic BP greater than or equal to the 95th percentile for age and sex measured on at least three separate occasions.

# Measurement of Blood Pressure in Children

Methods of BP measurement in children must be standardized.[21,22] BP in children is most conveniently measured with a standard clinical sphygmomanometer, using the stethoscope placed over the brachial artery pulse, proximal and medial to the cubital fossa, and below the bottom edge of the cuff (i.e., about 2 cm above the cubital fossa). Correct measurement of BP in children requires use of a cuff that is appropriate to the size of the child's upper right arm. The right arm is preferred for consistency and comparison to the standard tables. The equipment necessary to measure BP in children age 3 years through adolescence includes three pediatric cuffs of different sizes as well as a standard adult cuff, an oversized cuff, and a thigh cuff for leg BP measurement. The latter two cuffs may be needed for use in obese adolescents. A technique to establish an appropriate cuff size is to choose a cuff having a bladder width that is approximately 40 percent of the arm circumference midway between the olecranon and the acromion. This will usually be a cuff bladder that will cover 80 to 100 percent of the circumference of the arm (see figures 1, 2, 3, and 4). Use of the manufacturer's lines on the cuff facilitates choice of the correct cuff size for a given child. BP should be measured in a controlled environment and after 3 to 5 minutes of rest in the seated position with the cubital fossa supported at heart level. BP should be recorded at least twice on each occasion, and the average of each of the systolic and diastolic BP measure-

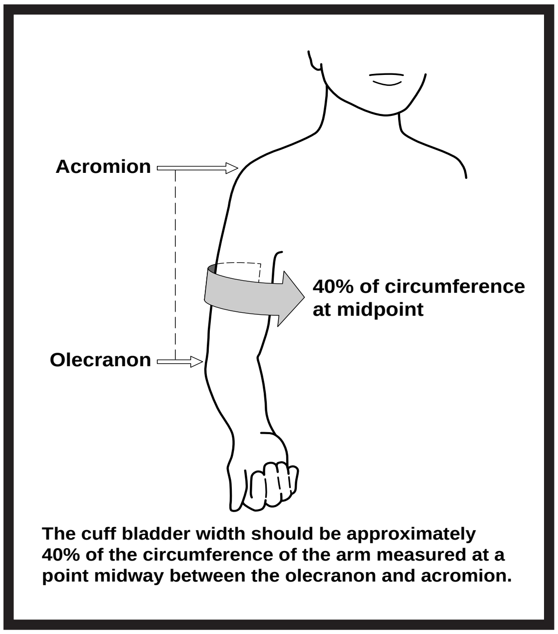
**Figure 1: Dimensions of Bladder and Cuff in Relation to Arm Circumference**




**A: Ideal arm circumference; B: Range of acceptable arm circumferences; C: Bladder length; D: Midline of bladder; E: Bladder width; F: Cuff width**

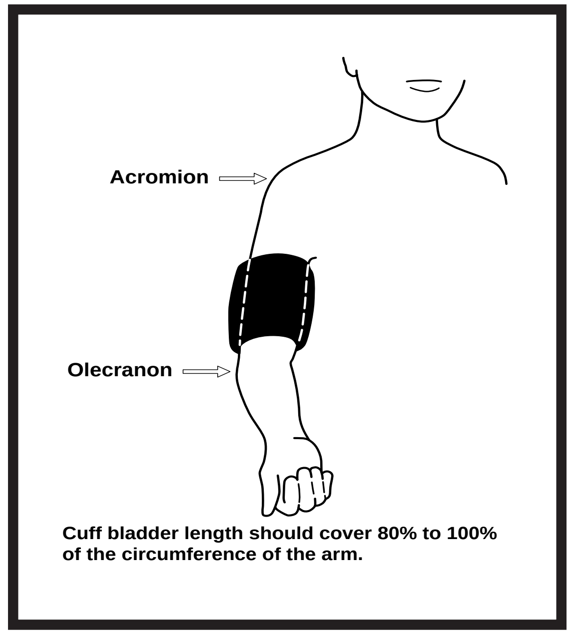
**Source: Perloff D et al. Human blood pressure determination by sphygmomanometry. Circulation. 1993;88:2460-2467. Copyright© 1993 American Heart Association. Reproduced with permission.**

**Figure 2: Determination of Proper Cuff Size, Step 1**



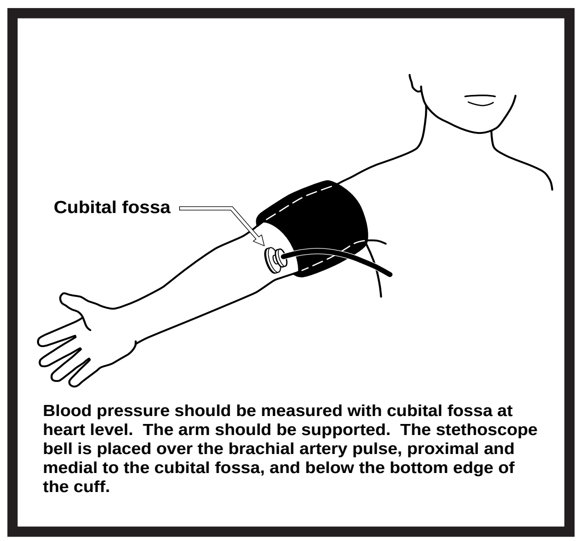

The cuff bladder width should be approximately 40% of the circumference of the arm measured at a point midway between the olecranon and acromion.

**Figure 3: Determination of Proper Cuff Size, Step 2**




Cuff bladder length should cover 80% to 100% of the circumference of the arm.

**Figure 4: Blood Pressure Measurement**




Blood pressure should be measured with cubital fossa at heart level. The arm should be supported. The stethoscope bell is placed over the brachial artery pulse, proximal and medial to the cubital fossa, and below the bottom edge of the cuff.

ments should be used to estimate BP level.

Systolic BP is determined by the onset of the "tapping" Korotkoff sounds. The phase of the Korotkoff sounds that defines diastolic BP has been somewhat controversial. The American Heart Association has established the fifth Korotkoff sound (K5), or the disappearance of Korotkoff sounds, as the definition of diastolic BP. In children, particularly preadolescents, a difference of several mm Hg is frequently present between K4, the muffling of Korotkoff sounds, and K5.[23] In some children, Korotkoff sounds can be heard to 0 mm Hg. When this occurs, it excludes diastolic hypertension. When the second task force report was published, the BP distribution curves were developed from the body of data available, which indicated that K5 was a reliable measure of diastolic BP for children age 13 years and older. The addition of more childhood BP data, with reanalysis of the entire database, now indicates that K5 can be used to define diastolic BP in children as well as adolescents and adults. This change to a K5 definition of diastolic BP enables a uniform designation of diastolic BP for all ages. The BP tables provided in this report use K5 as the diastolic BP.

In recent years, there has been increasing use of automated devices to measure BP in children. The most commonly used devices utilize oscillometric methodology to measure systolic and mean arterial BP. Diastolic BP is then calculated from these values. One advantage of these devices is their ease of use. Instances in which use of the automated devices is acceptable include BP measurement in newborns and young infants in whom auscultation is difficult as well as in the intensive care setting where frequent BP measurement is needed. However, the reliability of these instruments in a more standard clinical setting is less clear due to the need for frequent calibration of the instruments and the current lack of established reference standards. Under most circumstances, the recommended method of BP measurement in children is auscultation.

Ambulatory BP monitoring refers to portable BP devices worn by the patient that record BP over a specified period, usually 24 hours. Standards for ambulatory BP recording in children currently are not available, although some data have been published.[24,25] Ambulatory BP monitoring is becoming increasingly popular in the management of hypertension in adults. However, more data are needed before this procedure can be recommended for routine clinical use in children.

Elevated BP must be confirmed on repeated visits before characterizing an individual as having hypertension. This is because BP at the high levels tends to fall on subsequent measurement as the result of (1) an accommodation effect (i.e., reduction of anxiety by the patient from one visit to the next), and (2) regression to the mean, a nonbiological phenomenon that derives, in part, from mathematical considerations. BP level is not static but varies even under standard resting conditions. Therefore, a more precise characterization of an individual's BP level is an average of multiple BP measurements taken over weeks to months. With repeated measurement of BP using measurement techniques standardized for children, only about 1 percent of children and adolescents will be found to have hypertension.

Once a diagnosis of hypertension is confirmed by repeated BP measurements exceeding the 95th percentile, decisions must be made on further evaluation and treatment. Most children and adolescents with BP levels at or just above the 95th percentile for their age and sex are overweight and have a family history of hypertension.[3] For them, a careful history and physical examination are most important. They require few diagnostic tests other than a urinalysis and blood profiles to examine blood urea nitrogen and serum creatinine levels. A cardiovascular risk factor that may be associated with hypertension in children is abnormal lipids. A lipid profile may provide useful information because many overweight children and adolescents with hypertension have elevated triglycerides and low-density lipoprotein cholesterol levels with low high-density lipoprotein cholesterol.

Children and adolescents with both diastolic and systolic BP well above the 95th percentile frequently have an underlying cause of hypertension, usually some form of renal-related disease. In children with hypertension, femoral pulses should be palpated and BP also should be measured in the legs to rule out coarctation of the aorta. Previous reports have reviewed the type and expression of secondary hypertension during childhood and the diagnostic approach recommended to exclude causes of secondary hypertension.[3] Some genetic types of hypertension, such as glucocorticoid remediable aldosteronism, can now be identified by sending a blood sample to centers capable of performing the genetic testing. Although genetic testing for most children is unnecessary at this time, it is appropriate to consult with a physician experienced in the field of childhood hypertension for those children in whom further testing for underlying causes of hypertension is indicated to determine the type and extent of diagnostic testing necessary for a given child.

# New Blood Pressure Tables Adjusted for Height

Body size is the most important determinant of BP in childhood and adolescence. The concept that the differential growth rates present in children would require some adjustments in interpretation of the BP percentile for individual children was suggested in the second task force report. That report included tables for the 90th percentile of height and weight with the sex and age BP distribution curves and indicated that tall children with pressures that seem to be elevated may actually be normotensive if their height for a given age is beyond the 90th height percentile.[3] In a recent report that reanalyzed the national childhood BP data, the BP percentiles were refined and based not only on sex and age but also on height to determine age-, sex-, and height-specific systolic and diastolic BP percentiles.[26] This approach provides information that allows for consideration of different levels of growth in evaluating BP and demonstrates that BP standards that are based on sex, age, and height permit a more precise classification of BP according to body size.[26] More importantly, this approach avoids misclassifying children at the extremes of normal growth. For example, very tall children will not be misclassified as hyper-tensive, and very short children with high normal BP or even hypertension will not be missed. Although BP clearly is also associated with obesity, this association is believed to be a causal one, wherein the obesity contributes to higher BP and to increased risk for cardiovascular disease.

The BP data in this report on children and adolescents have been updated and reanalyzed to include height percentiles. The report now includes the data presented in the second task force report,[3] the data added in the report by Rosner et al.,[26] and newly obtained data from the 1988-91 National Health and Nutrition Examination Survey (NHANES III).[27] These normative tables are based on the first BP measured during screening on 61,206 children, including 31,158 boys and 30,048 girls. Demographic data for the study population are given in appendix 1.

The 90th and 95th percentiles of systolic and diastolic BP (using the fifth Korotkoff phase) for the 5th through 95th percentiles for height by sex and age are given for children in tables 1 and 2, respectively. The difference in the 90th and 95th percentiles for BP for children of the same age and sex but of different height is apparent in these tables.

The BP tables adjusted for height and age in this report, as compared with the tables using only age, alter the BP percentile estimates of boys and girls at all ages and particularly for very young children. In general, BPs in the 90th and 95th percentiles for sex, height, and age are lower for shorter children than BPs in the 90th and 95th percentiles given for children by age alone. Conversely, tall children are allowed higher normal BPs when their height is taken into consideration than when age alone is used.

Table 1

## Blood Pressure Levels for the 90th and 95th Percentiles of Blood Pressure for Boys Age 1 to 17 Years by Percentiles of Height

| Age | Height Percentiles* → BP† ↓ | Systolic BP (mm Hg) 5% | 10% | 25% | 50% | 75% | 90% | 95% | Diastolic BP (mm Hg) 5% | 10% | 25% | 50% | 75% | 90% | 95% |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | **90th** | 94 | 95 | 97 | 98 | 100 | 102 | 102 | 50 | 51 | 52 | 53 | 54 | 54 | 55 |
| | **95th** | 98 | 99 | 101 | 102 | 104 | 106 | 106 | 55 | 55 | 56 | 57 | 58 | 59 | 59 |
| 2 | **90th** | 98 | 99 | 100 | 102 | 104 | 105 | 106 | 55 | 55 | 56 | 57 | 58 | 59 | 59 |
| | **95th** | 101 | 102 | 104 | 106 | 108 | 109 | 110 | 59 | 59 | 60 | 61 | 62 | 63 | 63 |
| 3 | **90th** | 100 | 101 | 103 | 105 | 107 | 108 | 109 | 59 | 59 | 60 | 61 | 62 | 63 | 63 |
| | **95th** | 104 | 105 | 107 | 109 | 111 | 112 | 113 | 63 | 63 | 64 | 65 | 66 | 67 | 67 |
| 4 | **90th** | 102 | 103 | 105 | 107 | 109 | 110 | 111 | 62 | 62 | 63 | 64 | 65 | 66 | 66 |
| | **95th** | 106 | 107 | 109 | 111 | 113 | 114 | 115 | 66 | 67 | 67 | 68 | 69 | 70 | 71 |
| 5 | **90th** | 104 | 105 | 106 | 108 | 110 | 112 | 112 | 65 | 65 | 66 | 67 | 68 | 69 | 69 |
| | **95th** | 108 | 109 | 110 | 112 | 114 | 115 | 116 | 69 | 70 | 70 | 71 | 72 | 73 | 74 |
| 6 | **90th** | 105 | 106 | 108 | 110 | 111 | 113 | 114 | 67 | 68 | 69 | 70 | 70 | 71 | 72 |
| | **95th** | 109 | 110 | 112 | 114 | 115 | 117 | 117 | 72 | 72 | 73 | 74 | 75 | 76 | 76 |
| 7 | **90th** | 106 | 107 | 109 | 111 | 113 | 114 | 115 | 69 | 70 | 71 | 72 | 72 | 73 | 74 |
| | **95th** | 110 | 111 | 113 | 115 | 116 | 118 | 119 | 74 | 74 | 75 | 76 | 77 | 78 | 78 |
| 8 | **90th** | 107 | 108 | 110 | 112 | 114 | 115 | 116 | 71 | 71 | 72 | 73 | 74 | 75 | 75 |
| | **95th** | 111 | 112 | 114 | 116 | 118 | 119 | 120 | 75 | 76 | 76 | 77 | 78 | 79 | 80 |
| 9 | **90th** | 109 | 110 | 112 | 113 | 115 | 117 | 117 | 72 | 73 | 73 | 74 | 75 | 76 | 77 |
| | **95th** | 113 | 114 | 116 | 117 | 119 | 121 | 121 | 76 | 77 | 78 | 79 | 80 | 80 | 81 |
| 10 | **90th** | 110 | 112 | 113 | 115 | 117 | 118 | 119 | 73 | 74 | 74 | 75 | 76 | 77 | 78 |
| | **95th** | 114 | 115 | 117 | 119 | 121 | 122 | 123 | 77 | 78 | 79 | 80 | 80 | 81 | 82 |
| 11 | **90th** | 112 | 113 | 115 | 117 | 119 | 120 | 121 | 74 | 74 | 75 | 76 | 77 | 78 | 78 |
| | **95th** | 116 | 117 | 119 | 121 | 123 | 124 | 125 | 78 | 79 | 79 | 80 | 81 | 82 | 83 |
| 12 | **90th** | 115 | 116 | 117 | 119 | 121 | 123 | 123 | 75 | 75 | 76 | 77 | 78 | 78 | 79 |
| | **95th** | 119 | 120 | 121 | 123 | 125 | 126 | 127 | 79 | 79 | 80 | 81 | 82 | 83 | 83 |
| 13 | **90th** | 117 | 118 | 120 | 122 | 124 | 125 | 126 | 75 | 76 | 76 | 77 | 78 | 79 | 80 |
| | **95th** | 121 | 122 | 124 | 126 | 128 | 129 | 130 | 79 | 80 | 81 | 82 | 83 | 83 | 84 |
| 14 | **90th** | 120 | 121 | 123 | 125 | 126 | 128 | 128 | 76 | 76 | 77 | 78 | 79 | 80 | 80 |
| | **95th** | 124 | 125 | 127 | 128 | 130 | 132 | 132 | 80 | 81 | 81 | 82 | 83 | 84 | 85 |
| 15 | **90th** | 123 | 124 | 125 | 127 | 129 | 131 | 131 | 77 | 77 | 78 | 79 | 80 | 81 | 81 |
| | **95th** | 127 | 128 | 129 | 131 | 133 | 134 | 135 | 81 | 82 | 83 | 83 | 84 | 85 | 86 |
| 16 | **90th** | 125 | 126 | 128 | 130 | 132 | 133 | 134 | 79 | 79 | 80 | 81 | 82 | 82 | 83 |
| | **95th** | 129 | 130 | 132 | 134 | 136 | 137 | 138 | 83 | 83 | 84 | 85 | 86 | 87 | 87 |
| 17 | **90th** | 128 | 129 | 131 | 133 | 134 | 136 | 136 | 81 | 81 | 82 | 83 | 84 | 85 | 85 |
| | **95th** | 132 | 133 | 135 | 136 | 138 | 140 | 140 | 85 | 85 | 86 | 87 | 88 | 89 | 89 |

*Height percentile determined by standard growth curves.
†Blood pressure percentile determined by a single measurement.

Table 2

## BLOOD PRESSURE LEVELS FOR THE 90TH AND 95TH PERCENTILES OF BLOOD PRESSURE FOR GIRLS AGE 1 TO 17 YEARS BY PERCENTILES OF HEIGHT

| Age | Height Percentiles* → / BP† ↓ | Systolic BP (mm Hg) | | | | | | | Diastolic BP (mm Hg) | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 5% | 10% | 25% | 50% | 75% | 90% | 95% | 5% | 10% | 25% | 50% | 75% | 90% | 95% |
| 1 | **90th** | 97 | 98 | 99 | 100 | 102 | 103 | 104 | 53 | 53 | 53 | 54 | 55 | 56 | 56 |
| | **95th** | 101 | 102 | 103 | 104 | 105 | 107 | 107 | 57 | 57 | 57 | 58 | 59 | 60 | 60 |
| 2 | **90th** | 99 | 99 | 100 | 102 | 103 | 104 | 105 | 57 | 57 | 58 | 58 | 59 | 60 | 61 |
| | **95th** | 102 | 103 | 104 | 105 | 107 | 108 | 109 | 61 | 61 | 62 | 62 | 63 | 64 | 65 |
| 3 | **90th** | 100 | 100 | 102 | 103 | 104 | 105 | 106 | 61 | 61 | 61 | 62 | 63 | 63 | 64 |
| | **95th** | 104 | 104 | 105 | 107 | 108 | 109 | 110 | 65 | 65 | 65 | 66 | 67 | 67 | 68 |
| 4 | **90th** | 101 | 102 | 103 | 104 | 106 | 107 | 108 | 63 | 63 | 64 | 65 | 65 | 66 | 67 |
| | **95th** | 105 | 106 | 107 | 108 | 109 | 111 | 111 | 67 | 67 | 68 | 69 | 69 | 70 | 71 |
| 5 | **90th** | 103 | 103 | 104 | 106 | 107 | 108 | 109 | 65 | 66 | 66 | 67 | 68 | 68 | 69 |
| | **95th** | 107 | 107 | 108 | 110 | 111 | 112 | 113 | 69 | 70 | 70 | 71 | 72 | 72 | 73 |
| 6 | **90th** | 104 | 105 | 106 | 107 | 109 | 110 | 111 | 67 | 67 | 68 | 69 | 69 | 70 | 71 |
| | **95th** | 108 | 109 | 110 | 111 | 112 | 114 | 114 | 71 | 71 | 72 | 73 | 73 | 74 | 75 |
| 7 | **90th** | 106 | 107 | 108 | 109 | 110 | 112 | 112 | 69 | 69 | 69 | 70 | 71 | 72 | 72 |
| | **95th** | 110 | 110 | 112 | 113 | 114 | 115 | 116 | 73 | 73 | 73 | 74 | 75 | 76 | 76 |
| 8 | **90th** | 108 | 109 | 110 | 111 | 112 | 113 | 114 | 70 | 70 | 71 | 71 | 72 | 73 | 74 |
| | **95th** | 112 | 112 | 113 | 115 | 116 | 117 | 118 | 74 | 74 | 75 | 75 | 76 | 77 | 78 |
| 9 | **90th** | 110 | 110 | 112 | 113 | 114 | 115 | 116 | 71 | 72 | 72 | 73 | 74 | 74 | 75 |
| | **95th** | 114 | 114 | 115 | 117 | 118 | 119 | 120 | 75 | 76 | 76 | 77 | 78 | 78 | 79 |
| 10 | **90th** | 112 | 112 | 114 | 115 | 116 | 117 | 118 | 73 | 73 | 73 | 74 | 75 | 76 | 76 |
| | **95th** | 116 | 116 | 117 | 119 | 120 | 121 | 122 | 77 | 77 | 77 | 78 | 79 | 80 | 80 |
| 11 | **90th** | 114 | 114 | 116 | 117 | 118 | 119 | 120 | 74 | 74 | 75 | 75 | 76 | 77 | 77 |
| | **95th** | 118 | 118 | 119 | 121 | 122 | 123 | 124 | 78 | 78 | 79 | 79 | 80 | 81 | 81 |
| 12 | **90th** | 116 | 116 | 118 | 119 | 120 | 121 | 122 | 75 | 75 | 76 | 76 | 77 | 78 | 78 |
| | **95th** | 120 | 120 | 121 | 123 | 124 | 125 | 126 | 79 | 79 | 80 | 80 | 81 | 82 | 82 |
| 13 | **90th** | 118 | 118 | 119 | 121 | 122 | 123 | 124 | 76 | 76 | 77 | 78 | 78 | 79 | 80 |
| | **95th** | 121 | 122 | 123 | 125 | 126 | 127 | 128 | 80 | 80 | 81 | 82 | 82 | 83 | 84 |
| 14 | **90th** | 119 | 120 | 121 | 122 | 124 | 125 | 126 | 77 | 77 | 78 | 79 | 79 | 80 | 81 |
| | **95th** | 123 | 124 | 125 | 126 | 128 | 129 | 130 | 81 | 81 | 82 | 83 | 83 | 84 | 85 |
| 15 | **90th** | 121 | 121 | 122 | 124 | 125 | 126 | 127 | 78 | 78 | 79 | 79 | 80 | 81 | 82 |
| | **95th** | 124 | 125 | 126 | 128 | 129 | 130 | 131 | 82 | 82 | 83 | 83 | 84 | 85 | 86 |
| 16 | **90th** | 122 | 122 | 123 | 125 | 126 | 127 | 128 | 79 | 79 | 79 | 80 | 81 | 82 | 82 |
| | **95th** | 125 | 126 | 127 | 128 | 130 | 131 | 132 | 83 | 83 | 83 | 84 | 85 | 86 | 86 |
| 17 | **90th** | 122 | 123 | 124 | 125 | 126 | 128 | 128 | 79 | 79 | 79 | 80 | 81 | 82 | 82 |
| | **95th** | 126 | 126 | 127 | 129 | 130 | 131 | 132 | 83 | 83 | 83 | 84 | 85 | 86 | 86 |

*Height percentile determined by standard growth curves.
†Blood pressure percentile determined by a single measurement.

To use the tables in a clinical setting, the height percentile is determined from the standard growth charts. The child's measured systolic and diastolic BP is compared with the numbers provided in the table (boys or girls) for age and height percentile. The child is normotensive if BP is below the 90th percentile. If the child's BP (systolic or diastolic) is at or above the 95th percentile, the child may be hypertensive and repeated measurements are indicated. BP measurements between the 90th and 95th percentiles are high-normal and warrant further observation and consideration of other risk factors.

Standards for systolic and diastolic BP for infants younger than 1 year are available in the second task force report.[3] Additional data recently have been published.[28,29] In children younger than 1 year, systolic BP has been used to define hypertension.

# Treatment of Hypertension in Children and Adolescents

## Nonpharmacologic Therapy

Nonpharmacologic therapy comprises weight reduction, exercise, and dietary intervention. Nonpharmacologic therapy should be introduced not only in the care of patients with hypertension but also in children with high-normal BP (90th to 95th percentile BP distribution) and to complement drug therapy for patients with severe hypertension.

Body size is the major determinant for BP among children. In obese children, both systolic and diastolic BP may decrease in response to weight loss.[30] In addition, weight loss offers other benefits. The adverse effect of obesity on cardiovascular function[31] is compounded in the presence of hypertension, and overweight adolescents are at increased risk for cardiovascular disease as adults.[32] Weight loss also has a positive effect on serum lipid profiles, and, in obese children, weight loss diminishes the effect of dietary salt on BP.[33] The prevention of obesity in childhood would convey significant benefits in reducing risks for cardiovascular disease as well as other benefits. When elevated BP is associated with obesity, efforts should be directed at reducing obesity with strategies to lower excessive calorie intake and to increase physical exercise. Correction of obesity is difficult to achieve in children as well as adults. Because of the known benefits of weight control, efforts both to prevent and to control childhood obesity should be pursued. More effective weight loss strategies for children are developing, which should facilitate more effective treatment.[34-39]

BP also is directly related to degree of physical fitness. The benefit of the increased physical activity occurs gradually over months.[40] When increases in physical activity are combined with weight loss, the reduction in BP is superior to the effect resulting from weight reduction alone.[30] Hypertension usually is not a contraindication to participation in sports and strenuous activity, particularly because exercise has a beneficial effect on BP and other risk factors. Sudden death during sporting events has not been reported in athletes with hypertension as it has in athletes with hypertrophic cardiomyopathy or cardiac arrhythmias.

Although dietary interventions to control or reduce obesity in childhood have demonstrated benefit to BP, limited data support the benefit to BP of other dietary interventions in the young. The preponderance of evidence from published clinical trials suggests that dietary sodium restriction reduces BP in adults with hypertension.[41,42] Most studies to determine whether sodium reduction lowers BP in children have been very short term.[43-45] As yet, no clear evidence supports sodium reduction as beneficial in children or adolescents with mild hypertension. However, because sodium intake is generally well in excess of needs and mild BP elevation often is associated with obesity, a moderate reduction in dietary sodium can be beneficial. Sodium restriction is also of benefit in some types of secondary hypertension such as chronic glomerulonephritis. Practical dietary considerations include an increase in fresh fruits and vegetables, elimination of added salt to home-cooked foods in preparation and at the table, and a reduction in foods with high sodium content.

These strategies for nonpharmacologic therapy should be employed as initial treatment maneuvers for children with BP above the 90th percentile for age, gender, and height. Similarly, these nonpharmacologic methods are appropriate for children and adolescents with other risk factors for hypertension, particularly a strong family history of hypertension. Some childhood data sets[46] indicate that African American children have BP levels that are somewhat higher than those of white children, suggesting that the prevalence of high BP may be greater in African American children than white children. Recent data from California regarding Asian American children show that they also tend to have higher BP than white children.[47] With the known excess prevalence, morbidity, and mortality of essential hypertension among adult African Americans in the United States, it is advisable to be vigilant in monitoring BP and to encourage healthy diet, exercise, and weight control behaviors in African American children, especially in the presence of a family history of hypertension. This approach seems to be prudent for other groups with a higher prevalence of hypertension or individuals with a family history of high BP.

### Pharmacologic Therapy

When drug therapy is used, the goal is to reduce BP to below the 95th percentile. The second task force report provided guidelines for the use of antihypertensive drugs in childhood, which continue to be endorsed.[3] These drugs and their dosing recommendations are provided in table 3, which contains the drugs recommended for acute antihypertensive therapy, and in table 4, which lists the drugs used for chronic antihypertensive therapy. Antihypertensive drug therapy should be individualized, depending on the level of BP, the degree of response, the occurrence of side effects, and the patient's medical history. Diuretics and beta-blockers have been used in treating hypertension in children and adolescents, and these medications continue to be useful. Since publication of the second task force report, a number of newer antihypertensive agents have become available and are described below.

Angiotensin-converting enzyme (ACE) inhibitors have become one of the primary agents for antihypertensive therapy not only because of their effectiveness in reducing BP but also because of their positive benefits on cardiac function, peripheral vasculature, and renal function.[48] ACE inhibitors are effective in children and can be useful in young infants and newborns.[49] Both the potency and the duration of action seem greater in this age group than in older children.[50]

A significant adverse effect of ACE inhibitors on the kidneys is severe reduction in glomerular filtration in patients with bilateral renal artery stenosis or renal artery stenosis in a solitary or transplanted kidney.[51] A more recent observation is the adverse effect of ACE inhibitors on the developing fetus. The use of ACE inhibitors during the second and third trimesters of pregnancy is associated with oligohydramnios and fetal effects of pulmonary hypoplasia, renal tubular dysplasia, and hypocalvaria as well as with hypotension and anuria after birth.[52] Because of the teratogenic risk with fetal exposure, ACE inhibitors should be used with extreme caution in adolescent girls who may be sexually active.

Calcium channel blockers constitute a class of compounds that inhibit intracellular flux of calcium. At the present time, nifedipine is the calcium channel blocker used most often for treatment of childhood hypertension. The usefulness of nifedipine in treating chronic hypertension is limited by a short duration of action. Long-acting preparations have improved the effectiveness of nifedipine, but the tablet strength makes it impractical for use in small children. Because of recent concerns

Table 3

**Antihypertensive Drug Therapy for Hypertensive Emergencies in Children**

| Drug | Dose |
|---|---|
| Nifedipine | 0.25-0.5 mg/kg oral prn. May be repeated two times, if no response. |
| Sodium Nitroprusside | 0.5-1 mcg/kg/min IV initially. May be increased stepwise to 8 mcg/kg/min maximum. |
| Labetalol | 0.2-1 mg/kg/dose IV. May be increased incrementally to 1 mg/kg/dose until response achieved.<br>0.25-2 mg/kg/hr maintenance, either bolus or IV infusion. |
| Esmolol | 500-600 mcg/kg IV load dose over 1-2 min then 200 mcg/kg/min. May be increased by 50-100 mcg/kg q 5-10 min to max of 1,000 mcg/kg. |
| Diazoxide | 1-5 mg/kg/dose IV bolus up to max of 150 mg/dose. |
| Hydralazine | 0.2-0.4 mg/kg IV prn. May be repeated two times if no response. |
| Minoxidil | 0.1-0.2 mg/kg oral. |

about possible adverse effects of short-term calcium channel blockers used in adults, it has been recommended that physicians exercise caution in their use.[53,54] Presently there are no long-term data available on children using calcium channel blockers or any classes of antihypertensive agents. Most adverse effects are limited to a brief period of time after initial drug administration. The heart rate and cardiac output increase but usually return to pretreatment levels within a few weeks. Newer calcium channel blocking agents seem to have fewer side effects, although their use in children has been limited.

Benefit may be achieved with pharmacologic intervention at less severe levels of hypertension in some clinical situations. Children with confirmed chronic renal disease such as chronic glomerulonephritis should have therapy to reduce BP to below the 95th percentile to preserve renal function. Children with diabetes constitute another group of patients warranting very careful BP surveillance. There is evidence that some children with diabetes, especially those who have a strong family history of hypertension, are at greater risk for development of diabetic nephropathy.[55] Children, as well as adults, with diabetes are likely to achieve renal protective benefits from therapy to maintain BP below the 90th percentile.[56]

Extensive clinical trials have not been conducted to examine the benefits and risks of antihyper-tensive therapy in children and adolescents. Because of the limited data available on therapy outcomes, the guidelines for treatment of children with hypertension are conservative. Treatment of children with mild hypertension should focus on lifestyle- or health-related behavioral changes including weight reduction and increased physical activity. Children with secondary hypertension, which may or may not be curable, should have therapy directed at the underlying cause of the hypertension.

## Public Health Considerations

In the general population, it is estimated that more than 70 percent of premature morbidity

**Table 4**

## Antihypertensive Drug Therapy for Chronic Hypertension in Children

Listed in alphabetical order by drug class*

| Drug | Dose (mg/kg/day) Initial | Dose (mg/kg/day) Maximum | Dosing Interval |
|---|---|---|---|
| **Adrenergic-Blocking Agents** | | | |
| Alpha-/Beta-Blocker | | | |
| Labetalol | 1 | 3 | q 6-12 hr |
| Alpha-Blocker | | | |
| Prazosin | 0.05-0.1 | 0.5 | q 6-8 hr |
| Beta-Adrenergic Blockers | | | |
| Atenolol | 1 | 8 | q 12-24 hr |
| Propranolol | 1 | 8 | q 6-12 hr |
| **Alpha-Agonist** | | | |
| Clonidine | 0.05-0.1** | 0.5-.6† | q 6 hr |
| **Calcium Antagonists** | | | |
| Nifedipine | **0.25** | **3** | q 4-6 hr |
| Nifedipine XL | 0.25 | 3 | q 12-24 hr |
| **Converting Enzyme Inhibitors** | | | |
| Captopril | | | |
| Children | 1.5 | 6 | q 8 hr |
| Neonates | 0.03-0.15 | 2 | q 8-24 hr |
| Enalapril | 0.15 | not established | q 12-24 hr |
| **Diuretics** | | | |
| Bumetanide | 0.02-0.05 | 0.3 | q 4-12 hr |
| Furosemide | 1 | 12 | q 4-12 hr |
| Hydrochlorothiazide | 1 | 2-3 | q 12 hr |
| Metolazone | 0.1 | 3 | q 12-24 hr |
| Spironolactone | 1 | 3 | q 6-12 hr |
| Triamterene | 2 | 3 | q 6-12 hr |
| **Vasodilators** | | | |
| Hydralazine | 0.75 | 7.5 | q 6 hr |
| Minoxidil | 0.1-0.2 | 1 | q 12 hr |

*Other drugs are available in some classes, but data on dosage in children have not been published.
**Total initial dose in mg.
†Total daily dose in mg.

can be attributed to tobacco use, undertreatment of hypertension, and obesity.[57,58] From a public health perspective, health-related behaviors that reduce the risk of cardiovascular disease should be encouraged for all children and their families. In addition to monitoring BP, appropriate nutrition and exercise should be encouraged and smoking should be strongly discouraged during childhood.

# References


1. National Health and Nutrition Examination Survey: blood pressure levels of persons 6-74 years, U.S., 1971-74. Hyattsville, MD: National Center of Health Statistics, 1977; DHEW publication no. (HRA) 78-1648 (*Vital and Health Statistics*; series 11; no. 203):37-44.
2. National Heart, Lung, and Blood Institute. Report of the Task Force on Blood Pressure Control in Children. *Pediatrics.* 1977;59:797-820.
3. National Heart, Lung, and Blood Institute. Report of the Second Task Force on Blood Pressure Control in Children—1987. *Pediatrics.* 1987;79(1):1-25.
4. Loggie J. *Pediatric Hypertension.* Boston: Blackwell Scientific Publications, 1992.
5. Falkner B. Evaluation of the child and adolescent with hypertension. In: Izzo JL, Black HR, eds. *Hypertension Primer*. Dallas: American Heart Association, 1993;239-242.
6. Rocchini AP. Treatment of childhood hypertension. In: Izzo JL, Black HR, eds. *Hypertension Primer*. Dallas: American Heart Association, 1993;320-321.
7. Joint National Committee. The fifth report of the Joint National Committee on Detection, Evaluation, and Treatment of High Blood Pressure. *Arch Intern Med*. 1993;153: 154-183.
8. Sinaiko AR, Gomez-Marin O, Prineas RJ. Prevalence of “significant” hypertension in junior high school-aged children: the Children and Adolescent Blood Pressure Program. *J Pediatr.* 1989;114:664-669.
9. Sinaiko AR, Gillum RF, Jacobs DR Jr, Sopko G, Prineas RJ. Renin-angiotensin and sympathetic nervous system activity in grade school children. *Hypertension.* 1982;4:299-306.
10. Zinner SH, Rosner B, Oh W, Kass EH. Significance of blood pressure in infancy: familial aggregation and predictive effect on later blood pressure. *Hypertension.* 1985;7: 411-416.
11. Zinner SH, Levy PS, Kass EH. Familial aggregation of blood pressure in childhood. *N Engl J Med.* 1971;284:401-404.
12. Shear CL, Burke GL, Freedman DS, Berenson GS. Value of childhood blood pressure measurements and family history in predicting future blood pressure status: results from 8 years of follow-up in the Bogalusa Heart Study. *Pediatrics.* 1986;77: 862-869.
13. Prineas RJ, Gomez-Marin O, Gillum RF. Tracking of blood pressure in children and nonpharmacological approaches to the prevention of hypertension. *Ann Behav Med.* 1985;7:25-29.

14. Shieken RM, Clarke WR, Lauer RM. Left ventricular hypertrophy in children with blood pressures in the upper quintile of the distribution: the Muscatine Study. *Hypertension.* 1981;3:669-675.

15. Zahka KG, Neill CA, Kidd L, Cutilletta MA, Cutilletta AF. Cardiac involvement in adolescent hypertension: echocardiographic determination of myocardial hypertrophy. *Hypertension.* 1981;3:664-668.

16. Culpepper WS, Sodt PC, Messerli FH, Ruschhaupt DG, Arcilla RA. Cardiac status in juvenile borderline hypertension. *Ann Intern Med.* 1983;98:1-7.

17. Sinaiko AR, Bass J, Gomez-Marin O, Prineas RJ. Cardiac status of adolescents tracking with high and low blood pressure since early childhood. *J Hypertens.* 1985;4(suppl 5):S378-S380.

18. Daniels SD, Meyer RA, Loggie JMH. Determinants of cardiac involvement in children and adolescents with essential hypertension. *Circulation.* 1990;82:1243-1248.

19. Burke GL, Arcilla RA, Culpepper WS, Webber LS, Chiang Y-K, Berenson GS. Blood pressure and echocardiographic measures in children: the Bogulusa Heart Study. *Circulation.* 1987;75:106-114.

20. Lauer RM, Clarke WR. Childhood risk factors for high adult blood pressure: the Muscatine Study. *Pediatrics.* 1984;84:633-641.

21. Prineas RJ, Elkwiry ZM. Epidemiology and measurement of high blood pressure in children and adolescents. In: Loggie JMH, ed. *Pediatric and Adolescent Hypertension.* Boston: Blackwell Scientific Publications, 1992;91-103.

22. Prineas RJ, Sinaiko AR. Hypertension in children. In: Swales JD, ed. *Textbook of Hypertension.* Boston: Blackwell Scientific Publications, 1994;750-766.

23. Sinaiko AR, Gomez-Marin O, Prineas RJ. Diastolic fourth and fifth phase blood pressure in 10-15-year-old children: the Children and Adolescent Blood Pressure Program. *Am J Epidemiol.* 1990;132:647-655.

24. Reusz GS, Hóbor M, Tulassay T, Sallay P, Miltényi M. 24 hour blood pressure monitoring in healthy and hypertensive children. *Arch Dis Child.* 1994;70:90-94.

25. Harshfield GA, Alpert BS, Pulliam DA, Somes GW, Wilson DK. Ambulatory blood pressure recordings in children and adolescents. *Pediatrics*. 1994;94:180-184.

26. Rosner B, Prineas RJ, Loggie JMH, Daniels SR. Blood pressure nomograms for children and adolescents, by height, sex, and age, in the United States. *J Pediatr.* 1993;123:871-886.

27. Centers for Disease Control and Prevention, National Center for Health Statistics. National Health and Nutrition Examination Survey (NHANES III), 1988-1991, data computed for the National Heart, Lung, and Blood Institute. Atlanta, GA: Centers for Disease Control and Prevention.

28. Hulman S, Edwards R, Chen YQ, Polansky M, Falkner B. Blood pressure patterns in the first three days of life. *J Perinatol*. 1991;11:231-234.

29. Zubrow A, Hulman S, Kushner H, Falkner B. Determinants of blood pressure in infants admitted to neonatal intensive care units: a prospective, multicenter study. *J Perinatol*. 1995;15:470-479.

30. Rocchini AP, Katch V, Anderson J, Hinderliter J, Becque D, Martin M, Marks C. Blood pressure in obese adolescents: effect of weight loss. *Pediatrics*. 1988;82:16-23.

31. Messerli FH, Sundgaard-Riise K, Reisin E, Dreslinski G, Dunn FG, Frohlich E. Disparate cardiovascular effects of obesity and arterial hypertension. *Am J Med*. 1983;74(5):808-812.

32. Must A, Jacques PF, Dallal GE, Bajema CJ, Dietz WH. Long-term morbidity and mortality of overweight adolescents. *N Engl J Med*. 1992;327:1350-1355.

33. Rocchini AP, Key J, Bondie D, Chico R, Moorehead C, Katch V, Martin M. The effect of weight loss on the sensitivity of blood pressure to sodium in obese adolescents. *N Engl J Med*. 1989;321:580-585.

34. Epstein LH, Valoski A, McCurley J. Effect of weight loss by obese children on long-term growth. *Am J Dis Child*. 1993;147:1076-1080.

35. Himes JH, Dietz WH. Guidelines for overweight in adolescent preventive services: recommendations from an expert committee. *Am J Clin Nutr.* 1994;59:307-316.

36. Brownell KD, Kelman J, Stunkard J. Treatment of obese children with and without their mothers: change in weight and blood pressure. *Pediatrics.* 1983;71:515-523.

37. Epstein LH, Valoski A, Wing RR, McCurley J. Ten-year follow-up of behavioral, family-based treatment for obese children. *JAMA.* 1990;264:2519-2523.

38. Mellin LM, Frost L. Child and adolescent obesity: the nurse practitioner's use of the SHAPEDOWN Method. *J Pediatr Health Care*. 1992;6:187-193.

39. Mellin LM. To: President Clinton, Re: Combating childhood obesity. *J Am Diet Assoc.* 1993;93:265-266.

40. Hansen HS, Froberg K, Hyldebrandt N, Nielsen JR. A controlled study of eight months of physical training and reduction of blood pressure in children: the Odense School-Child Study. *Br Med J.* 1991;303:682-685.

41. Law MR, Frost CD, Wald NJ. By how much does dietary salt reduction lower blood pressure? III. Analysis of data from trials of salt reduction. *Br Med J*. 1991;302:819-824.

42. Cutler JA, Follmann D, Elliott P, Suh I. An overview of randomized trials of sodium reduction and blood pressure. *Hypertension.* 1991;17(suppl I):I27-I33.

43. Cooper R, Van Horn L, Liu K, Trevisan M, Nanas S, Ueshima H, Larbi E, Yu C-S, Sempos C, LeGrady D, Stamlar J. A randomized trial on the effect of decreased dietary sodium intake on blood pressure in adolescents. *J Hypertens*. 1984;2:361-366.

44. Howe PRC, Cobiac L, Smith RM. Lack of effect of short-term changes in sodium intake on blood pressure in adolescent schoolchildren. *J Hypertens*. 1991;9:181-186.

45. Prineas RJ. Salt intake and blood pressure in childhood: implications for clinical practice and public health. In: Filer LJ, Lauer RM, Luepker RV, eds. *Prevention of Atherosclerosis and Hypertension Beginning in Youth*. Philadelphia: Lea & Febiger, 1994;120-128.

46. Berenson GS, Voors AW, Webber LS, Dalferes ER Jr, Harsha DW. Racial difference of parameters associated with blood pressure levels in children: the Bogalusa Heart Study. *Metabolism*. 1979;28:1218-1228.

47. Hohn AR, Dwyer KM, Dwyer JH. Blood pressure in youth from four ethnic groups: the Pasadena Prevention Project. *J Pediatr*. 1994;125:368-373.

48. Doyle AE. Angiotensin-converting enzyme (ACE) inhibition: benefits beyond blood pressure control. *Am J Med*. 1992;92(4B): 1S-107S.

49. Mirkin BL, Newman TJ. Efficacy and safety of captopril in the treatment of severe childhood hypertension: report of the International Collaborative Study Group. *Pediatrics.* 1985;75:1091-1100.

50. O'Dea RF, Mirkin BL, Alward CT, Sinaiko AR. Treatment of neonatal hypertension with captopril. *J Pediatr*. 1988;113:403-406.

51. Hricik DE, Dunn MJ. Angiotensin-converting enzyme inhibitor-induced renal failure: causes, consequences, and diagnostic uses. *J Am Soc Nephrol*. 1990;1:845-858.

52. Pryde PG, Sedman AB, Nugent CE, Barr M. Angiotensin-converting enzyme inhibitor fetopathy. *J Am Soc Nephrol*. 1993;3:1575-1582.

53. Furberg CD, Psaty BM, Meyer JV. Nifedipine: dose-related increase in mortality in patients with coronary heart disease. *Circulation.* 1995;92:1326-1331.

54. National Heart, Lung, and Blood Institute. *New Analyses Regarding the Safety of Calcium-Channel Blockers: A Statement for Health Professionals From the National Heart, Lung, and Blood Institute*. Bethesda, MD: National Institutes of Health, 1995.

55. Krolewski AS, Canessa M, Warram JH, Laffel LMB, Christlieb AR, Knowler WC, Rand LI. Predisposition to hypertension and susceptibility to renal disease in insulin-dependent diabetes mellitus. *N Engl J Med.* 1988;318:140-145.

56. National High Blood Pressure Education Program. Working group report on hypertension and diabetes. *Hypertension.* 1994;23: 145-158.

57. Lawrence M, Arbeit M, Johnson CC, Berenson GS. Prevention of adult heart disease beginning in childhood: intervention programs. *Cardiovasc Clin*. 1991;21:249-262.

58. Konner, M. *Medicine at the Crossroads: The Crisis in Health Care*. New York: Pantheon Books, 1993;220.

59. Harlan WR, Cornoni-Huntley J, Leaverton PE. Blood pressure in childhood: the National Health Examination Survey. *Hypertension*. 1979;1:559-565.

60. 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;119:541-553.

61. Fixler DE, Laird WP. Validity of mass blood pressure screening in children. *Pediatrics*. 1983;72:459-463.

62. Baron AE, Freyer B, Fixler DE. Longitudinal blood pressure in blacks, whites and Mexican Americans during adolescence and early adulthood. *Am J Epidemiol*. 1986;123:809-817.

63. Voors AW, Foster TA, Frerichs RR, Webber LS, Berenson GS. Studies of blood pressure in children, ages 5-14 years in a total biracial community: the Bogalusa Heart Study. *Circulation*. 1976;54:319-327.

64. Berenson GS, McMahan CA, Voors AW, et al. *Cardiovascular Risk Factors in Children: The Early Natural History of Atherosclerosis and Essential Hypertension*. New York: Oxford University Press, 1980.

65. Berenson GS. *Causation of Cardiovascular Risk Factors in Children: Perspectives on Cardiovascular Risk in Early Life*. New York: Raven Press, 1986.

66. Gutgesell M, Terrell G, Labarthe D. Pediatric blood pressure: ethnic comparison in a primary care center. *Hypertension*. 1981;3:39-49.

67. Lackland DT, Riopel DA, Shepard DM, Wheller FC. Blood pressure and anthropometric measurement results of the South Carolina Dental Health and Pediatric Blood Pressure Study. Columbia: South Carolina Department of Health and Environmental Control, 1985.

68. Clarke WR, Schrott HG, Leaverton PE, Connor WE, Lauer RM. Tracking of blood lipids and blood pressures in school-age children: the Muscatine study. *Circulation*. 1978;58:626-634.

69. Lauer RM, Clarke WR, Beaglehole R. Level, trend, and variability of blood pressure during childhood: the Muscatine study. *Circulation*. 1984;69:242-249.

70. Gomez O, Prineas RJ, Sinaiko AR. The sodium-potassium blood pressure trial in children. *Controlled Clin Trials*. 1991;12:408-423.

# Appendix 1. Demographic Data on Height/Blood Pressure Distribution Curves of Study Population

| Source | Age (year) | Gender: Boys | Gender: Girls | Ethnic Group: Black | Hispanic | White | Asian | Native American | Other | Missing | Persons[a] (Visits) SBP Available | Persons[b] (Visits) DBP (K5) Available | Total No. of Persons[c] (Visits) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| NIH[59] | 6-17 | 1,901 | 1,751 | 600 | 0 | 2,968 | 0 | 0 | 84 | 0 | 3,647 (3,647) | 3,614 (3,614) | 3,652 (3,652) |
| Pittsburgh[60] | 1-5 | 150 | 137 | 109 | 0 | 177 | 0 | 0 | 0 | 1 | 287 (899) | 0 (0) | 287 (899) |
| Dallas[61,62] | 13-17 | 5,916 | 5,649 | 5,266 | 1,570 | 4,729 | 0 | 0 | 0 | 0 | 11,565 (21,860) | 11,565 (21,852) | 11,565 (21,860) |
| Bogalusa[63-65] | 1-17 | 3,752 | 3,611 | 2,483 | 0 | 4,880 | 0 | 0 | 0 | 0 | 7,363 (15,922) | 0 (0) | 7,363 (15,922) |
| Houston[66] | 3-17 | 1,457 | 1,378 | 638 | 1,341 | 748 | 23 | 0 | 0 | 85 | 2,835 (2,835) | 0 (0) | 2,835 (2,835) |
| South Carolina[67] | 4-17 | 3,167 | 3,264 | 3,110 | 0 | 3,321 | 0 | 0 | 0 | 0 | 6,431 (6,431) | 6,369 (6,369) | 6,431 (6,431) |
| Iowa[68,69] | 5-17 | 2,100 | 1,993 | 0 | 0 | 4,093 | 0 | 0 | 0 | 0 | 4,093 (4,093) | 0 (0) | 4,093 (4,093) |
| Providence[10] | 1-3 | 231 | 231 | 24 | 4 | 432 | 0 | 0 | 2 | 0 | 462 (906) | 371 (566) | 462 (906) |
| Minnesota[70] | 9-17 | 9,995 | 9,425 | 3,422 | 556 | 11,320 | 1,678 | 644 | 1,800[d] | 0 | 19,420 (19,420) | 19,217[e] (19,217) | 19,420 (19,420) |
| NHANES III[27] | 5-17 | 2,489 | 2,609 | 1,793 | 1,851 | 1,334 | 64 | 10 | 12 | 34 | 5,027 (5,027) | 4,291[e] (4,291) | 5,098 (5,098) |
| Total | 1-17 | 31,158 | 30,048 | 17,445 | 5,322 | 34,002 | 1,765 | 654 | 1,898 | 120 | 61,130 (81,040) | 45,427 (55,909) | 61,206 (81,116) |
| Percent of Total Number of People | | (51) | (49) | (29) | (9) | (56) | (3) | (1) | (3) | (0) | | | |

SBP = systolic blood pressure; DBP = diastolic blood pressure; K5 = fifth Korotkoff sound; NIH = National Institutes of Health.
[a]Number of persons (visits) at which SBP was available.
[b]Number of persons (visits) at which DBP (K5) was available.
[c]Number of persons (visits) at which either SBP or DBP (K5) was available.
[d]These children were mostly of mixed ancestry, with the predominant categories white/black or white/Hispanic.
[e]Excludes subjects with a value of 0 for the fifth Korotkoff sound.

# Appendix 2. Quick-Reference Diagnostic Charts

## Quick-Reference Diagnostic Charts

The quick-reference diagnostic charts are for use in the clinical setting. By following the steps listed below, clinicians can make a quick assessment for classification of blood pressure.

### Classification of Blood Pressure in Children and Adolescents*

| | |
|---|---|
| SBP and DBP < 90th percentile | Normal |
| SBP or DBP ≥ 90th percentile and < 95th percentile | High-Normal** |
| SBP or DBP ≥ 95th percentile | Hypertension** |

* for age and sex

** for age and sex measured on at least three separate occasions

SBP = systolic blood pressure
DBP = diastolic blood pressure

## Using the Charts

1. Use the standard height charts to determine the height percentile.
2. Measure the child's blood pressure. Record SBP and DBP.
3. Use the correct gender chart for 90th percentile of DBP.
4. Find the child's age on the right side of the chart. Follow the age line horizontally across the chart to the intersection of the line for the height percentile (vertical line).
5. Move UP or DOWN the height percentile line to the intersection of measured blood pressure.

**Result on 90th Percentile Chart:**

- If you move DOWN on the height percentile line, blood pressure is **NORMAL.** Repeat steps 3 through 5 on the chart for 90th percentile SBP.
- If you move UP on the height percentile line, you must repeat steps 3 through 5 on the chart for 95th percentile DBP.

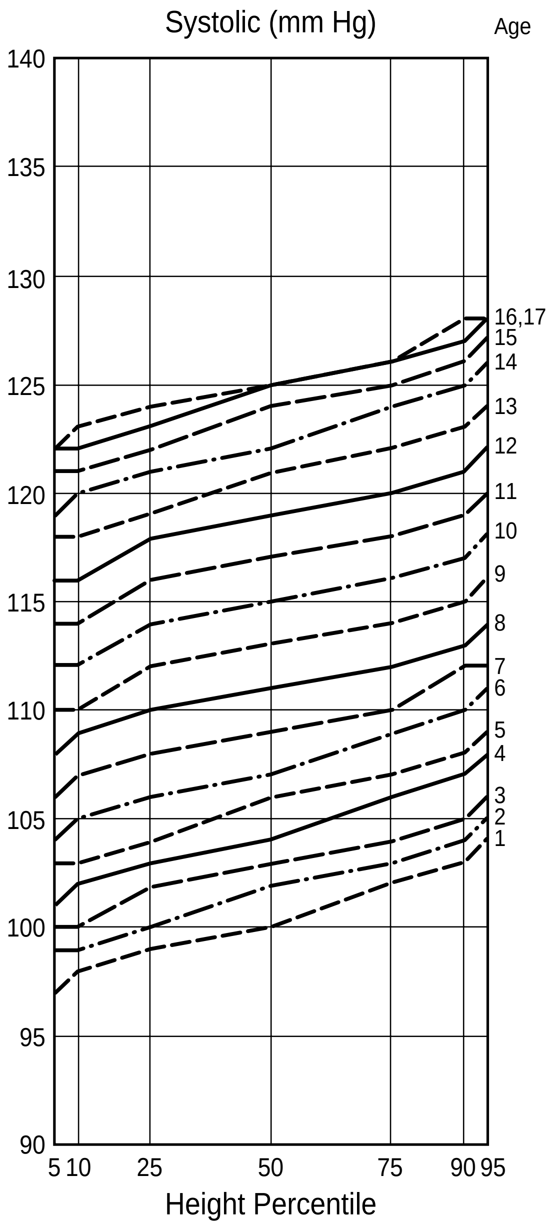
**Result on 95th Percentile Chart:**

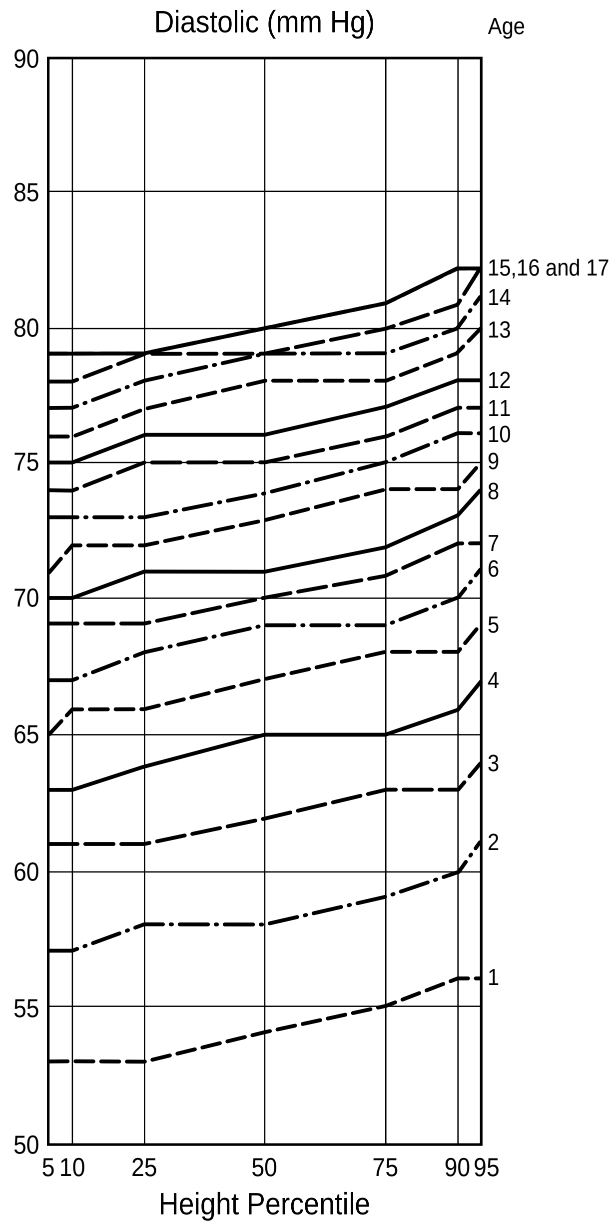
- If you move DOWN on the height percentile line, blood pressure is **HIGH-NORMAL.** Repeat steps 3 through 5 on the chart for 95th percentile SBP.
- If you move UP on the height percentile line, **HYPERTENSION*** is indicated. Repeat steps 3 through 5 on the chart for 95th percentile SBP.

Data points for the Quick-Reference Diagnostic Charts are found in tables 1 and 2.

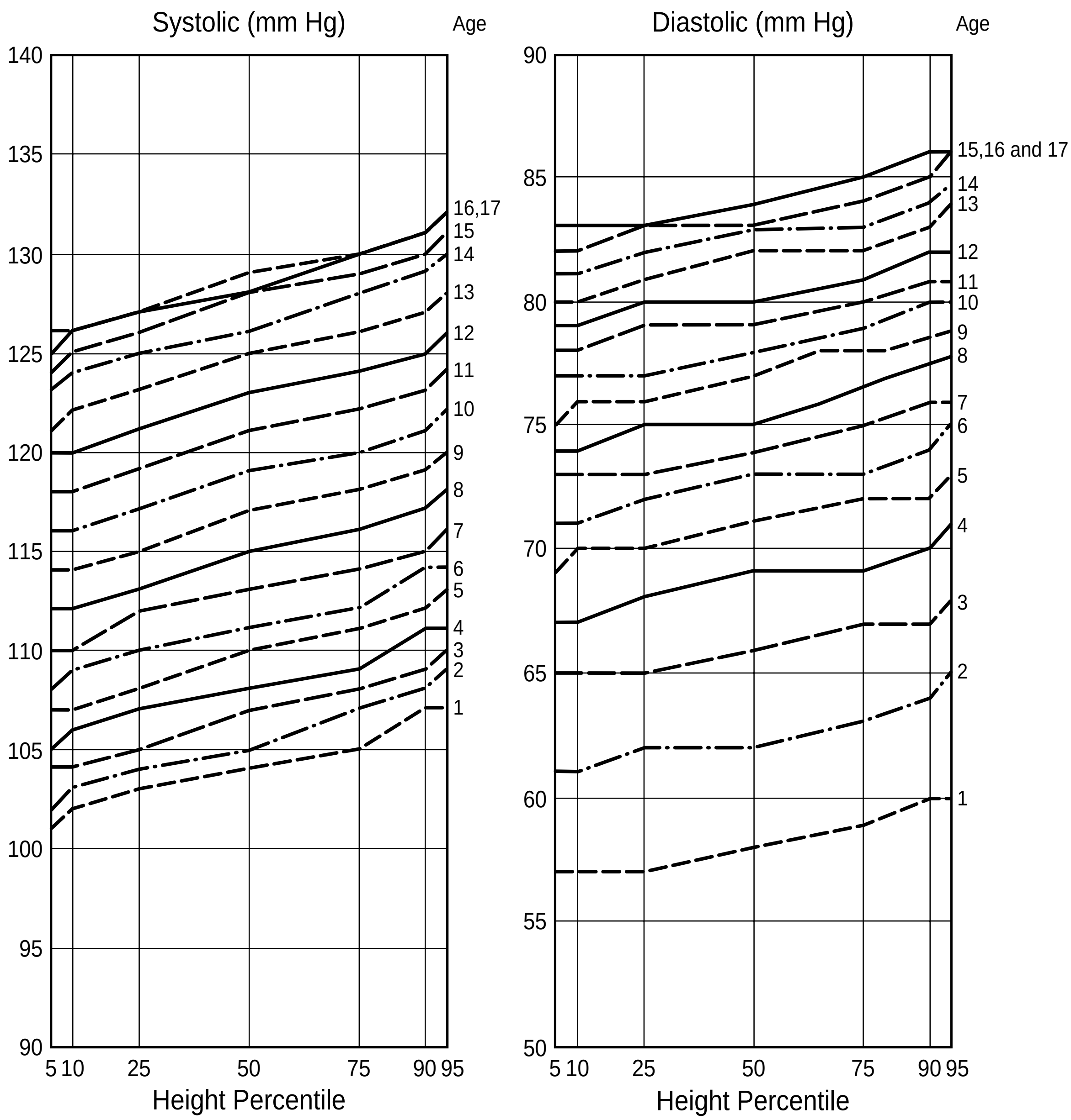
*Note that hypertension is diagnosed after three consecutive BP readings above the 95th percentile on three separate occasions.

## 90th Percentile of Systolic and Diastolic Blood Pressure by Height and Age, Girls

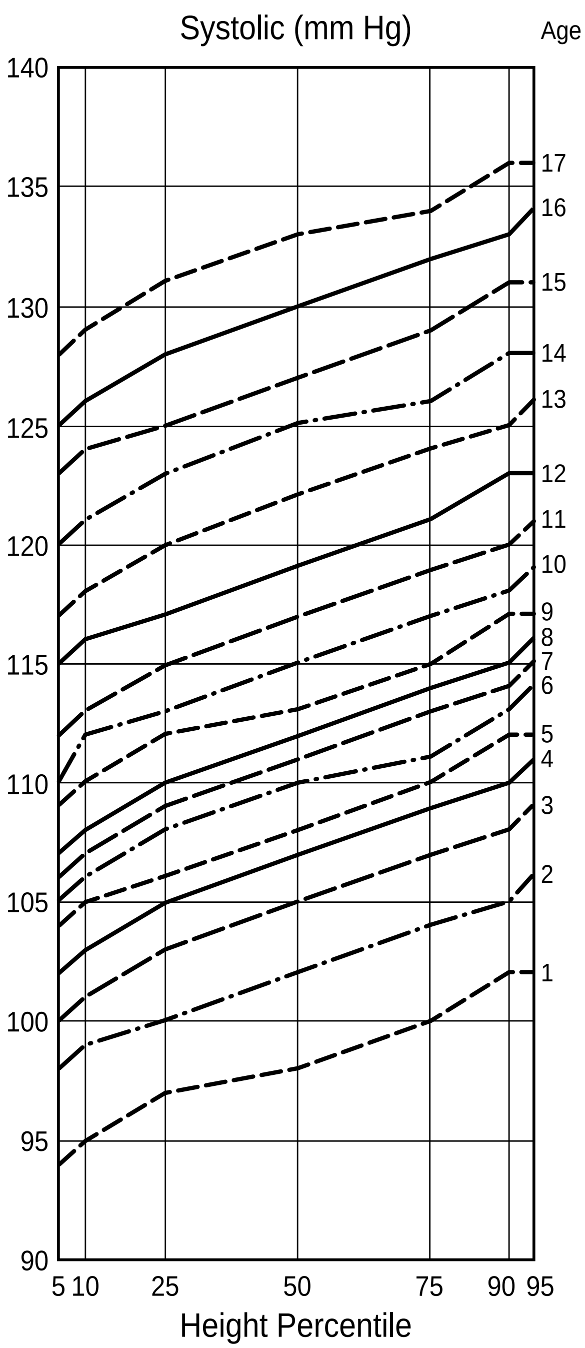


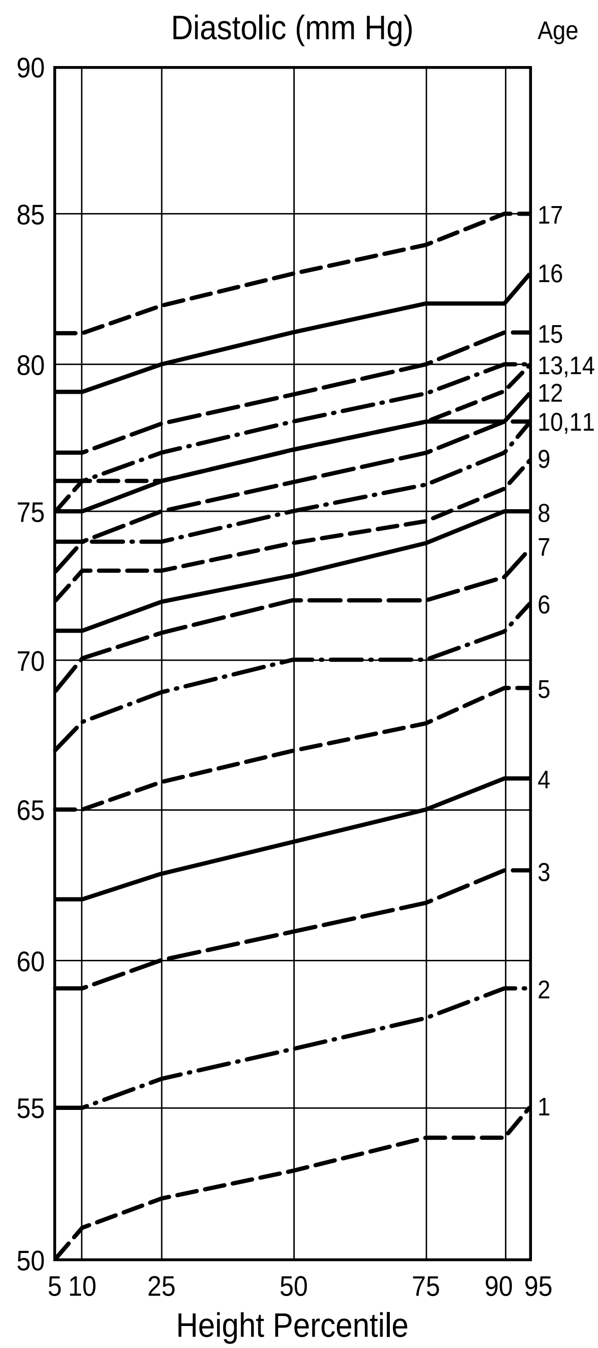



# 95th Percentile of Systolic and Diastolic Blood Pressure by Height and Age, Girls



# 90th Percentile of Systolic and Diastolic Blood Pressure by Height and Age, Boys



## 95TH PERCENTILE OF SYSTOLIC AND DIASTOLIC BLOOD PRESSURE BY HEIGHT AND AGE, BOYS