ARTICLE

Effects of Individual Components, Time, and Sex on Prevalence of Metabolic Syndrome in Adolescents

Kenn B. Daratha, PhD; Ruth C. Bindler, RNC, PhD

Objectives: To examine selected clinical characteristics for cohorts of similar adolescents over 4 survey periods from 1999-2006, to examine changes in rates of adolescents who exceed cutoff points for individual components of metabolic syndrome (MetS), to describe sex differences in individual components of MetS, to describe changes in MetS prevalence from 1999-2006 using 4 common MetS definitions, and to describe sex differences in MetS prevalence from 1999-2006.

Design: Cross-sectional, US representational National Health and Nutrition Examination Survey from 1999-2006.

Setting: Mobile examination centers conducted by the Centers for Disease Control and Prevention.

Participants: For 1999-2000, 613 adolescents (aged 12-19 years); for 2001-2002, 892 adolescents; for 2003-2004, 857 adolescents; and for 2005-2006, 814 adolescents. Exclusions were pregnancy, taking insulin or diabetic pills, and incomplete measurements.

Main Outcome Measures: Fasting plasma glucose level, triglyceride level, high-density lipoprotein cholesterol level, waist circumference, and systolic and diastolic blood pressures.

Results: Increases in fasting plasma glucose and high-density lipoprotein cholesterol levels and decreases in diastolic blood pressure were observed. Rates of adolescents exceeding cutoff points for fasting plasma glucose levels have increased. Compared with girls, adolescent boys had higher rates exceeding cutoff points for fasting plasma glucose and high-density lipoprotein cholesterol levels. Adolescent girls had higher rates exceeding cutoff points for waist circumference. The prevalence of MetS among adolescents has not changed. No sex differences in MetS prevalence were observed.

Conclusions: Some criteria for MetS have remained stable (triglyceride level and systolic blood pressure) and one has improved for boys (high-density lipoprotein cholesterol level), but waist circumference has increased in girls and the rate of an elevated fasting plasma glucose level has nearly doubled for both boys and girls. Adolescent MetS prevalence has remained stable from 1999-2006.

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METABOLIC SYNDROME (MetS) describes characteristics associated with insulin resistance, a state of decreased sensitivity at the cellular level to normal levels of insulin,[1] which is predictive for emergence of both cardiovascular disease and type 2 diabetes mellitus.[2] Criteria for MetS in adults vary among the World Health Organization, the International Diabetes Federation, and the National Cholesterol Education Program Adult Treatment Panel III, although increased abdominal adiposity, atherogenic dyslipidemia, increased blood pressure (BP), and elevated fasting plasma glucose level are common criteria for all of the groups. Reviews have compared the MetS criteria of the International Diabetes Federation and the World Health Organization,[3,4] but controversy exists about which criteria are the best clinical measurement tools for adverse health conditions.[5,6]

The syndrome has been even more diversely defined and its usefulness challenged in children and adolescents. Researchers have adapted National Cholesterol Education Program Adult Treatment Panel III, International Diabetes Federation, and World Health Organization adult criteria for use in children, but the application of criteria to children has taken several forms by different researchers, with up to 40 unique definitions identified.[4,7-12] Prevalence of MetS varies widely depending on the criteria used and their cutoff points.[13] For example, prevalence of adolescent MetS varied from 2.0% to 9.4% using National Health and Nutrition Examination Survey (NHANES) data for 1999-2002 depending on the definitions applied.[14,15] In a study of 99 girls aged 6 to 9 years with overweight or obesity, 39%

Author Affiliations:
Washington State University College of Nursing, Spokane.

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to 60% had MetS depending on the definition used.[16] In another study of 1205 children aged 4 to 16 years with obesity, MetS was found in 6% to 39% depending on the definition of the syndrome.[17] An increase in the syndrome was described from 1988-2000.[18] In a 10-year longitudinal study, 3.5% of black girls and 2.3% of white girls developed MetS, and central adiposity was most strongly associated with emergence of the syndrome.[19] Two studies examined collective MetS criteria, identifying an increase in MetS among US adolescents from 4.2% to 6.4% between 1988 and 2000.[7,8] The application of the various criteria for MetS in adolescence leads to different prevalence rates.[14,20,21] The Pediatric Metabolic Syndrome Working Group is studying traditional pediatric MetS criteria as well as the usefulness of adding criteria such as levels of adiponectin and inflammatory biomarkers.[22]

Questions remain about variation of individual components of MetS in adolescents over time, what changes have occurred in the prevalence of MetS, and what cutoff points should be applied.[23,24] However, the rapid increase in adolescents' overweight over the last 3 decades, the emergence of type 2 diabetes in this age group, and data that show longitudinal tracking of cardiovascular risk factors from childhood to adulthood suggest that translation of MetS work to adolescence is needed.[25,26]

The purposes of our study were as follows: (1) to examine selected clinical characteristics for cohorts of similar adolescents over 4 survey periods from 1999-2006; (2) to examine changes in rates of adolescents who exceed cutoff points for individual components of MetS; (3) to describe sex differences in individual components of MetS; (4) to describe changes in MetS prevalence from 1999-2006 using 4 common MetS definitions; and (5) to describe sex differences in MetS prevalence from 1999-2006.

METHODS

SAMPLE

Study samples were drawn from the NHANES 1999-2000, 2001-2002, 2003-2004, and 2005-2006. The NHANES samples the civilian noninstitutionalized US population using a complex multistage design. Our sample (n=3176) was drawn from participants in the survey who were aged 12 to 19 years, were not taking insulin or diabetic pills, were not pregnant, completed physical examinations, and fasted for at least 8 hours prior to blood testing. Waist circumference, BP, and serum levels for fasting plasma glucose, high-density lipoprotein cholesterol (HDL-C), and triglycerides were recorded for all of the participants in this sample. Parents or guardians provided consent, and research participants younger than 18 years provided assent. Human subject approval was obtained by the Centers for Disease Control and Prevention.

PROTOCOLS AND DEFINITIONS

Fasting blood samples were obtained by venipuncture at mobile examination centers and transported in recommended methods to laboratories for analysis. Triglycerides and HDL-C were processed enzymatically in a series of coupled reactions by the Johns Hopkins University Lipid Analytic Laboratory. Levels of HDL-C showed an average increase of 3.0 mg/dL (to convert to millimoles per liter, multiply by 0.0259) in the last 2 survey periods compared with the first 2 survey periods. It is most likely that a change in methods was responsible for the increase in HDL-C values.[27] Accordingly, in this study each research participant's HDL-C value for 2003-2006 was lowered by 3.0 mg/dL. The fasting plasma glucose level was determined by the Collaborative Studies Clinical Laboratory using the Roche/Hitachi 911 instrument (Roche Diagnostics GmbH, Mannheim, Germany). (See http://www.cdc.gov/nchs/nhanes.htm for further details about the measurement and laboratory procedures.) For this study, dichotomous variables were derived for healthy and unhealthy values for each cut point including triglyceride (≥110 mg/dL [to convert to millimoles per liter, multiply by 0.0113]), fasting plasma glucose (≥110 mg/dL and ≥100 mg/dL [to convert to millimoles per liter, multiply by 0.0555]), and HDL-C (≤40 mg/dL and ≤35 mg/dL) levels.

Waist circumference was measured at the midpoint between the bottom of the rib cage and above the top of the iliac crest during minimal respiration to the nearest 0.1 cm. Waist circumference greater than or equal to the 90th percentile for age and sex provided the cutoff for the dichotomous variable of abdominal obesity.[28]

Measurements of BP were completed during the physical examination following a standardized protocol, including measurement on the right arm with a cuff bladder two-thirds of the arm circumference and 1 inch above the antecubital fossa. Up to 4 BP measurements were collected and the mean of all but the first reading was calculated. A systolic or diastolic BP mean greater than or equal to the 90th percentile based on age, sex, and stature using the National Heart, Lung, and Blood Institute guidelines[29] provided the cutoff for the dichotomous variable of hypertension. Metabolic syndrome was defined as participants having 3 or more of 5 criteria (elevated triglyceride levels, low HDL-C levels, elevated fasting plasma glucose levels, elevated abdominal obesity, and hypertension).

STATISTICAL ANALYSIS

Sampling weights based on fasting participants were used to complete a complex sampling analysis. Estimated mean percentages and 95% confidence intervals (CIs) as well as national estimates of the prevalence of MetS and each component of the syndrome were calculated. Temporal and sex differences in MetS and each component were compared using complex sampling t tests and χ^2 test for proportions. Statistical significance of $\alpha = .05$ was established a priori.

RESULTS

Adolescent respondents over 4 survey periods showed similar demographic characteristics and clinical characteristics (**Table 1**). The average age of respondents over the 4 survey periods was 15.45 years (95% CI, 15.33-15.56 years), and 47.9% (95% CI, 45.4%-50.4%) were female. Triglyceride levels remained stable ($t_{1399}=0.845$; $P=.40$) from 1999-2000 (mean, 87.09 mg/dL; 95% CI, 81.73-92.44 mg/dL) to 2005-2006 (mean, 90.59 mg/dL; 95% CI, 84.46-96.73 mg/dL). The average waist circumference did not change ($t_{1399}=0.881$; $P=.38$) from 1999-2000 (mean, 80.52 cm; 95% CI, 78.71-82.34 cm) to 2005-2006 (mean, 81.58 cm; 95% CI, 80.08-83.09 cm). The systolic BP remained stable ($t_{1399}=0.101$; $P=.92$) from 1999-2000 (mean, 110.18 mm Hg; 95% CI, 108.88-111.48 mm Hg) to 2005-2006 (mean, 110.10 mm Hg; 95% CI, 109.10-111.09 mm Hg).

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Table 1. Demographic and Clinical Characteristics of Adolescents in the National Health and Nutrition Examination Survey

Characteristic	Survey Period 1999-2000 (n=613)	2001-2002 (n=892)	2003-2004 (n=857)	2005-2006 (n=814)
Age, mean (95% CI), y	15.40 (15.09-15.72)	15.34 (15.15-15.54)	15.53 (15.32-15.74)	15.49 (15.27-15.70)
Female, % (95% CI)	47.7 (41.4-54.2)	48.7 (44.4-53.0)	47.5 (42.8-52.2)	47.6 (42.7-52.4)
Triglycerides, mean (95% CI), mg/dL	87.09 (81.73-92.44)	96.01 (87.59-104.43)	93.37 (88.01-98.74)	90.59 (84.46-96.73)
Fasting plasma glucose, mean (95% CI), mg/dL	90.41 (89.56-91.26)	92.85 (92.06-93.65)	90.68 (89.94-91.42)	93.12 (92.42-93.81)[a]
HDL-C, mean (95% CI), mg/dL	48.02 (46.71-49.34)	48.36 (47.39-49.34)	49.20 (48.01-50.38)	50.06 (48.90-51.21)[b]
Waist circumference, mean (95% CI), cm	80.52 (78.71-82.34)	79.64 (78.51-80.76)	81.82 (80.48-83.17)	81.58 (80.08-83.09)
Systolic BP, mean (95% CI), mm Hg	110.18 (108.88-111.48)	108.39 (107.38-109.41)	108.98 (108.00-109.96)	110.10 (109.10-111.09)
Diastolic BP, mean (95% CI), mm Hg	65.50 (64.25-66.74)	63.09 (62.24-63.93)	60.47 (59.49-61.44)	60.28 (59.12-61.43)[a]

Abbreviations: BP, blood pressure; CI, confidence interval; HDL-C, high-density lipoprotein cholesterol.
SI conversion factors: To convert to millimoles per liter, multiply by 0.0113 for triglycerides, by 0.0555 for fasting plasma glucose, and by 0.0259 for HDL-C.
[a] Significant difference reported from 1999-2000 to 2005-2006 ($P<.01$).
[b] Significant difference reported from 1999-2000 to 2005-2006 ($P<.05$).

Table 2. Components of Metabolic Syndrome by Sex Over 4 Survey Periods

Survey Period	Participants, % (95% CI): BP ≥90th Percentile	Fasting Plasma Glucose Level ≥110 mg/dL	Fasting Plasma Glucose Level ≥100 mg/dL	Triglyceride Level ≥110 mg/dL	HDL-C Level ≤40 mg/dL	HDL-C Level ≤35 mg/dL	Waist Circumference ≥90th Percentile
All Research Participants							
1999-2000	8.3 (5.6-12.2)	0.7 (0.2-2.6)	8.9 (6.0-12.9)	23.0 (18.0-28.8)	22.3 (17.5-27.9)	11.1 (7.8-15.7)	15.5 (11.5-20.4)
2001-2002	7.7 (5.7-10.3)	2.4 (1.4-4.0)	13.1 (10.4-16.2)	25.8 (22.1-29.9)	24.2 (20.5-28.2)	10.4 (7.8-13.7)	14.1 (11.5-17.2)
2003-2004	6.5 (4.6-9.1)	0.9 (0.5-1.9)	10.5 (8.0-13.8)	26.0 (22.0-30.5)	24.9 (21.0-29.3)	13.7 (10.6-17.5)	18.9 (15.5-22.9)
2005-2006	8.8 (6.3-12.1)	0.9 (0.4-2.0)	18.4 (14.9-22.5)[a]	24.2 (20.2-28.7)	23.5 (19.6-27.9)	8.6 (6.2-11.8)	17.7 (14.3-21.6)
Boys							
1999-2000	10.3 (6.4-16.3)	1.1 (0.2-5.2)	12.5 (8.1-18.8)	25.1 (18.3-33.4)	26.6 (19.9-34.5)	14.0 (9.2-20.7)	15.1 (10.2-21.8)
2001-2002	6.9 (4.6-10.2)	3.0 (1.6-5.5)	18.5 (14.2-23.7)	30.0 (24.6-36.1)	29.7 (24.3-35.6)	15.9 (11.6-21.4)	13.5 (9.9-18.2)
2003-2004	7.3 (4.7-11.2)	1.0 (0.4-2.5)	15.3 (11.2-20.7)	28.9 (23.3-35.4)	34.4 (28.5-40.9)	20.3 (15.3-26.4)	19.2 (14.5-25.0)
2005-2006	8.7 (5.3-13.8)	1.2 (0.4-3.3)	25.5 (20.0-31.9)[a]	24.1 (18.8-30.3)	27.8 (22.2-34.2)	9.4 (6.1-14.0)	13.7 (9.8-18.7)
Girls							
1999-2000	6.1 (3.0-12.0)	0.2 (0.0-1.0)	4.9 (2.1-10.9)	20.6 (14.1-29.2)	17.5 (11.4-26.0)	8.0 (4.0-15.2)	15.9 (10.1-24.1)
2001-2002	8.6 (5.6-13.0)	1.7 (0.7-4.4)	7.3 (4.8-10.9)	21.4 (16.7-27.0)	18.3 (13.7-24.0)	4.5 (2.4-8.3)	14.8 (11.2-19.2)
2003-2004	5.6 (3.2-9.7)	0.9 (0.3-2.5)	5.2 (3.0-9.0)	22.8 (17.4-29.4)	17.5 (11.4-26.0)	6.5 (3.8-10.9)	18.6 (13.9-24.3)
2005-2006	8.9 (5.6-13.8)	0.6 (0.2-1.4)	10.6 (7.0-15.5)	24.4 (18.7-31.9)	18.7 (13.8-24.9)	7.7 (4.7-12.6)	22.1 (16.9-28.4)

Abbreviations: BP, blood pressure; CI, confidence interval; HDL-C, high-density lipoprotein cholesterol.
SI conversion factors: To convert to millimoles per liter, multiply by 0.0113 for triglycerides, by 0.0555 for fasting plasma glucose, and by 0.0259 for HDL-C.
[a] Significant difference observed from 1999-2000 to 2005-2006 ($P<.01$).

Some clinical characteristics changed from 1999-2000 to 2005-2006 (Table 1). Fasting plasma glucose levels increased significantly ($t_{1399}=4.827$; $P<.001$) from 1999-2000 (mean, 90.41 mg/dL; 95% CI, 89.56-91.26 mg/dL) to 2005-2006 (mean, 93.12 mg/dL; 95% CI, 92.42-93.81 mg/dL). The HDL-C levels averaged 48.02 mg/dL (95% CI, 46.71-49.34 mg/dL) in 1999-2000 and increased ($t_{1399}=2.274$; $P=.02$) to an average of 50.06 mg/dL (95% CI, 48.90-51.21 mg/dL) in 2005-2006. The diastolic BP decreased ($t_{1399}=6.019$; $P<.001$) from 1999-2000 (mean, 65.50 mm Hg; 95% CI, 64.25-66.74 mm Hg) to 2005-2006 (mean, 60.28 mm Hg; 95% CI, 59.12-61.43 mm Hg).

Most rates of adolescents exceeding cutoff points for individual components defining MetS did not change over the 4 survey periods (**Table 2**). In 1999-2000, 8.3% (95% CI, 5.6%-12.2%) of research participants had BP greater than or equal to the 90th percentile. In 2005-2006, 8.8% (95% CI, 6.3%-12.1%) of research participants had BP greater than or equal to the 90th percentile ($\chi^2=0.09$; $P=.84$). In 1999-2000, 23.0% (95% CI, 18.0%-28.8%) of research participants had triglyceride levels of 110 mg/dL or higher. In 2005-2006, 24.2% (95% CI, 20.2%-28.7%) of research participants had triglyceride levels of 110 mg/dL or higher ($\chi^2=0.30$; $P=.72$). In 1999-2000, 22.3% (95% CI, 17.5%-27.9%) of research participants had HDL-C levels of 40 mg/dL or lower. In 2005-2006, 23.5% (95% CI, 19.6%-27.9%) of research participants had HDL-C levels of 40 mg/dL or lower ($\chi^2=0.28$; $P=.72$). Finally, in 1999-2000, 15.5% (95% CI, 11.5%-20.4%) of research participants had a waist circumference greater than or equal to the 90th percentile for age and sex. In 2005-2006, 17.7% (95% CI, 14.3%-21.6%) of research participants had a waist circumference greater than or equal to the 90th percentile for age and sex ($\chi^2=1.20$; $P=.45$).

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Table 3. Prevalence of Metabolic Syndrome Over 4 Survey Periods Using 4 Definitions

Survey Period	Participants, % (95% CI)			
	Definition 1[a]	Definition 2[b]	Definition 3[c]	Definition 4[d]
		All Research Participants		
1999-2000	7.6 (4.9-11.5)	8.6 (5.7-12.7)	5.8 (3.5-9.4)	6.8 (4.3-10.5)
2001-2002	6.3 (4.6-8.7)	8.8 (6.5-11.6)	3.4 (2.2-5.2)	5.1 (3.4-7.6)
2003-2004	6.5 (4.5-9.4)	7.7 (5.5-10.7)	5.4 (3.6-8.1)	6.6 (4.5-9.4)
2005-2006	7.2 (5.0-10.2)	10.6 (7.9-14.2)	5.4 (3.5-8.2)	8.2 (5.8-11.4)
		Boys		
1999-2000	11.0 (6.7-17.6)	11.8 (7.4-18.3)	9.2 (5.3-15.4)	9.9 (5.9-16.0)
2001-2002	8.2 (5.5-12.0)	11.6 (8.1-16.5)	4.9 (3.0-8.1)	7.5 (4.6-12.0)
2003-2004	8.7 (5.6-13.4)	10.6 (7.1-15.5)	7.8 (4.8-12.4)	9.7 (6.2-14.4)
2005-2006	7.0 (4.2-11.4)	12.2 (8.3-17.4)	5.2 (2.9-9.2)	8.9 (5.7-13.6)
		Girls		
1999-2000	3.8 (1.5-8.9)	5.0 (2.2-11.0)	2.1 (0.7-6.2)	3.4 (1.3-8.7)
2001-2002	4.4 (2.6-7.4)	5.7 (3.6-9.0)	1.7 (0.7-3.9)	2.6 (1.3-5.1)
2003-2004	4.1 (2.2-7.7)	4.6 (2.5-8.2)	2.8 (1.3-6.0)	3.2 (1.6-6.4)
2005-2006	7.3 (4.3-12.1)	8.9 (5.6-14.1)	5.7 (3.1-10.2)	7.3 (4.3-12.2)

Abbreviation: CI, confidence interval.

SI conversion factors: To convert to millimoles per liter, multiply by 0.0113 for triglycerides, by 0.0555 for fasting plasma glucose, and by 0.0259 for high-density lipoprotein cholesterol (HDL-C).

[a] Waist circumference greater than or equal to the 90th percentile; blood pressure greater than or equal to the 90th percentile; triglyceride level of 110 mg/dL or higher; HDL-C level of 40 mg/dL or lower; and fasting plasma glucose level of 110 mg/dL or higher.

[b] Waist circumference greater than or equal to the 90th percentile; blood pressure greater than or equal to the 90th percentile; triglyceride level of 110 mg/dL or higher; HDL-C level of 40 mg/dL or lower; and fasting plasma glucose level of 100 mg/dL or higher.

[c] Waist circumference greater than or equal to the 90th percentile; blood pressure greater than or equal to the 90th percentile; triglyceride level of 110 mg/dL or higher; HDL-C level of 35 mg/dL or lower; and fasting plasma glucose level of 110 mg/dL or higher.

[d] Waist circumference greater than or equal to the 90th percentile; blood pressure greater than or equal to the 90th percentile; triglyceride level of 110 mg/dL or higher; HDL-C level of 35 mg/dL or lower; and fasting plasma glucose level of 100 mg/dL or higher.

Rates of adolescents exceeding cutoff points for fasting plasma glucose levels changed over the 4 survey periods. When setting a cutoff point at 110 mg/dL, 0.7% (95% CI, 0.2%-2.6%) of research participants in 1999-2000 exceeded this level. In 2005-2006, 0.9% (95% CI, 0.4%-2.0%) of research participants had fasting plasma glucose levels of 110 mg/dL or higher (χ^2=0.26; P=.69). However, when the cutoff point for the fasting plasma glucose level was set at 100 mg/dL, 8.9% (95% CI, 6.0%-12.9%) of research participants in 1999-2000 exceeded this level. By 2005-2006, 18.4% (95% CI, 14.9%-22.5%) of research participants had fasting plasma glucose levels of 100 mg/dL or higher (χ^2=24.59; P=.001).

Sex differences were observed in the rates of adolescents exceeding cutoff points for individual components of MetS. No differences in rates were detected in 2005-2006 for BP or triglyceride levels. However, boys had higher rates (25.5%; 95% CI, 20.0%-31.9%) of fasting plasma glucose levels of 100 mg/dL or higher compared with girls (10.6%; 95% CI, 7.0%-15.5%) (χ^2=30.24; P<.001). Boys had higher rates (27.8%; 95% CI, 22.2%-34.2%) of HDL-C levels of 40 mg/dL or lower compared with girls (18.7%; 95% CI, 13.8%-24.9%) (χ^2=9.33; P=.03). Finally, girls had higher rates (22.1%; 95% CI, 16.9%-28.4%) of waist circumference exceeding the 90th percentile considering age and sex compared with boys (13.7%; 95% CI, 9.8%-18.7%) (χ^2=9.91; P=.02).

The prevalence of MetS did not change from 1999-2000 to 2005-2006 (**Table 3**). We analyzed the prevalence of MetS with the 4 most common sets of criteria used to define this syndrome in adolescence. Definition 1 (waist circumference ≥90th percentile; BP ≥90th percentile; triglyceride level ≥110 mg/dL; HDL-C level ≤40 mg/dL; and fasting plasma glucose level ≥110 mg/dL) resulted in a MetS prevalence of 7.6% (95% CI, 4.9%-11.5%) in 1999-2000 and 7.2% (95% CI, 5.0%-10.2%) in 2005-2006 (χ^2=0.08; P=.85). Definition 2 (waist circumference ≥90th percentile; BP ≥90th percentile; triglyceride level ≥110 mg/dL; HDL-C level ≤40 mg/dL; and fasting plasma glucose level ≥100 mg/dL) resulted in a MetS prevalence of 8.6% (95% CI, 5.7%-12.7%) in 1999-2000 and 10.6% (95% CI, 7.9%-14.2%) in 2005-2006 (χ^2=1.65; P=.39). Definition 3 (waist circumference ≥90th percentile; BP ≥90th percentile; triglyceride level ≥110 mg/dL; HDL-C level ≤35 mg/dL; and fasting plasma glucose level ≥110 mg/dL) resulted in a MetS prevalence of 5.8% (95% CI, 3.5%-9.4%) in 1999-2000 and 5.4% (95% CI, 3.5%-8.2%) in 2005-2006 (χ^2=0.09; P=.84). Finally, definition 4 (waist circumference ≥90th percentile; BP ≥90th percentile; triglyceride level ≥110 mg/dL; HDL-C level ≤35 mg/dL; and fasting plasma glucose level ≥100 mg/dL) resulted in a MetS prevalence of 6.8% (95% CI, 4.3%-10.5%) in 1999-2000 and 8.2% (95% CI, 5.8%-11.4%) in 2005-2006 (χ^2=0.89; P=.52).

The prevalence of MetS has historically been higher for adolescent boys compared with adolescent girls (Table 3). The prevalence of MetS among boys in 1999-2000 ranged from 9.2% (95% CI, 5.3%-15.4%) to 11.8% (95% CI, 7.4%-18.3%) depending on the criteria used to define MetS. The prevalence of MetS among adolescent girls in 1999-2000 ranged from 2.1% (95% CI, 0.7%-6.2%) to 5.0% (95% CI, 2.2%-11.0%) depending on the criteria used.

For the survey period of 2005-2006, no significant sex differences were reported for any set of criteria used to define MetS. The prevalence of MetS among boys in 2005-

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2006 ranged from 5.2% (95% CI, 2.9%-9.2%) to 12.2% (95% CI, 8.3%-17.4%) depending on the criteria used to define MetS. The prevalence of MetS among adolescent girls in 2005-2006 ranged from 5.7% (95% CI, 3.1%-10.2%) to 8.9% (95% CI, 5.6%-14.1%) depending on the criteria used.

COMMENT

This study examined selected clinical characteristics for cohorts of similar adolescents over 4 survey periods from 1999-2006; examined changes in rates of adolescents exceeding cutoff points for individual components of MetS; described sex differences in individual components of MetS; described changes in MetS prevalence from 1999-2006 using 4 common MetS definitions; and described sex differences in MetS prevalence from 1999-2006. We found increases in fasting plasma glucose and HDL-C levels and decreases in diastolic BP when comparing the 2005-2006 cohort with the 1999-2000 cohort. Rates of adolescents exceeding cutoff points for fasting plasma glucose levels have increased. Compared with girls, adolescent boys had higher rates exceeding cutoff points for fasting plasma glucose and HDL-C levels. Adolescent girls had higher rates exceeding cutoff points for waist circumference. The prevalence of MetS among adolescents did not change from 1999-2006 regardless of the MetS definition used. Finally, although boys have had historically higher prevalence rates of MetS compared with girls, by 2005-2006 no sex differences were observed.

Specifically, girls are showing an alarming increase in waist circumference. Waist circumference, a measure of abdominal adiposity, has been associated with incidence of cardiovascular disease in adults. In children and adolescents, waist circumference has been identified as a predictor of insulin resistance.[30] In conjunction with body mass index, waist circumference predicts coronary artery disease risk factors.[31] Children with increased waist circumference at age 8 years were 4 times as likely to have cardiovascular risk factor clustering during adolescence than those with smaller waist circumference.[32] The increase in prevalence of elevated waist circumference (≥90th percentile) in girls from 15.9% in the 1999-2000 data to 22.1% in the 2005-2006 data is cause for concern. Clinicians should measure body mass index and waist circumference and should evaluate results using standardized growth grids.[33] Elevations of central adiposity measures are reason to perform comprehensive screening for other health risks and to apply appropriate interventions for lifestyle behaviors such as diet and activity.

Rates of elevated fasting plasma glucose levels nearly doubled from 1999-2006 for both boys and girls when using 100 mg/dL as the cutoff value. The difference in the prevalence of elevated fasting plasma glucose levels using 2 different cutoffs is intriguing. Fasting plasma glucose level, as any other criterion, can be viewed as a continuous variable rather than as a dichotomous variable. It has been noted that we are lacking large prospective studies that can determine the best cutoff for fasting plasma glucose levels.[23] At the very least, it seems logical to apply the cutoff of 100 mg/dL (rather than ≥110 mg/dL) for adolescents because the lower level is presently recommended for adults. When doing so, the results are startling. The prevalence of elevated fasting plasma glucose levels increased from 0.7% to 8.9% in 1999-2000, from 2.4% to 13.1% in 2001-2002, from 0.9% to 10.5% in 2003-2004, and from 0.9% to 18.4% in 2005-2006 when using 100 mg/dL instead of 110 mg/dL. It is also striking that when using 100 mg/dL for the cutoff, boys showed an increase in the prevalence of elevated levels from 12.5% in 1999-2000 to 25.5% in 2005-2006, and girls showed an increase from 4.9% in 1999-2000 to 10.6% in 2005-2006. The reason for this increase in elevated fasting plasma glucose levels is not clear but suggests that adolescents are at higher risk for development of insulin resistance and type 2 diabetes.

The improvement in HDL-C levels in boys is encouraging. Even after adjustments accounting for increases in HDL-C levels among NHANES samples in 2003-2006, rates of adolescent boys exceeding the cutoff have improved. The increasing levels of HDL-C have helped to stabilize MetS rates and offset the increasing fasting plasma glucose levels. Similar to fasting plasma glucose levels, the more stringent HDL-C level of 40 mg/dL (rather than 35 mg/dL) is helpful to the clinician. For example, in 2005-2006 data, only 9.4% of boys and 7.7% of girls had HDL-C levels of 35 mg/dL or lower, whereas 27.8% of boys and 18.7% of girls had levels of 40 mg/dL or lower.

Sex differences do exist in the rates of individual MetS components. In all of the 4 survey periods, higher rates of elevated fasting plasma glucose levels were observed in boys compared with girls. In the most recent survey period (2005-2006), higher rates of central adiposity were observed for girls compared with boys.

When examining the criteria collectively, the prevalence of MetS in adolescence was unchanged from the survey periods of 1999-2000 through 2005-2006 regardless of the individual criteria used to define MetS. Historical sex differences were found in the rates of MetS, with boys having significantly higher rates of MetS compared with girls in 3 survey periods, whereas there were no sex differences in the rates of MetS in 2005-2006.

Findings from the survey period of 1999-2000 fall within prevalence rates for MetS previously reported.[14,15] Different inclusion and exclusion criteria in the analyses by Cook et al,[7] Duncan et al,[8] and de Ferranti et al[9] explain their differences in subject numbers and specific results. In some studies, adolescents who were missing MetS criteria measurements were included; in other cases, no exclusion was made for pregnancy or glucose-altering medication use; in 1 case, a 6-hour fast rather than an 8-hour fast enabled subject inclusion; and finally, in some studies a mean of all BP measurements taken rather than the mean of all but the first (as recommended by NHANES) was calculated.

Limitations of this study include those of the Centers for Disease Control and Prevention sample itself, such as sampling and laboratory errors. For example, sample weighting for calculation of population totals are based on US Census Bureau data. On the other hand, the stratified probability sample of the NHANES data enables researchers to extrapolate the data to the entire population of US adolescents. Levels of HDL-C were higher in the last 2 survey periods compared with the first 2 survey periods. It is

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most likely that a change in methods was responsible for the increase in HDL-C levels.[27] Other covariates may explain some of the increased HDL-C levels but are unlikely to account for most of the mean increases in HDL-C levels. Further investigations are necessary to attempt to explain the increased HDL-C levels and provide further guidance on the interpretation of HDL-C levels for the NHANES 1999-2006.[27] Cross-sectional data such as NHANES provide a snapshot in time but do not aid in tracking specific individuals for MetS over an extended period. An additional limitation is that subjects themselves provided the information regarding medication use that led to study exclusion. A universal limitation of the work on MetS for adolescents is that the definitions, criteria, and cutoffs are not agreed on by consensus. However, this work contributes to the understanding of individual criteria and cutoffs, the elucidation of sex differences in specific criteria, and the reporting of MetS prevalence over time.

Criteria for MetS individually and collectively can be used to examine historical epidemiological trends and to evaluate individual adolescents as part of a comprehensive health care approach.

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Correspondence: Kenn B. Daratha, PhD, Washington State University College of Nursing, PO Box 1495, Spokane, WA 99210-1495 (kdaratha@wsu.edu).
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