

Prevalence of Risk Factors for Metabolic Syndrome in Adolescents

National Health and Nutrition Examination Survey (NHANES), 2001-2006

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Objective: To investigate the prevalence of distinct combinations of components of the metabolic syndrome among adolescents.

Design: A complex, multistage, stratified geographic area design for collecting representative data from the non-institutionalized US population.

Setting: The NHANES, an ongoing surveillance of the nation's health conducted by the Centers for Disease Control and Prevention.

Participants: Two thousand four hundred fifty-six Hispanic, white, and black adolescents aged 12 to 19 years observed in the 2001-2002, 2003-2004, and 2005-2006 NHANES data releases.

Main Outcome Measures: Metabolic syndrome was defined as having 3 or more disorders in the following measurements: waist circumference, blood pressure, fasting triglycerides, high-density lipoprotein serum cholesterol, and glucose.

Results: About half of the participants had at least 1 disordered measurement, with an overall metabolic syndrome prevalence of 8.6% (95% confidence interval, 6.5%-10.6%). Prevalence was higher in males (10.8%) than females (6.1%), and in Hispanic (11.2%) and white (8.9%) individuals than in black individuals (4.0%). In black females, there was a high prevalence of a large waist circumference (23.3%), but no component of metabolic syndrome dominated its diagnosis in black adolescents of either sex. A large waist circumference and high fasting triglyceride and low high-density lipoprotein serum cholesterol concentrations were salient factors in Hispanic and white adolescents of both sexes; high glucose concentrations were prominent among Hispanic and white males.

Conclusion: The low prevalence of metabolic syndrome in black adolescents, in parallel with uniformly low prevalence of all 5 risk factors among those with metabolic syndrome, portend ethnic disparities in the time table for early onset of cardiometabolic disorders.

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PREVALENCE TRENDS FOR OBESITY, type 2 diabetes mellitus, and other obesity-related disorders in the United States and many other countries are disturbing.¹ Obesity's role in the series of concurrent cardiometabolic changes that often precede more serious cardiovascular disorders is being recognized with increasing urgency. Obesity, especially abdominal and central adiposity, as measured herein by waist circumference (WC), is often linked to insulin resistance and other diagnostic correlates of metabolic syndrome: elevated triglyceride concentrations, low high-density lipoprotein cholesterol (HDL-C) concentrations, elevated blood pressure (BP), and elevated fasting glucose concentrations. These 5 factors appear to be closely allied with increased risk of developing type 2 diabetes mellitus and cardiovascular diseases. When a person is found to have any

3 of the 5 component risk factors, concern grows, warranting a diagnosis of metabolic syndrome (MetS).²⁻⁵ Although conflicting opinions have been reported concerning the diagnostic value of MetS,^{6,7} the concept provides a readily measured set of criteria that could lead to more intense clinical focus on the underlying causes and thereby reinforces the utility of lifestyle changes and perhaps additional clinical interventions.⁸ Our argument is that several cardiometabolic risk factors within 1 individual, even at sub-clinical levels that would trigger traditional treatment options, predict future progression to overt chronic disease. Thus, MetS may be a sentinel marker for highlighting the need for more aggressive intervention efforts beyond the traditional treatment options for overweight and obese youths.

According to recent estimates, MetS affects, depending on the definition, 21% to

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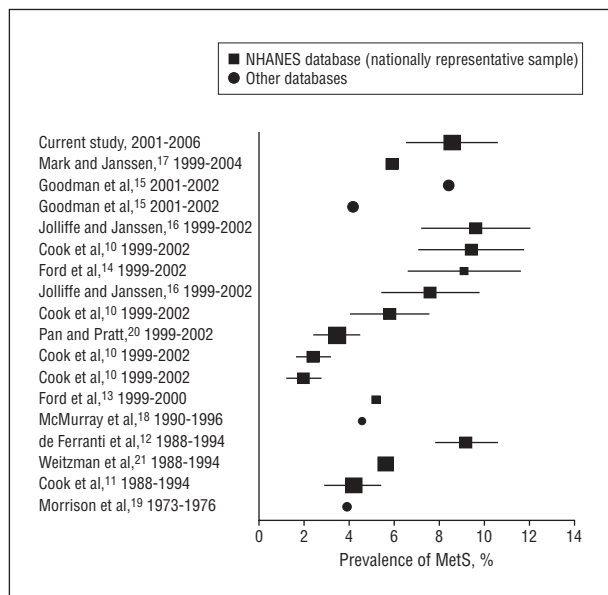


Figure 1. Prevalence (and 95% confidence intervals) of the metabolic syndrome (MetS) in US adolescents in various studies. NHANES indicates National Health and Nutrition Examination Survey.

38.9% of the US adult population overall; the prevalence in adults aged 20 to 29 years was found to be between 9.5% and 19.6%.⁹ Many authors have reported adolescent prevalence data for MetS using numerous diagnostic criteria.¹⁰⁻²¹ Although agreement is lacking on criteria for diagnosing MetS in adolescents, the diagnostic criteria typically involve the same 5 risk factors identified in adults, with modifications to the cut-off values for defining disorders in specific components. The cut-off values give rise to conflicting definitions and prevalences of MetS in adolescents. Cook et al^{10,11} investigated 4 previously reported definitions of adolescent MetS that included application of adult cutoffs in addition to 3 sets of modified cutoffs. These definitions led to disparate estimates, ranging from 2.0% to 9.4%, for the prevalence of adolescent MetS. As shown in **Figure 1**, other studies have also reported instabilities in prevalence estimates as different diagnostic criteria are invoked.²²

The cardiovascular risk related to MetS appears to travel from childhood to young adulthood.²³⁻²⁵ A better understanding of the determinants of MetS during adolescence might provide insights into preventive interventions for improving health outcomes during adolescence and reducing the incidence of cardiovascular disease in adults. The aim of this study was to investigate the prevalence of different combinations of the 5 component risk factors for MetS in search of the most influential diagnostic determinants among adolescents aged 12 to 19 years in the United States. A second objective was to determine differences in overall prevalence of MetS in 6 sex-ethnicity subgroups.

METHODS

STUDY SAMPLE

The study sample was representative of the US adolescent population aged 12 to 19 years. The data were obtained as part of

the National Health and Nutrition Examination Survey (NHANES). The NHANES is an ongoing sample survey that uses a complex, multistage, stratified geographic area design for collecting nationally representative data from the noninstitutionalized US population. Newly collected data are released in 2-year increments. The survey uses trained personnel to conduct home interviews for collecting reliable data that include demographic, socioeconomic, dietary, and health-related information. Medical personnel obtain medical, dental, and physiological measurements as well as results from laboratory tests. A detailed description of these assessments has been published previously.²⁶

The study sample is composed of data pooled from 3 waves of NHANES data that were collected during 2001-2006. Data were retained for analysis of 2859 adolescents who had complete data for all 5 component variables used to diagnose MetS. In addition, adolescents were excluded if their ethnicity was not Hispanic, white, or black (n=130); they did not have a value for the sample weight (n=204); they were currently pregnant (n=59); or they reported being previously diagnosed as having diabetes or were currently taking medication classified as a blood-glucose regulator, such as insulin (n=10). Thus, 403 adolescents did not meet the inclusion criteria, bringing the final study sample size to 2456 males and females aged 12 to 19 years of Hispanic, white, or black ethnicity.

DATA FOR DIAGNOSING MetS

Participants were required to come to the mobile examination clinic before 9 AM after fasting for at least 9 hours. If they arrived having fasted for less than 8.5 hours, they were assigned a sampling weight equal to 0 as part of the NHANES protocol. This reduced the sample size for our analysis by 204 participants. Waist circumference was measured to the nearest 0.1 cm at minimal respiration at the end of normal expiration with a steel measuring tape placed at the high point of the iliac crest when the participant was in a standing position. Diastolic and systolic BP measurements were obtained using replicated measurements. After resting quietly in a sitting position for 5 minutes and determination of the maximum inflation level, up to 4 consecutive BP readings were obtained with a mercury manometer. Mean values of replicate systolic and diastolic measurements provided estimates of current BP levels. Glucose concentration was determined by a hexokinase method, triglyceride concentration was measured enzymatically using a series of coupled reactions, and HDL-C concentration was measured directly.²⁶ Unfortunately, the Centers for Disease Control and Prevention have issued an advisory regarding making inferences from HDL-C data in 2003-2006 NHANES releases, warning that specific measurements may be overestimated by a mean of 3 mg/dL (to convert to millimoles per liter, multiply by 0.0259).

DIAGNOSTIC CRITERIA FOR MetS

In this communication, adolescents were classified as having MetS if they had any 3 of the following: a WC in the 90th percentile for their age and sex according to 1988-1994 NHANES III data²⁷; either systolic or diastolic BP in the 90th percentile for their height, age, and sex as previously specified²⁸; triglyceride concentration of 110 mg/dL or greater (to convert to millimoles per liter, multiply by 0.0113); HDL-C concentration of 40 mg/dL or less; and glucose concentration of 100 mg/dL or greater (to convert to millimoles per liter, multiply by 0.0555).²⁹ These criteria are the same as those used by Ford et al.¹⁴

STATISTICAL ANALYSIS

All analyses were performed using procedures for sample survey data that are readily available in SAS, version 9.1 (SAS Institute, Cary, North Carolina). Prevalence data were reported for MetS and disorders (elevated or low measurements) in the 5 component variables used to classify adolescents with respect to their MetS status. Estimates of the number of adolescents in various subpopulations were also reported. Prevalence data expressed as a percentage with 95% confidence intervals (CIs), weighted to be nationally representative, were compiled for the overall sample, males and females, ethnicity groups, and within sex-ethnicity subgroups. Ethnicity was categorized as Hispanic, white, or black. Overall and sex-specific time trends were evaluated during the periods 2001-2002, 2003-2004, and 2005-2006.

RESULTS

SAMPLE DESCRIPTION

There were 2456 adolescents in the study sample, which represented a population of almost 29 million adolescents (**Table 1**). Slightly more than half of the weighted sample were males (51.6%); most were white (68%); 16.9% were Hispanic; and 15.1% were black. There were 11.2% to 13.1% in each age group (12-19 years).

PREVALENCE OF MetS

An estimated 8.6% of adolescents in the study had MetS (95% CI, 6.5%-10.6%), which extrapolates to almost 2.5 million adolescents in the general population (**Table 2**). The prevalence of MetS was highest in Hispanic males (odds ratio [OR], 3.69; 95% CI, 2.05-6.65), followed by white males (OR, 3.33; 95% CI, 1.61-6.88), Hispanic females (OR, 2.58; 95% CI, 1.20-5.54), white females (OR, 1.52; 95% CI, 0.75-3.09), and black females (OR, 1.09; 95% CI, 0.47-2.56) (white females were the reference). Prevalence estimates throughout the 2-year period did not reveal clear trends.

PREVALENCE OF INDIVIDUAL RISK FACTORS

Overall, 19.1% (95% CI, 16.2%-22.0%) of the adolescents had excess central adiposity (large WC). In black adolescents, large WCs were more prevalent in females than males (23.3% vs 11.9%). Among males, large WCs were more prevalent in Hispanic (21.5%) and white (18.4%) adolescents compared with black adolescents (11.9%). Almost 2 million adolescents (6.9%; 95% CI, 5.1%-8.6%) were calculated to have elevated BP. Among males, the prevalence of high BP was lower in Hispanic adolescents (4.9%) than in black adolescents (8.3%), whereas among females, prevalence was lowest for white adolescents (6.4%). Overall, a high triglyceride concentration was the most prevalent disorder (25.6%). The prevalence was significantly greater in Hispanic (26.1%) and white (28.9%) adolescents than in black adolescents (9.8%). Ethnicity prevalence differences in males were similar to those in females, corresponding to overall disparities. About nineteen percent

Table 1. Characteristics of Study Sample and Estimated US Adolescent Population Aged 12 to 19 Years

Characteristic	No. of Adolescents		%
	Study Sample	Population Estimate, ×1000	
Total	2456	28 729	
Sex			
M	1288	14 810	51.6
F	1168	13 918	48.4
Ethnicity			
Hispanic	899	4868	16.9
White	715	19 528	68.0
Black	842	4333	15.1
Age, y			
12	310	3500	12.2
13	325	3762	13.1
14	292	3449	12.0
15	297	3716	12.9
16	318	3742	13.0
17	314	3655	12.7
18	315	3694	12.9
19	285	3209	11.2

(19.3%) of sampled adolescents had a low HDL-C concentration; prevalence was significantly greater among males (24.6%) than in females (13.7%) and in Hispanic (19.9%) and white (21.1%) adolescents than in black adolescents (10.6%). Ethnicity prevalence differences in males were similar to overall disparities, whereas in females, the prevalence was lower but ethnic disparities were within the range of sampling variability. We estimated that more than 4 million adolescents (14.0%) have an elevated glucose concentration. Prevalence was greater among males than females (19.8% vs 7.9%) and in Hispanic (15.2%) and white (14.8%) compared with black (9.4%) adolescents. Ethnic differences within sex were similar to corresponding overall disparities but was significant only in Hispanic compared with black males (22.4% vs 13.5%).

PREVALENCE OF RISK FACTOR COMBINATIONS

About half of the adolescents had disorders for 1 or more components of MetS, 42% had disorders for 1 or 2 components, and 8.6% had 3 or more disorders. More males than females had at least 1 disorder (55.5% vs 45.5%); 3.2% of males compared with 2.0% of females had 4 or more disorders. Fewer adolescents were found to have 3 or more disorders in 2003-2004, in congruence with the findings summarized in **Table 3**. This appears to be a result of fewer males having 3 disordered components and more males having 2 (pre-MetS) components in addition to fewer females having 3 and more having 0 disordered components in 2003-2004.

Prevalence estimates for distinct combinations of diagnostic components for MetS are presented in Table 3. The prevalence of only 1 disordered component among males was highest for high triglyceride concentration (8.8%) followed by high glucose concentration (8.3%). In females, it was highest for triglyceride concentration (9.7%) followed by high WC (8.1%). The prevalence of

Table 2. Population Prevalence of Metabolic Syndrome and Its Risk Factors in US Adolescents Aged 12 to 19 Years^a

Characteristic	% (95% Confidence Interval)		
	Overall	Males	Females
Metabolic syndrome, ≥ 3 of 5 criteria			
Hispanic	11.2 (8.0-14.5)	12.9 (9.3-16.6)	9.4 (4.7-14.1)
White	8.9 (6.1-11.7)	11.8 (7.3-16.4)	5.8 (3.6-7.9)
Black	4.0 (2.7-5.4)	3.9 (1.8-5.9)	4.2 (1.9-6.5)
Total	8.6 (6.5-10.6)	10.8 (7.3-14.3)	6.1 (4.6-7.7)
NHANES period			
2001-2002	9.0 (5.2-12.7)	12.5 (5.0-20.0)	5.5 (2.4-8.5)
2003-2004	6.5 (4.1-9.0)	8.6 (4.5-12.8)	4.2 (1.7-6.8)
2005-2006	10.1 (5.3-14.9)	11.5 (4.2-18.8)	8.6 (5.7-11.6)
Waist circumference, ≥ 90 th percentile			
Hispanic	22.7 (18.6-26.7)	21.5 (17.0-26.0)	23.9 (19.0-28.8)
White	18.5 (14.8-22.2)	18.4 (14.4-22.5)	18.6 (13.4-23.9)
Black	17.5 (14.6-20.4)	11.9 (9.1-14.7)	23.3 (18.8-27.8)
Total	19.1 (16.2-22.0)	18.0 (14.6-21.4)	20.2 (16.0-24.5)
Blood pressure, ≥ 90 th percentile			
Hispanic	6.9 (3.5-10.2)	4.9 (2.7-7.0)	9.0 (3.7-14.3)
White	6.3 (4.2-8.5)	6.3 (3.8-8.8)	6.4 (3.4-9.4)
Black	9.1 (7.5-10.8)	8.3 (6.0-10.5)	10.1 (7.5-12.6)
Total	6.9 (5.1-8.6)	6.3 (4.0-8.7)	7.4 (4.9-10.0)
Triglycerides, ≥ 10 mg/dL			
Hispanic	26.1 (22.0-30.1)	27.5 (23.1-31.9)	24.6 (19.1-30.1)
White	28.9 (24.7-33.2)	31.5 (24.8-38.2)	26.2 (21.3-31.0)
Black	9.8 (8.0-11.6)	10.2 (7.7-12.7)	9.4 (6.9-11.9)
Total	25.6 (22.4-28.8)	27.7 (22.8-32.5)	23.3 (19.7-27.0)
HDL-C, ≤ 40 mg/dL			
Hispanic	19.9 (16.5-23.4)	24.0 (20.0-27.9)	15.6 (9.7-21.6)
White	21.1 (18.1-24.1)	27.9 (23.3-32.4)	13.9 (10.2-17.6)
Black	10.6 (8.2-12.9)	10.6 (7.5-13.7)	10.6 (7.1-14.1)
Total	19.3 (17.1-21.6)	24.6 (21.2-28.1)	13.7 (10.7-16.6)
Fasting glucose, ≥ 100 mg/dL			
Hispanic	15.2 (11.7-18.6)	22.4 (17.6-27.2)	7.4 (5.2-9.7)
White	14.8 (11.1-18.5)	20.6 (15.3-25.8)	8.6 (5.8-11.4)
Black	9.4 (6.9-11.9)	13.5 (9.6-17.3)	5.2 (2.4-8.1)
Total	14.0 (11.4-16.6)	19.8 (16.2-23.5)	7.9 (5.8-9.9)

Abbreviations: HDL-C, high-density lipoprotein cholesterol; NHANES, National Health and Nutrition Examination Survey.

SI conversion factors: To convert fasting glucose to millimoles per liter, multiply by 0.0555; HDL-C to millimoles per liter, multiply by 0.0259; and triglycerides to millimoles per liter, multiply by 0.0113.

^aSample weights were used to calculate population estimates.

a distinct combination of 2 risk factors among males was highest for high triglyceride and HDL-C concentrations (4.9%) followed by high triglyceride and glucose concentrations (2.6%); in females, it was highest for high WC and triglyceride concentration (3.8%) followed by high triglyceride and low HDL-C concentrations (2.6%). The highest prevalence for 3 distinct components was high WC, high triglyceride concentration, and low HDL-C concentration for both males (3.7%) and females (2.1%). Among the 10.8% of males with MetS, 34.3% had disorders for WC, triglycerides, and HDL-C; in females, the comparable value was 34.4%. An estimated 2.2% of males vs 0.9% of females had simultaneous disorders for WC and triglyceride, HDL-C, and glucose concentrations; among those with MetS, this figure rises to 20.4% and 14.8% in males and females, respectively.

PREVALENCE OF INDIVIDUAL DISORDERS IN ADOLESCENTS WITH MetS

With examination of the prevalence of individual components of MetS in adolescents who have any distinct com-

bination of 3 or more components, it appears that elevated BP does not play a primary role in early onset of this syndrome (**Figure 2**). Among Hispanic and white adolescents, prevalence is prominent for disorders in WC, triglycerides, and HDL-C, which seem to be the most influential contributors to the diagnosis of MetS in both sexes, with glucose concentration having some degree of importance in males. Although black females demonstrated a moderately high prevalence of central adiposity, a leading driver of MetS was not found in black adolescents.

COMMENT

Our findings affirm others' conclusion that the prevalence of impaired biomarkers for early-onset metabolic abnormalities represents a legitimate health concern. The reported prevalence of MetS in adolescents living in the United States has varied widely from study to study (10%-21%). At least some of this variability is attributable to the use of different criteria in defining MetS in adoles-

Table 3. Patterns of Disordered Diagnostic Components for Metabolic Syndrome in US Adolescents in the NHANES, 2001-2006^a

Disordered Components ^b	Study Participants, No. (%)		
	Overall (n=2456)	Males	Females
None	1297 (49.3)	640 (44.5)	657 (54.5)
WC	163 (5.9)	55 (3.8)	108 (8.1)
BP	60 (1.8)	30 (1.8)	30 (1.8)
TG	171 (9.2)	86 (8.8)	85 (9.7)
HDL-C	123 (5.1)	77 (6.5)	46 (3.6)
GLU	150 (6.1)	110 (8.3)	40 (3.6)
WC + BP	20 (0.6)	7 (0.4)	13 (1.0)
WC + TG	63 (2.7)	23 (1.7)	40 (3.8)
WC + HDL-C	38 (1.9)	18 (2.4)	20 (1.4)
WC + GLU	24 (0.7)	15 (0.9)	9 (0.5)
BP + TG	11 (0.6)	4 (0.1)	7 (1.2)
BP + HDL-C	10 (0.7)	5 (0.7)	5 (0.7)
BP + GLU	6 (0.4)	4 (0.5)	2 (0.3)
TG + HDL-C	67 (3.8)	44 (4.9)	23 (2.6)
TG + GLU	36 (1.7)	27 (2.6)	9 (0.8)
HDL-C + GLU	28 (0.8)	25 (1.4)	3 (0.2)
WC + BP + TG	8 (0.3)	2 (0.3)	6 (0.4)
WC + BP + HDL-C	9 (0.3)	4 (0.4)	5 (0.3)
WC + BP + GLU	5 (0.2)	1 (<0.1)	4 (0.4)
WC + TG + HDL-C	65 (2.9)	38 (3.7)	27 (2.1)
WC + TG + GLU	16 (0.5)	10 (0.7)	6 (0.2)
WC + HDL-C + GLU	6 (0.3)	6 (0.6)	0
BP + TG + HDL-C	5 (0.3)	3 (0.3)	2 (0.3)
BP + TG + GLU	5 (0.4)	5 (0.7)	0
BP + HDL-C + GLU	2 (0.1)	1 (0.1)	1 (<0.1)
TG + HDL-C + GLU	13 (0.6)	9 (0.7)	4 (0.5)
WC + BP + TG + HDL-C	5 (0.3)	1 (<0.1)	4 (0.6)
WC + BP + TG + GLU	5 (0.2)	3 (0.3)	2 (<0.1)
WC + BP + HDL-C + GLU	3 (0.1)	2 (0.1)	1 (0.1)
WC + TG + HDL-C + GLU	34 (1.6)	27 (2.2)	7 (0.9)
BP + WC + TG + HDL-C + GLU	8 (0.5)	6 (0.7)	2 (0.3)

Abbreviations: BP, blood pressure; GLU, glucose; HDL-C, high-density lipoprotein cholesterol; NHANES, National Health and Nutrition Examination Survey; TG, triglyceride; WC, waist circumference.

^aSample weights were used to calculate population estimates.

^bWaist circumference in the 90th percentile; BP in the 90th percentile; TG, 110 mg/dL or greater (to convert to millimoles per liter, multiply by 0.0113); HDL-C, 40 mg/dL or less (to convert to millimoles per liter, multiply by 0.0259); and GLU, 100 mg/dL or greater (to convert to millimoles per liter, multiply by 0.0555).

cents; certainly more consistency will be achieved once the definition stabilizes. With use of the latest available NHANES data (2001-2006), our estimated overall prevalence of 8.6% is in the upper tertile of estimates from other studies (Figure 1). Overall prevalence was highest among Hispanic adolescents (11.2%), followed by white (8.9%) and black (4.0%) adolescents. In white adolescents, prevalence was significantly higher in males than females. There are some indications in Figure 1 as well as in Table 2 that prevalence of MetS in adolescents is increasing with time, but the evidence is not conclusive.

Prevalence of central adiposity was lowest in black males at 11.9%, but it exceeded 18.4% in all other sex-ethnic groups. It was highest in Hispanic females (23.9%) followed by black females (23.3%), Hispanic males (21.5%), white females (18.6%), and white males (18.4%). Prevalence of elevated triglyceride concentration was strikingly high in Hispanic and white adolescents of both sexes

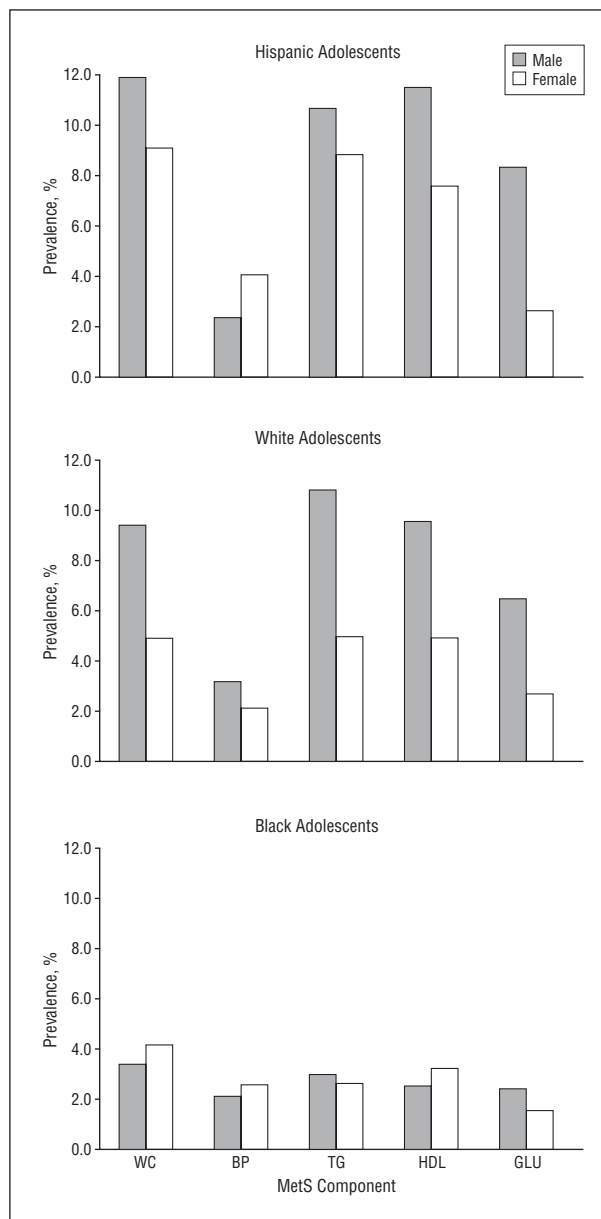


Figure 2. Prevalence of individual components of metabolic syndrome (MetS) in adolescents who have any distinct combination of components with 3 or more components by ethnicity and sex. BP indicates high blood pressure; GLU, high glucose concentration; HDL, low high-density lipoprotein concentration; TG, high triglyceride concentration; WC, large waist circumference.

but relatively low in black adolescents. Low HDL-C was highly prevalent in both sexes of Hispanic and white adolescents compared with black adolescents. Prevalence of elevated glucose concentration was high in Hispanic and white males, intermediate in black males, and relatively low in all females. Prevalence of elevated BP was moderately low in all sex-ethnicity groups.

Among Hispanic and white males who met the criteria for MetS, high WC, and high triglyceride and low HDL-C concentrations were individually the most prevalent risk factors followed closely by high glucose concentration. Whereas prevalence of disordered WC, triglyceride concentration, and HDL-C concentration was also high in Hispanic females, disordered glucose con-

centration was not. However, prevalence of disordered WC, triglyceride concentration, and HDL-C concentration was only moderately high in white females. Although WC was slightly elevated in black adolescents, none of the individual components of MetS stood out significantly as determinants of the syndrome. Overall, BP made only a minor contribution to MetS; this result is consistent with results of a previous study in European, African, and Cuban American adults aged 25 to 44 years in whom insulin resistance, obesity, and lipid factors most strongly represented MetS.³⁰ We observed a low prevalence of MetS in black adolescents of both sexes, but prevalence of large WCs stood out only slightly in females, and overall we did not find a pattern of WC or any other specific components driving the diagnosis of MetS.

Pediatric MetS has been reported to predict adult MetS and type 2 diabetes mellitus.¹⁹ In adults, as in adolescents, the epidemiology of MetS is unclear because the diagnostic definition lacks consensus of scientific opinions; hence, the implications of disparities among prevalence estimates have often been conflicting.⁹ We found prevalence to be highest in Hispanic adolescents (males higher than females) followed by white adolescents (males significantly higher than females) and black adolescents (males only slightly lower than females). This relatively high prevalence of MetS in Hispanic and white adolescents and the conflicting low prevalence in black adolescents has been recently observed by others.¹⁰⁻¹² Although the low prevalence of MetS among black individuals during adolescence would be expected to translate to a subsequent lower risk of developing comorbidities, prevalence has been found to be high in black compared with white adults for hypertension, diabetes, and cardiovascular disease.³¹ The prevalence of MetS was found to be very high among adult black participants in the Jackson Heart Study; moreover, elevated BP, large WC, and low HDL-C were each highly prevalent among those with MetS.³²

A natural hypothesis is that the sequence of events leading to definitive MetS begins with the development of obesity and/or insulin resistance then continues by taking many alternate pathways until metabolic irregularities evolve into life-threatening diseases. We found that many adolescents were not obese and yet had impairments in 1 or more of the following 4 components: BP, triglycerides, HDL-C, and glucose (Table 3). That many adolescents develop other metabolic disorders before they become centrally obese suggests that there may be additional origins of MetS. On the other hand, our definition of large WC may be too conservative in relation to identifying risk of metabolic disorder, so that overweight adolescents who are below our cut-off point for central obesity may be at risk for impaired triglyceride, HDL-C, and glucose concentrations. Also, some adolescents may be obese overall without being centrally obese. However, the high correlation between body mass index and WC found in our investigation as well as in a previous study ($r=0.94$ and $r=0.93$, respectively) does not support this hypothesis.³³ Using the 95th percentile for body mass index as the threshold criterion for obesity, we found the overall prevalence of MetS to be 8.3% (a value that is comparable with the prevalence of high WC [8.6%]). Using body

mass index rather than WC as the criterion for determining obesity, we observed that the revised prevalence was 12.5% (vs 12.9%) in male and 8.8% (vs 9.4%) in female Hispanic adolescents; 12.0% (vs 11.8%) in male and 5.1% (vs 5.8%) in female white adolescents; and 4.2% (vs 3.9%) in male and 4.2% (vs 4.2%) in female black adolescents. There is evidence that additional cardiometabolic risk due to obesity in adults is minimal once the risk attributable to having an excessively large WC is accounted for.³⁴ Furthermore, poor cardiorespiratory fitness may place many at metabolic risk,³⁵ and fitness may play a role even in those who are not obese.

The cross-sectional data in this NHANES study prohibit a direct calculation of disease incidence and therefore we cannot make direct comparisons among subgroups regarding risk of developing MetS. Because specific measurements of HDL-C may have been overestimated in 2003-2006 NHANES releases and in light of the fact that low concentrations of HDL-C are in the direction of impairment, the prevalence data for HDL-C and MetS may be underestimated in our analysis. The data also limit our ability to investigate the time in which specific individuals develop disorders in the criteria used to classify adolescents with respect to MetS prevalence. Furthermore, despite the large samples overall, sampling variability becomes large and the stability of estimates is compromised, as the sample sizes decrease when numerous subgroups are investigated. As a result, some observed differences among sex-ethnic subgroups may be large, yet within the range of sampling variability and other subgroup differences, such as those among sex-ethnic subgroups with respect to different component combinations, were not investigated.

The American Heart Association recommends that treatment options for childhood obesity be based on the severity of obesity and the presence or absence of comorbidities.³⁶ In the present study, 5.9% of the adolescents had an elevated WC in the absence of other component risk factors (Table 3). However, an additional 7.2% of the adolescents had an elevated WC in the presence of MetS. Of the 472 participants who had an elevated WC, 164 (35%) had other component risk factors to make the diagnosis of MetS. Of the 25 study participants who had MetS but did not have an elevated WC, 20 had an elevated glucose concentration as 1 of their 3 disorders, whereas the other 5 had elevated BP and triglyceride concentrations and low HDL-C. Although each component risk factor may be managed separately, it would be prudent to identify those with multiple disorders, irrespective of obesity, and provide them with more aggressive treatment and management options.

This work clearly identifies a different timetable and perhaps a different pathway for developing MetS in black adolescents. Although the prevalence of central adiposity remained substantially lower in black males than in other sex-ethnicity groups throughout adolescence, it was very high in black females, but males and females both had a relatively low prevalence of MetS. It is possible that black individuals have a propensity for developing clusters of component disorders later in adolescence and, hence, demonstrate a lower prevalence of metabolic disorders despite greater proclivity for cardiometabolic dis-

eases in early adulthood compared with Hispanic and white individuals. The relatively low prevalence of all of the individual components among black individuals, except for the elevated prevalence of large WC in females, is consistent with a delayed onset, but a complete explanation of the ethnic disparities requires further study.

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