

IDENTIFYING AND EVALUATING THE METABOLIC SYNDROME IN CHILDREN AND ADOLESCENTS

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The prevalence of the metabolic syndrome phenotype in children and adolescents has increased over the last decade in parallel with sharp increases in childhood overweight and obesity. Insulin resistance, blood pressure elevation, glucose intolerance, and dyslipidemia all increase with increasing body mass index (BMI). These relationships between elements of the metabolic syndrome and excess adiposity are apparent even in children as young as 2–5 years of age. Among obese 12- to 19-year-olds, 25% have elevated blood pressure and more than 30% have at least three elements of the metabolic syndrome. Height, weight, BMI and blood pressure are simple, noninvasive measures routinely obtained during periodic visits to primary care providers. In order to identify children and adolescents with features of metabolic syndrome who may require further evaluation or treatment, primary care providers should evaluate these simple measures relative to age- and sex-specific norms. This review focuses on methods for assessing BMI and blood pressure in routine clinical practice and on recommendations for further clinical evaluation and interventions of children and adolescents with abnormalities. (*Ethn Dis.* 2007;17(Supp 4):S4-1–S4-6)

Key Words: Obesity, Body Mass Index, Blood Pressure, Child, Adolescent, Hypertension, Metabolic Syndrome, Insulin Resistance, Type 2 Diabetes

INTRODUCTION

During the 1990s, the overall prevalence of the metabolic syndrome phenotype in 12- to 19-year-olds increased from 4.2% (NHANES III, 1988–1992) to 6.4% (NHANES 1999–2000). Though non-Hispanic Black youth consistently had a lower prevalence than non-Hispanic White or Mexican-American youth, the greatest increase in metabolic syndrome prevalence occurred among non-Hispanic Black youth. In this group, the frequency more than doubled, rising from 2.0 to 5.1%. Rates in Mexican-American and non-Hispanic White youth rose respectively from 5.6 to 8.5% and from 4.8 to 7.2%. Among overweight adolescents (those with a body mass index (BMI) $\geq 95^{\text{th}}$ percentile for age and sex) in the NHANES 1999–2000 sample, 25.6% had elevated blood pressure (defined as a value $\geq 90^{\text{th}}$ percentile for sex, age and height) and 32.8% had at least three elements of the metabolic syndrome.¹ With the apparently relentless increase in the prevalence and extent of overweight in youth comes a need to identify those children at greatest risk and to initiate interventions to treat obesity-related comorbidities to prevent future disease and disability. This review focuses on assessment of body mass index and blood pressure in children and adolescents in routine clinical practice and on recommendations for further clinical evaluation and interventions in those with abnormalities.

EXTENT OF OVERWEIGHT AND FEATURES OF THE METABOLIC SYNDROME

Surveillance reports describe the prevalence of degrees of adiposity in

children and adolescents by placing them in one of four BMI categories, underweight, normal weight, at risk of overweight, and overweight, corresponding to BMI $< 5^{\text{th}}$ percentile, BMI $\geq 5^{\text{th}}$ and $< 85^{\text{th}}$ percentile, BMI $\geq 85^{\text{th}}$ and $< 95^{\text{th}}$ percentile, and BMI $\geq 95^{\text{th}}$ percentile, respectively. Some authors prefer the term overweight for children and adolescents with BMI $\geq 85^{\text{th}}$ and $< 95^{\text{th}}$ percentile and obese for those with BMI $\geq 95^{\text{th}}$ percentile. The age- and sex-specific 95th percentile obtained from populations sampled before 1994 is the threshold for classifying children as obese. This leads to the potentially confusing observation that 17% of children surveyed in 2003–2004 have a BMI above the 95th percentile.² This reflects an overall rightward shift in the BMI distribution curve and is consistent with an approach that considers the degree to which an individual exceeds a desirable or healthy body weight to identify children at greatest risk of obesity-related comorbidities. Therefore, some authors have further characterized youth with BMI $\geq 95^{\text{th}}$ percentile as moderately or severely obese (Table 1).

From 2000 to 2004, obesity among 2- to 19-year-olds increased from 14% to 17% overall. In 2- to 5-year-olds, the rate rose from 10% to 14%. Within this age group, non-Hispanic Black and Mexican-American children were most severely affected with rates in 2003–2004 of 13% and 19%, respectively, compared to and prevalence of 11.5% in Whites.² Poor children, 2 to 4 years of age, participating in the Special Supplemental Nutrition Program for Women, Infants, and Children (WIC) between 1989 and 2004 had similar obesity rates.^{3,4} In the New York State WIC Program, obesity prevalence increased

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Table 1. Classification of BMI in adults and children ^{2,7,11}

Adults	BMI kg/m ²	Children 2 – 18 yrs	BMI Percentile	BMI z score
Underweight	<18.5	Underweight	<5 th	<-1.6
Normal	18.5–24.9	Normal	≥5 th , <85 th	≥-1.6, <1.0
Overweight	25.0–29.9	Overweight*	≥85 th , <95 th	≥1.0, <1.6
Obesity Class I	30.0–34.9	Obese†	≥95 th	≥1.6, <2.0
Obesity Class II	35.0–39.9	Moderately Obese	≥98 th	≥2.0, <2.5
Obesity Class III	≥40.0	Severely Obese	>99 th	≥2.5

* At Risk for Overweight.

† Overweight.

0.28 [±0.05,SE] percentage points annually between 1989 and 2003. Furthermore, the distribution of BMI levels shifted toward higher values for all children; among 3- and 4-year-olds, the heaviest children examined in 2003 were heavier than the heaviest children assessed in 1989.⁴ Similarly, data from recent NHANES surveys of 2- to 19-year-olds and for youth (13- to 20-year-olds) and young adults (19- to 26-year-olds) participating in the National Longitudinal Study of Adolescent Health showed substantial rightward shifts in the BMI distribution compared to NHANES I (1971–1974).^{5,6}

Components of the metabolic syndrome, including hypertension, glucose intolerance, and dyslipidemia, are directly associated with increasing BMI in youth, as they are in adults. The proportion of adolescents (12 to 19 years of age) with three or more components of metabolic syndrome is 0.1% among those of normal weight, and 7.9 and 32.8% in overweight and obese adolescents respectively.¹ Among children and adolescents evaluated in a weight management clinic, 39% of the moderately obese and 50% of the severely obese met the criteria for metabolic syndrome.⁷ Impaired glucose tolerance (IGT) occurs more commonly in severely obese children than in those who are moderately obese and persistent weight gain is associated with further deterioration in glucose tolerance. Among 117 obese youth followed for an average of two years, 33 were found to have IGT at baseline. Of these, 8

(24%) developed type 2 diabetes, 10 (30%) had IGT, and 15 (45%) reverted to normal glucose tolerance. Those who developed type 2 diabetes gained more weight and had significantly higher

BMI z scores than those who reverted to normal glucose tolerance (2.76 [SD ± 0.21] vs 2.41 [SD ± 0.35], *P*<.003).⁸

Blood pressure and atherogenic dyslipidemia also increase with increasing adiposity. A review of electronic medical records of routine well-child examinations in more than 18,000 pediatric patients in a large, multisite, primary care pediatric clinic, revealed a significant association between higher BMI and higher blood pressure in all age groups including children 2 to 5 years of age (Figure 1). Overall, 7.2% had elevated blood pressure (BP ≥95th percentile for age, sex, and

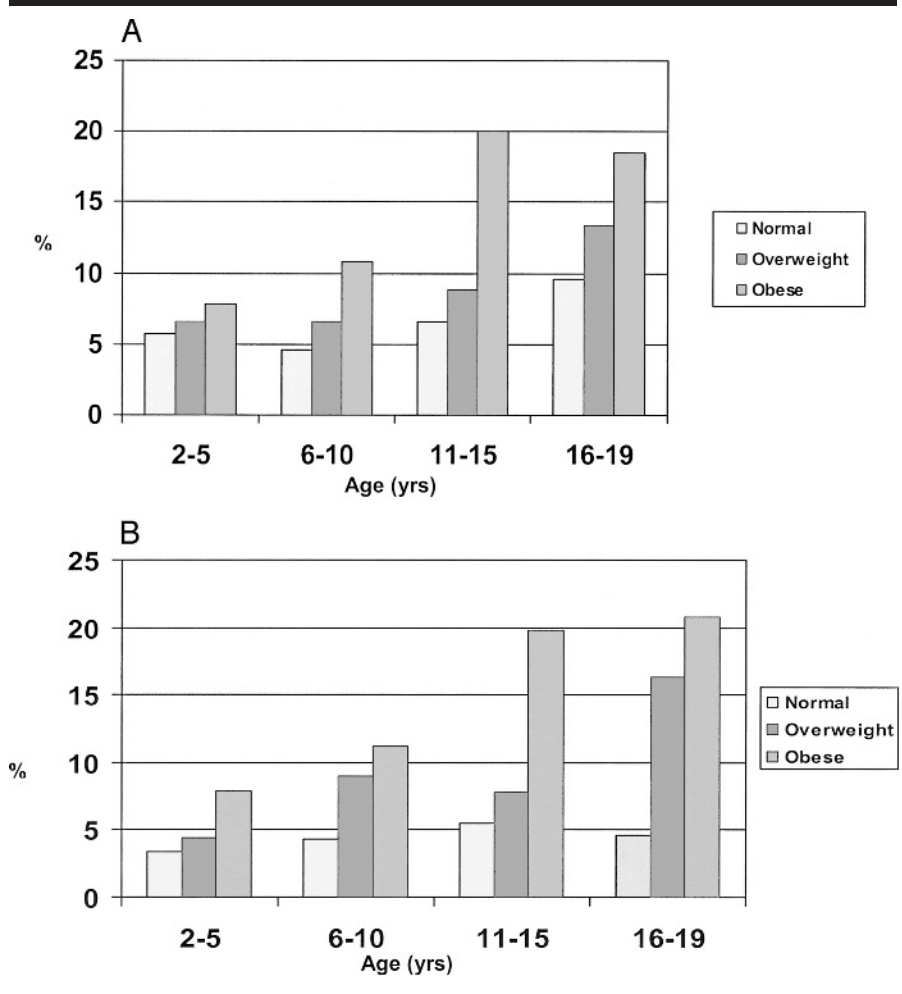


Fig 1a. Prevalence (%) of systolic and/or diastolic blood pressure ≥95th percentile in males by age group and BMI category.⁹ Fig 1b. Prevalence (%) of systolic and/or diastolic blood pressure ≥95th percentile in females by age group and BMI category.⁹

height). More than 15% of obese older children and adolescents had blood pressures requiring further evaluation.⁹ Among children and adolescents evaluated in a weight management clinic, prehypertension or hypertension occurred in 25% of those who were moderately obese and 43% of those who were severely obese.¹⁰ Among adolescents, 12 to 19 years of age, examined during 1999–2000, low HDL cholesterol was present in 19%, 29%, and 39% of youth in the normal, overweight, and obese BMI categories, respectively.¹

ASSESSING BMI IN CHILDREN

BMI (calculated as wt [kg]/ht [m]^2) is an acceptable clinical screening tool for identifying children with excess adiposity who may be at risk for insulin resistance and thus for cardiovascular disease and the development of glucose intolerance and type 2 diabetes. In adults, overweight and obesity are classified based on BMI using discrete, age-independent cut offs that are the same for males and females.¹¹ In children, however, both the nomenclature and the threshold values are different from those in adults (Table 1). The interpretation of BMI in children and adolescents is slightly more complex than in adults as the threshold values are based on comparisons to age- and sex-specific normative data. A complete assessment of the child's BMI includes obtaining accurate height (without shoes) using a wall-mounted stadiometer and weight using a calibrated scale with the child wearing light clothing. BMI can then be calculated or determined using standard charts [http://www.cdc.gov/nccdphp/dnpa/growthcharts/bmi_tools.htm]. Height, weight, and BMI should be plotted on a sex-specific growth chart kept with the child's medical records so that the individual values and a longitudinal

record of the child's growth can be examined and evaluated. [<http://www.cdc.gov/growthcharts/>].¹² The degree of overweight, the extent to which the child's BMI deviates from the 50th percentile, can be estimated once the value is plotted on the appropriate growth chart.^a Plotted values should be assessed to determine: 1) whether the child is following consistently along a particular percentile line; 2) how much plotted values deviate from the child's prior pattern of growth; and 3) where these values fall relative to the norms in the chart.^b

ASSESSING BLOOD PRESSURE IN CHILDREN

The National Heart Lung and Blood Institute (NHLBI) provides guidelines for the measurement, evaluation, and treatment of high blood pressure in youth.¹³ As blood pressure varies with age, sex, and height, each of these factors must be considered in determining whether a child has a normal or elevated blood pressure. Complete tables have been published and free software for use with personal electronic devices is available [http://hp2010.nhlbihin.net/nhlbi_peds/hbppedpa.htm]. Figure 2 illustrates the importance of using these tables to evaluate a child's measured blood pressure.¹⁴ The NHLBI guidelines include a management algorithm describing further action based on routine assessments of height, weight, BMI, and blood pressure.¹³

a. BMI z-scores are used for research and for more precise quantification of the degree of overweight. Tables are available at www.cdc.gov/nchs/data/nhanes/growthcharts/zscore/zbmiage.txt.

b. An interactive training manual on the use of CDC growth charts is available at www.cdc.gov/nccdphp/dnpa/growthcharts/traingon/modules/index.htm.

ASSESSMENTS FOR OTHER OBESITY-RELATED COMORBIDITIES

The American Academy of Pediatrics and American Diabetes Association consensus panel¹⁵ recommends that health-care providers consider the following criteria and guidelines for the early identification of type 2 diabetes in children:

1. Criteria: overweight (BMI >85th percentile) and any two of the following risk factors: family history of type 2 diabetes in 1st or 2nd degree relative; race/ethnicity American Indian, African-American, Hispanic/Latino, Asian American, or Pacific Islander; and/or signs of insulin resistance or conditions associated with insulin resistance (acanthosis nigricans, hypertension, dyslipidemia, polycystic ovarian syndrome)
2. Age to begin testing: 10 years or at onset of puberty
3. Testing frequency: every 2 years
4. Test: fasting plasma glucose

Although inexpensive and convenient, fasting plasma glucose is an insensitive measure of glucose intolerance. In obese adults¹⁶ and children,¹⁷ fasting plasma glucose is less sensitive than an oral glucose tolerance test (OGTT) for detecting IGT or diabetes. The frequency of IGT is high in severely obese children and adolescents who are at high risk of developing type 2 diabetes.^{7,8} Therefore, some experts recommend an OGTT to improve detection of IGT and undiagnosed type 2 diabetes to facilitate early initiation of interventions that can prevent development of overt disease in the former and avert complications in the latter.¹⁸ Fasting lipid profiles should be obtained in all overweight children and assessed as follows: for children and adolescents between 2 and 19 years of age, acceptable levels of total cholesterol and LDL cholesterol are <170 mg/dL and

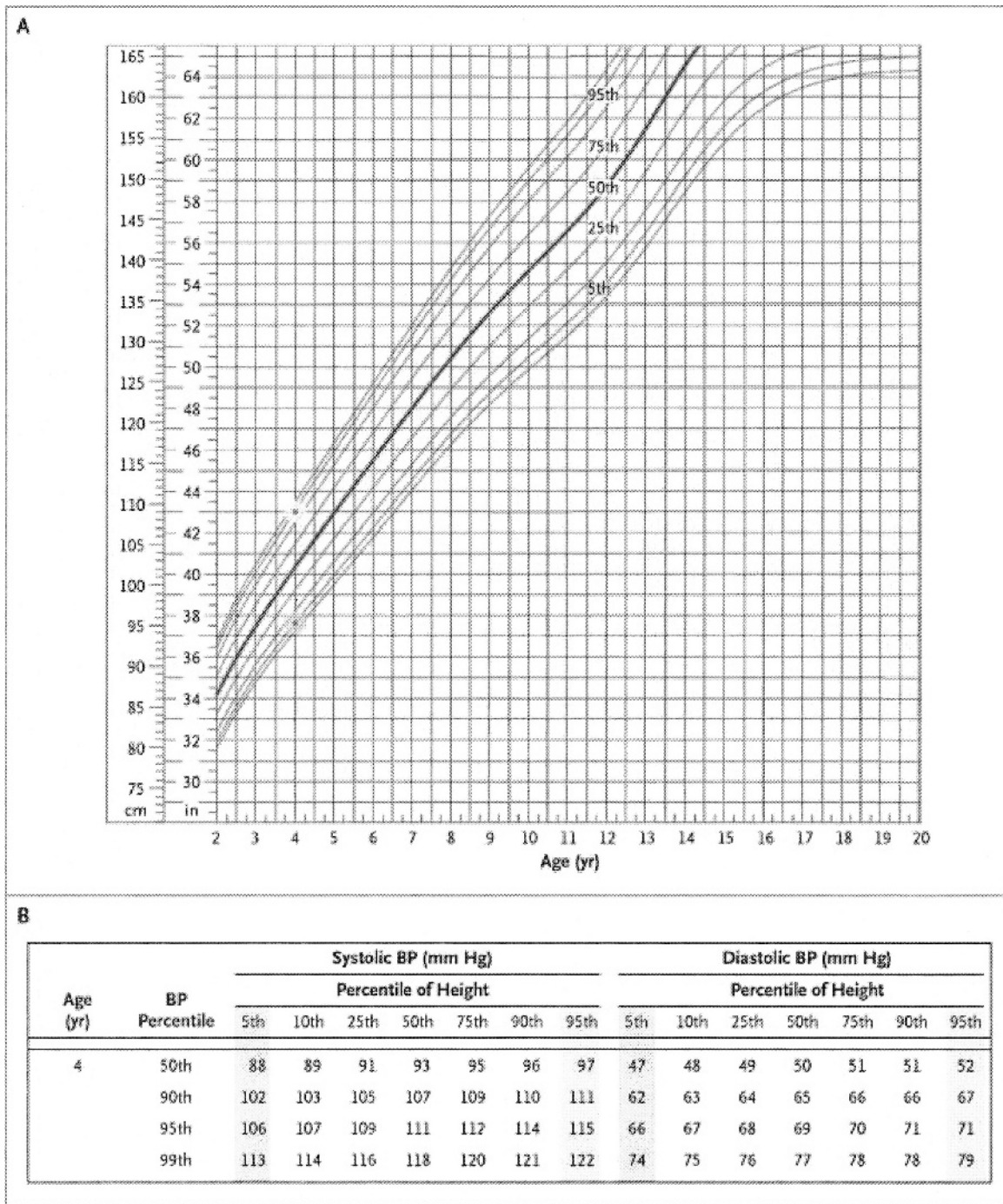


Fig 2. Determining whether a child's blood pressure is normal. The child's height and blood pressure (BP) are measured and the growth charts and tables from the Task Force report are used. In this example, one four-year-old boy is 43.0 in. (109.2 cm) tall (95th percentile, upper dot). As shown in the right columns of the tables for systolic and diastolic BP, for this boy, a blood pressure of 106/66 mm Hg would be in the normal range — between the 50th and 90th percentiles. In contrast, another four-year-old boy is 37.5 in. (95.2 cm) tall (5th percentile, lower dot and left columns in the tables); for him, a blood pressure of 106/66 mm Hg would be at the 95th percentile, which would be categorized as hypertensive.¹⁴ Reprinted with permission. Copyright©2004. Massachusetts Medical Society. All rights reserved.

<110 mg/dL, respectively; borderline levels, 170 to 199 mg/dL and 110 to 129 mg/dL; and high levels, ≥ 200 mg/dL and ≥ 130 mg/dL. An acceptable HDL cholesterol is ≥ 40 mg/dL.¹⁹⁻²¹

Since persistent weight gain with increasing BMI z score is a risk factor for the development of type 2 diabetes and other features of the metabolic syndrome, children identified as having an elevated BMI should be followed at frequent intervals with repeat measurements of height, weight, BMI, blood pressure, and fasting lipid profile, as well as an assessment of glucose tolerance using a fasting glucose and/or an oral glucose tolerance test.¹⁸

TREATMENT AND PREVENTION OF THE METABOLIC SYNDROME AND ITS SEQUELAE IN YOUTH

Once identified, children with obesity-related comorbidities including hypertension, dyslipidemia and type 2 diabetes require pharmacologic treatments that are beyond the scope of this review to describe. The mainstay of all therapeutic approaches to obesity prevention and to treatment of obesity-related comorbidities is therapeutic lifestyle change. Altering diet and physical activity to promote weight loss and improve fitness can improve insulin sensitivity, decrease blood pressure, improve lipid profiles, and decrease the risk of type 2 diabetes.²²⁻²⁶ Clinical trials have demonstrated the feasibility of achieving these goals in controlled situations.²⁷ Translating these findings into practical, cost-effective clinical and public health interventions is the challenge that we face. New clinical care models must be devised and tested. These may require multidisciplinary approaches and collaboration between clinicians caring for family members throughout the life cycle. Primary care physicians looking

after adults and children may need to collaborate so that behavioral interventions can incorporate all members of affected families thereby increasing the likelihood of successful lifestyle modifications.²⁸

Outside the medical care setting, public health practitioners and policy-makers must address economic and environmental barriers that patients face when they try to follow healthcare providers' recommendations for healthy diets and increased physical activity. Public health practitioners should develop local, population-based surveillance methods to track changes in prevalence and distribution of obesity that can inform program development and resource allocation and permit evaluation of interventions. For youth, these data will become available as BMI assessment becomes part of health screening programs in schools.^{29,30}

Fifty years ago, we learned that atherosclerotic changes begin in the first and second decades of life and we began to investigate the pediatric antecedents of cardiovascular disease in adulthood.³¹ Today, we are no longer talking about pediatric antecedents of adult disease. Hypertension and left ventricular hypertrophy with severe cardiovascular deconditioning occur in severely overweight youth^{10,32} and type 2 diabetes now accounts for a substantial proportion of newly diagnosed diabetes in children and adolescents.³³ Children have diseases formerly seen almost exclusively in adults. Primary care providers can identify youth at greatest risk for cardiovascular and metabolic disorders using simple, noninvasive, routine measures. Height, weight, BMI, and blood pressure, evaluated in relation to age- and sex-specific norms, can prompt further assessments and interventions.

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