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# Trends and Clustering of Cardiometabolic Risk Factors in American Adolescents From 1999 to 2008

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**See Editorial p. 107**

A B S T R A C T

**Aim:** To characterize trends and clustering of cardiometabolic risk factors in 12–17-year-old non-Hispanic white, non-Hispanic black (NHB), Mexican-American (MA), and multiracial American (MRA) adolescents.
**Methods:** Data from the 1999–2000 to 2007–2008 U.S. National Health and Nutrition Examination Surveys were used for this investigation. Clustering of cardiometabolic risk factors was determined using cardiometabolic risk factor clustering score (cMetS) computed by aggregating z scores of mean arterial blood pressure, triglycerides, fasting blood glucose, waist circumference, and high-density lipoprotein cholesterol.
**Results:** There were significant increases in waist circumference and high-density lipoprotein cholesterol, and decreases in low density lipoprotein cholesterol, triglycerides, and mean arterial blood pressure in the 10-year period between 1999–2000 and 2007–2008. There were gender and racial/ethnic differences in cMetS, with NHB having a more favorable cMetS for each studied time point. Overall, cMetS decreased by 93% in the 10-year period between 1999–2000 and 2007–2008. cMetS decreased by 98% and 77.3% for male and female adolescents, respectively, in the period between 1999–2000 and 2007–2008. With the exception of Mexican-American and multiracial American female adolescents, all racial/ethnic groups had improved cMetS values on comparing mean cMetS values of 1999–2000 with mean values of 2007–2008. Compared with other racial/ethnic groups, NHB male and female adolescents had the most improved cMetS.
**Conclusion:** Because clustering of cardiometabolic risk factors is predictive of adult health status, early lifestyle intervention in adolescence may help slow down the progress and delay or prevent the onset of cardiovascular diseases in adulthood.


The assemblage of adverse cardiometabolic risk factors, often referred to as metabolic syndrome (MetS), increases the risk for cardiovascular disease-associated morbidity and mortality as well as all-cause mortality [1–3]. These cardiometabolic risk factors include elevated abdominal adiposity, blood pressure, glucose, and triglycerides, and lowered high-density lipoprotein cholesterol (HDL-C). Many definitions of MetS with regard to adults have been recommended by various working groups [4,5], but still needs to be well defined in youths. The availability of several diagnostic criteria of clustering of cardiometabolic risk factors in adults has created confusion concerning its prognostic utility. The main difference between these diagnostic criteria lies in the way in which the various components for the diagnosis are grouped and combined. The National Cholesterol Education Program Adult Treatment Panel III criteria give the same weightage

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to abdominal obesity, hypertension, hyperglycemia, hypertriglyceridemia, and low HDL-C (3 or more of these components must be present for a diagnosis) [4]. The American Heart Association and National Heart, Lung, and Blood Institute define clustering of cardiometabolic risk factors using two or more of the conditions [5]. Despite this limitation, the prevalence of cardiometabolic risk factors clustering is high among obese American children and adolescents, and is increasing with worsening obesity in youngsters [6]. Clustering of cardiometabolic risk factors in childhood has been associated with accelerated atherogenesis in adulthood [7]. Studies have shown that clustering of cardiometabolic risk factors often tracks down from childhood to adulthood [8] and is also associated with a lifetime elevated risk for cardiovascular diseases [9].

In the adults from the United States, increasing trends of individual cardiometabolic risk factors and clustering of cardiometabolic risk factors have been noted [10]. However, the clustering of cardiometabolic risk factors among American adolescents is poorly understood. The lack of clarity may be due to the use of adult cut-points in defining cardiometabolic risk factors and clustering of cardiometabolic risk factors in youths [2,4,5]. To overcome this limitation, a continuous measure of clustering of cardiometabolic risk factor scores (cMetS) has been suggested [11] to eliminate the need to dichotomize these factors. cMetS is derived by aggregating *z* scores across individual cardiometabolic risk factors. Other procedures for deriving cMetS include principal components analysis and percentile rankings [12–14]. cMetS has these advantages: (a) because cardiovascular risk is a progressive function of several cardiometabolic risk factors, the use eliminates the need to dichotomize these factors [15]; (b) as a continuous variable, cMetS is more sensitive and less error prone compared with categorical measures of MetS; (c) statistical power is increased with the use of cMetS [16]. The American Diabetes Association and the European Association for the Study of Diabetes have recommended using cMetS as an index for clustering of cardiometabolic risk factors [11].

Previous studies suggest gender and race/ethnic differences in clustering of cardiometabolic risk factors in American youths [17,18]. Different cardiometabolic risk factors seem to predominate the clustering of cardiometabolic risk factors across gender and racial/ethnic groups [19,20]. A large waist circumference is more evident in clustering of cardiometabolic risk factors in non-Hispanic black (NHB) females [19]. Enlarged waist, elevated triglycerides, and low HDL-C concentrations are more common in Hispanic and non-Hispanic white (NHW) adolescents of both genders than their NHB and Mexican-American (MA) counterparts [20]. In MA, high glucose concentration is prominent [20]. To tailor prevention programs more effectively, rigorous examinations of the trends in adolescents' onset of clustering of cardiometabolic risk factors and general trends in individual components of cardiometabolic risk factors in this age group are needed. Tracking and understanding the extent to which cardiometabolic risk factors and clustering of cardiometabolic risk factors are stable in various racial/ethnic groups may also provide insights into preventive interventions for improving risks for cardiovascular diseases.

The aim of this study is to describe trends over time of cardiometabolic risk factors, including waist circumference, blood pressure, fasting blood glucose (FBG), triglycerides, HDL-C, and clustering of cardiometabolic risk factors defined using cMetS in NHW, NHB, MA, and multiracial American (MRA) adolescents.

## Methods

### *Subjects and study design*

The 1999–2000, 2001–2002, 2003–2004, 2005–2006, and 2007–2008 National Health and Nutrition Examination Surveys (NHANES) data that were used for this investigation were obtained from the U.S. National Center for Health Statistics. The NHANES are based on complex cross-sectional multistage sampling designs done in representative samples of the civilian noninstitutionalized individuals within the U.S. population. Descriptions of the plans and operations of the surveys have been described by other investigators [21,22]. Briefly, the NHANES samples included oversampling of youths. The NHANES study protocols were approved by the institutional review board of U.S. National Center for Health Statistics. Oral and written informed consent was obtained from adult participants. Assent was obtained from subjects under the age of 16 after obtaining oral and written informed consent from their parents. Of the approximately 51,623 persons who completed the 1999–2000 to 2007–2008 NHANES, 15.7% were adolescents, aged 12–17 years.

### *Study population*

In this study, only 12–17-year-old adolescents who had values for age, height, weight, waist circumference, and assays for total cholesterol, FBG, low-density lipoprotein cholesterol (LDL-C), HDL-C, and triglycerides were eligible for investigation. Adolescents who were not measured for blood pressure and were not assayed were excluded from this study. Other variables included in this study are gender, race/ethnicity, and body mass index. In NHANES, gender and race/ethnicity status were based on self-reports.

### *Measures*

Descriptions of variable measurements and assays are available online [23], and have also been described by other investigators [10]. Height was measured using a fixed stadiometer with a vertical backboard and a moveable headboard. Weight was measured at a standing position using a Toledo digital weight scale (Seritex, Carlstadt, New Jersey). Waist circumference was measured between bony landmarks, the lateral border of the ilium and uppermost lateral border of the right ilium. The measurement was made at the end of a normal expiration and to the nearest .1 cm. Three consecutive blood pressure readings were obtained at a one-time examination visit using a standard protocol. In this investigation, averages of the three systolic and diastolic blood pressure readings were used as representative of the participants' systolic and diastolic blood pressure values. Triglycerides, HDL-C, and blood glucose were analyzed after 8 hours of overnight fasting. Triglycerides and glucose were measured enzymatically in serum using a series of coupled reactions. Serum HDL-C was measured using HDL-C direct immunoassay method. LDL-C values were calculated from measured values of total cholesterol, according to the Friedewald method [23].

In this study, racial/ethnic groups were categorized as NHW, NHB, MA, and MRA. MRA included other Hispanics and other races. Other racial/ethnic groups were combined into MRA because of the small sample size of the other groups. BMI was calculated by dividing weight in kilograms by height in meters squared.

**Table 1**
Basic anthropometric characteristics of eligible 12–17-year-old American adolescents, 1999–2000 to 2007–2008

| Variables | 1999–2000 | 2001–2002 | 2003–2004 | 2005–2006 | 2007–2008 | *p* value |
|---|---|---|---|---|---|---|
| | | | Males | | | |
| N | 933 | 916 | 905 | 845 | 491 | |
| Age (years) | 14.3 ± .001 | 14.6 ± .001 | 14.4 ± .001 | 14.6 ± .001 | 14.3 ± .001 | <.001 |
| Height (m) | 167.8 ± .004 | 169.4 ± .004 | 169.3 ± .004 | 170.0 ± .004 | 170.1 ± .004 | <.001 |
| Weight (kg) | 62.7 ± .007 | 66.7 ± .007 | 66.5 ± .001 | 65.5 ± .001 | 66.4 ± .001 | <.001 |
| Body mass index (kg/m$^2$) | 21.9 ± .001 | 22.2 ± .001 | 22.4 ± .001 | 22.7 ± .001 | 22.8 ± .001 | <.001 |
| Waist circumference (cm) | 78.5 ± .005 | 79.4 ± .005 | 80.5 ± .005 | 80.7 ± .005 | 80.8 ± .005 | <.001 |
| | | | Females | | | |
| N | 914 | 989 | 819 | 859 | 454 | |
| Age (years) | 14.4 ± .001 | 14.5 ± .001 | 14.6 ± .001 | 14.4 ± .001 | 14.6 ± .001 | <.001 |
| Height (m) | 164.0 ± .008 | 168.6 ± .008 | 169.1 ± .007 | 168.5 ± .007 | 168.6 ± .007 | <.001 |
| Weight (kg) | 69.1 ± .017 | 64.8 ± .015 | 67.6 ± .015 | 66.7 ± .018 | 67.1 ± .015 | <.001 |
| Body mass index (kg/m$^2$) | 22.7 ± .005 | 23.1 ± .004 | 23.5 ± .005 | 23.7 ± .005 | 23.9 ± .004 | <.001 |
| Waist circumference (cm) | 75.0 ± .013 | 75.9 ± .011 | 78.6 ± .012 | 79.2 ± .012 | 79.7 ± .011 | <.001 |

*p*-value is from one-way one-way analysis of variance and tests values (means ± standard errors) differences across study time point.

*Derivation of clustering of cardiometabolic risk factors*

Clustering of cardiometabolic risk factors was determined using cMetS. cMetS was computed using standardized residuals (*z* score) of mean arterial blood pressure (MABP), triglycerides, FBG, waist circumference, and HDL-C. MABP was calculated using the formula MABP = ([(systolic blood pressure − diastolic blood pressure)/3] + diastolic blood pressure). Standardization of the individual metabolic syndrome variables was done by regressing them onto age, sex, and race/ethnicity [24]. Because the standardized HDL-C is inversely related to metabolic risk it was multiplied by −1. cMetS was calculated as the sum of standardized residuals of MABP, triglycerides, blood glucose, waist circumference, and HDL-C. A higher score indicates a less favorable cardiometabolic profile [24].

*Statistical analysis*

Statistical programs available in SAS for Windows (SAS Release 8.02) and SUDAAN [25] were used in this analysis. To account for unequal probabilities of selection, oversampling, and non-response, appropriate sampling weights were used for the analyses. Standard error estimates were calculated using the SUDAAN statistical program. All variables were checked for normality and transformed before standardization. Time point-specific racial/ethnic differences in mean values of waist circumference, arterial blood pressure, FBG, triglycerides, HDL-C, and other cardiometabolic risk factors were assessed by one-way analysis of variance. Tukey tests for multiple comparisons of means were used as post hoc tests. Analyses of linear trends were performed using one-way analysis of variance for cardiometabolic risk factors and CMetS across study periods. The customary *p* values of <.05 were used to indicate statistical significance.

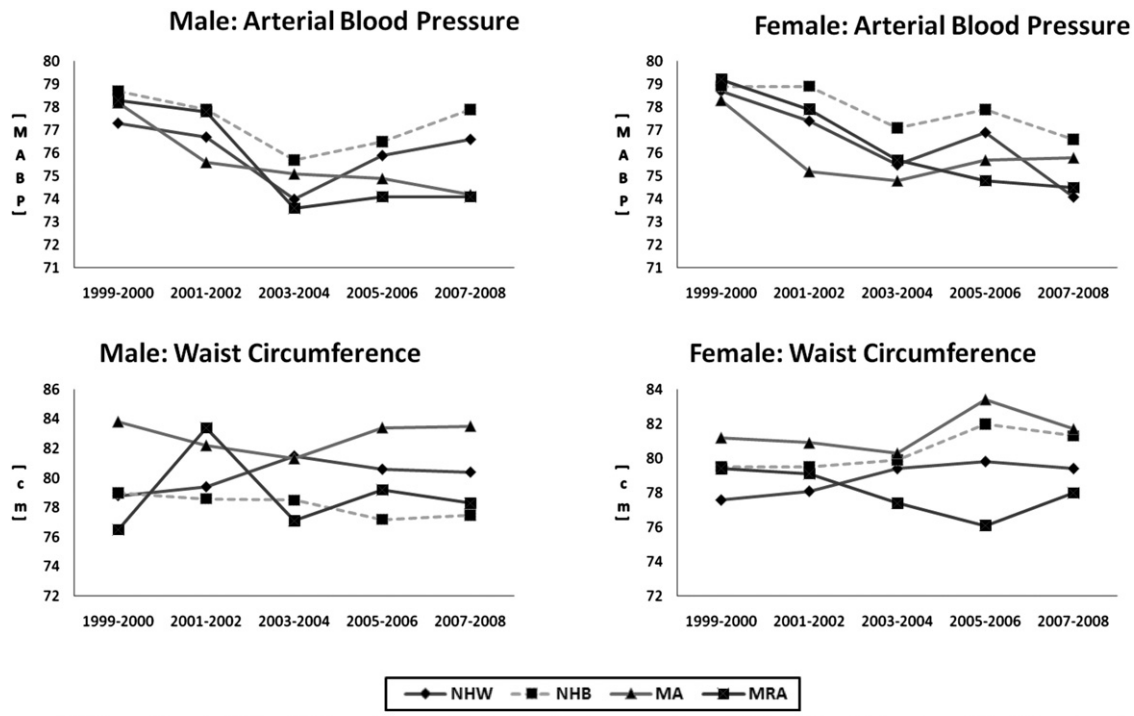
## Results

Overall, 4,095 male and 4,035 female adolescents were eligible for this study. Gender-specific anthropometric and clinical characteristics of the eligible adolescents by study time points are presented in Tables 1 and 2, respectively. There was a gradient of increasing BMI and waist circumference in male and female adolescents, decreasing values of total cholesterol in male and female adolescents, and decreasing values of LDL-C, triglycerides, and MABP in female adolescents from 1999–2000 to

**Table 2**
Basic clinical characteristics of eligible 12–17-year-old American adolescents, 1999–2000 to 2007–2008

| Variables | 1999–2000 | 2001–2002 | 2003–2004 | 2005–2006 | 2007–2008 | Relative change[a] | *p* value |
|---|---|---|---|---|---|---|---|
| | | | Males | | | | |
| Total cholesterol (mg/dL) | 158.6 ± .009 | 158.3 ± .010 | 156.1 ± .009 | 154.4 ± .009 | 154.4 ± .008 | −4.2* | <.001 |
| Blood glucose (mg/dL) | 91.3 ± .003 | 96.6 ± .009 | 94.4 ± .008 | 97.9 ± .012 | 97.4 ± .003 | +6.1* | <.001 |
| LDL-C (mg/dL) | 93.1 ± .011 | 96.3 ± .014 | 89.2 ± .013 | 83.1 ± .011 | 86.5 ± .011 | −6.6* | <.001 |
| HDL-C (mg/dL) | 46.6 ± .003 | 46.8 ± .003 | 49.5 ± .003 | 50.3 ± .004 | 48.6 ± .003 | +2.0* | <.001 |
| Triglycerides (mg/dL) | 88.5 ± .025 | 83.2 ± .025 | 89.7 ± .024 | 83.9 ± .019 | 83.9 ± .019 | −4.6* | <.001 |
| MABP (mm Hg) | 77.6 ± .003 | 76.7 ± .003 | 74.4 ± .003 | 75.7 ± .003 | 76.2 ± .003 | −1.4* | <.001 |
| | | | Females | | | | |
| Total cholesterol (mg/dL) | 160.9 ± .010 | 162.9 ± .008 | 162.6 ± .009 | 161.5 ± .008 | 158.6 ± .009 | −2.3* | <.001 |
| Blood glucose (mg/dL) | 93.8 ± .023 | 90.3 ± .004 | 88.5 ± .004 | 91.2 ± .004 | 95.8 ± .005 | +2.0* | <.001 |
| LDL-C (mg/dL) | 89.4 ± .013 | 89.4 ± .011 | 88.8 ± .012 | 88.8 ± .011 | 88.5 ± .011 | −.9* | <.001 |
| HDL-C (mg/dL) | 51.0 ± .004 | 50.4 ± .003 | 56.3 ± .004 | 54.4 ± .004 | 52.0 ± .004 | +1.0* | <.001 |
| Triglycerides (mg/dL) | 88.7 ± .020 | 85.4 ± .018 | 84.1 ± .020 | 83.2 ± .022 | 81.6 ± .018 | −7.1* | <.001 |
| MABP (mm Hg) | 78.6 ± .002 | 77.2 ± .002 | 76.6 ± .002 | 74.4 ± .002 | 76.7 ± .002 | −1.9* | <.001 |

*p* value is from one-way ANOVA and tests values (means ± standard errors) across study time point.
− and + represents in decreased and increased values in the period between 1999–2000 and 2007–2008.
LDL-C = low density-lipoprotein cholesterol; HDL-C = high density lipoprotein cholesterol; MABP = mean arterial blood pressure.
[a]Relative change, value differences between 2007–2008 and 1999–2000.
* Significant at $p < .001$.




NHW, non-Hispanic Whites; NHB, non-Hispanic Blacks; MA, Mexican; Americans; MRA, Multi-racial Americans (other Hispanics and other races)

**Figure 1.** Racial/ethnic Trends in Mean Arterial Blood Pressure and Waist Circumference in 12–17-year-old American Adolescents, 1999–2000 to 2007–2008. NHW, non-Hispanic whites; NHB, non-Hispanic blacks; MA, Mexican; Americans; MRA, Multiracial Americans (other Hispanics and other races).

2007–2008 ($p < .05$ for linear trends). Overall, there were gender differences in height, BMI, and waist circumference in each study period ($p < .001$). As shown in Table 1, regardless of study time point, male adolescents were taller and had larger waist circumference than female adolescents. Female adolescents had greater BMI values at each study time points compared with male adolescents. In male adolescents, absolute difference in mean BMI between 1999–2000 and 2007–2008 was .9 kg/m$^2$. The corresponding value in female adolescents was 1.2 kg/m$^2$. In each study time point, female adolescents presented higher values of total cholesterol and HDL-C as compared with male adolescents. When comparing values in 1999–2000 and 2007–2008, blood glucose increased the most while total cholesterol decreased the most in male adolescents, whereas blood glucose increased the most and triglycerides decreased the most in female adolescents.

We compared race/ethnic specific trends in MABP and waist circumference from 1999–2000 to 2007–2008 for male and female adolescents (Figure 1). MABP decreased consecutively over the study period for both genders across study time points. However, the changes in values were slightly u-shaped for male adolescents. Overall, MABP decreased by 2.2% in the 10-year period between 1999–2000 and 2007–2008. Racial/ethnic differences in arterial blood pressure were evidenced in male and female adolescents, with NHB male adolescents tending to have higher values in each study period ($p < 001$). A similar higher value for arterial blood pressure in NHB female adolescents was also observed across study periods ($p < .001$). The highest decrease in average arterial blood pressure between 1999–2000 and 2007–2008 in male adolescents was observed in MA male and MRA female adolescents and decreased by 5.1% and 5.9%, respectively ($p < .05$). There were statistically significant racial/ethnic differences in mean values of waist circumference at each studied time point, with MA male and female adolescents having larger waist values compared with other racial/ethnic groups ($p < .001$). An overall 1.3 cm increase in waist circumference was observed in male and female adolescents between 1999–2000 and 2007–2008. A trend of increase in waist circumference for female adolescents was noticeable, which was most profound in NHW female adolescents.

In Figure 2, we compared race/ethnic specific trends in lipid components (FBG, HDL-C, and triglycerides) that were used for computing cardiometabolic risk factor clustering. As shown, increase in FBG was recorded in male adolescents of all racial/ethnic groups as well as NHW females, NHB females, and MA female adolescents in the study period between the study time point 1999–2000 and 2007–2008. On the contrary, MRA female adolescents recorded decreased values of 30.1% in the study time point between 1999–2000 and 2007–2008. With the exception of MA male adolescents, increase in HDL-C concentration was observed in all racial/ethnic groups. NHB male adolescents and female adolescents recorded higher HDL-C at every study periods compared with other racial/ethnic groups. NHB male and female adolescents recorded 7.9% and 2.4% higher HDL-C values, respectively, between 1999–2000 and 2007–2008. In male and female adolescents, NHW and MRA groups recorded the worst improvement in triglycerides in the period between 1999–2000 and 2007–2008 compared with other groups. NHB male and female adolescents also recorded a better triglyceride profile in each study period compared with other racial/ethnic groups.

Using cMetS, trends in clustering of cardiometabolic risk factors were compared across racial/ethnic groups stratified by gender (Table 3). As shown, there were racial/ethnic differences

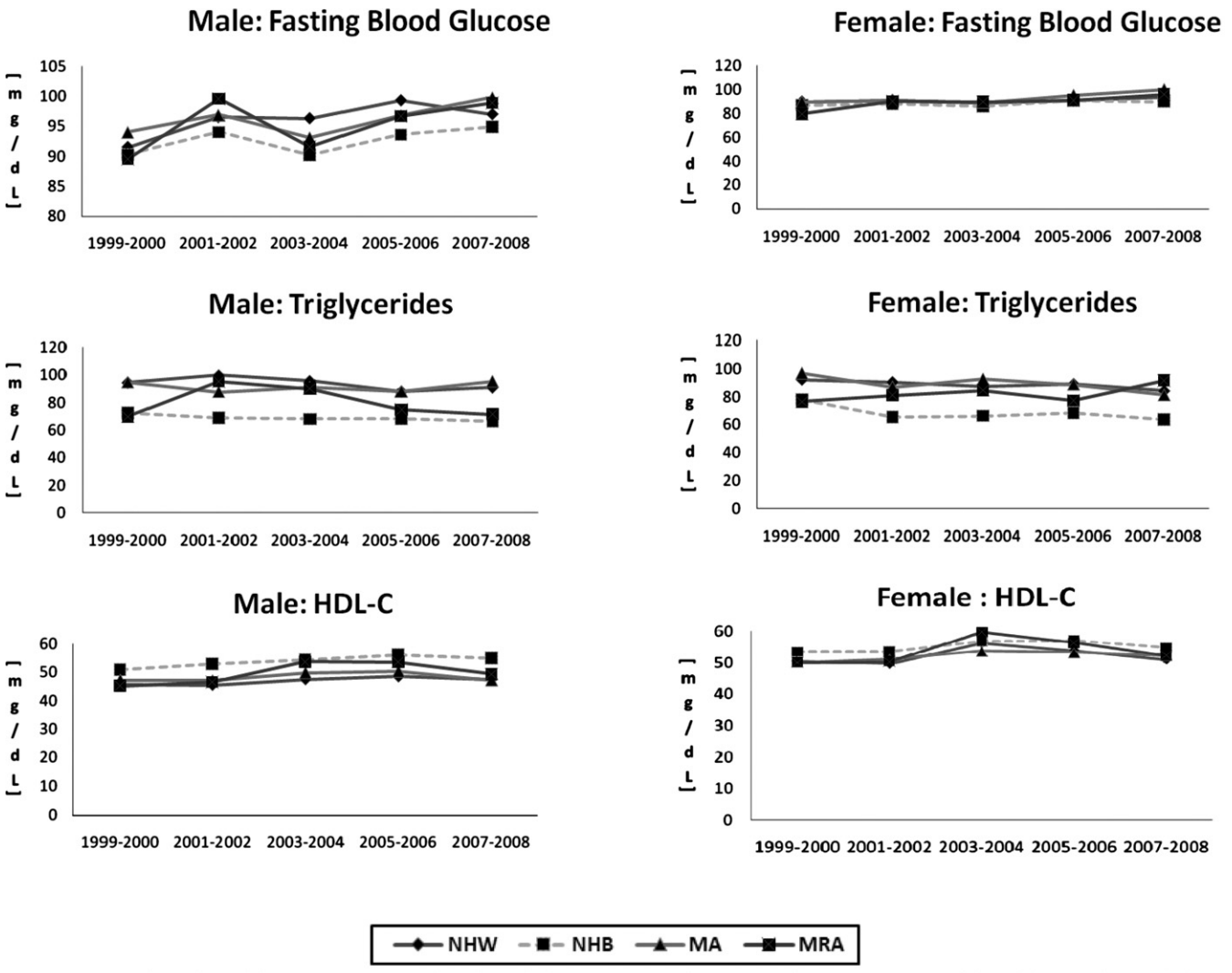



**Figure 2.** Racial/ethnic Trends in Fasting Blood Glucose, HDL-C, and Triglycerides in 12–17-year-old American Adolescents, 1999–2000 to 2007–2008. NHW, non-Hispanic whites; NHB, non-Hispanic blacks; MA, Mexican; Americans; MRA, Multiracial Americans (other Hispanics and other races).

in the mean values of cMetS for each of the studied time points. Overall, cMetS decreased by 93% in the 10-year period between 1999–2000 and 2007–2008. cMetS decreased by 98% and 77.3% for male and female adolescents, respectively, in the period between 1999–2000 and 2007–2008. With the exception of MA and MRA female adolescents, improved cMetS values were recorded for all racial/ethnic groups on comparing mean cMetS values of 1999–2000 with mean values of 2007–2008. The greatest improvement in clustering of cardiometabolic risk factors was observed in the NHB male and female adolescents compared with other racial/ethnic groups.

## Discussion

Although cardiovascular diseases continue to be the leading causes of death in American adults, a steady decline in mortality rates have been observed since the second half of the last century [26,27], and evidence indicates that cardiovascular disease death rates are now leveling off in young adults [28]. On the contrary, the prevalence of many established cardiovascular disease risk factors have not improved or have even increased among adults in past decades [29,30]. Trends in clustering of these cardiometabolic risk factors in U.S. adolescents are unclear because of lack of agreements on cut-points for defining clustering of cardiometabolic risk factors. Studies are usually limited to clustering of cardiometabolic risk factors that is based on risk factor categorization. Because individual cardiometabolic risk factors and clustering of cardiometabolic risk factors early in life are associated with a substantial increase in the risk for cardiovascular disease later, tracking individual cardiometabolic risks factors and clustering of cardiometabolic risk factors in youths are critical for developing behavioral models for forestalling later onset of cardiovascular diseases.

In this study, we described trends of individual cardiometabolic risk factors and clustering of cardiometabolic risk factors using cMetS in a representative sample of NHW, NHB, MA, and

**Table 3**
Trends in clustering of cardiometabolic risk factors in 12–17-year-old American adolescents, 1999–2000 to 2007–2008

| Race/ethnicity | 1999–2000 | 2001–2002 | 2003–2004 | 2005–2006 | 2007–2008 | Relative change[a] (%) | *p* values |
|---|---|---|---|---|---|---|---|
| | | | Males | | | | |
| Non-Hispanic white | .86 ± .002 | 1.12 ± .002 | .69 ± .002 | .57 ± .002 | .32 ± .001 | −62.8* | <.001 |
| Non-Hispanic black | −.22 ± .003 | −.64 ± 004 | −1.30 ± .003 | −1.43 ± .003 | −.67 ± .003 | −64.4* | <.001 |
| Mexican–American | 1.21 ± .004 | .33 ± .003 | −.07 ± .004 | .41 ± .004 | .62 ± .004 | −48.8* | <.001 |
| Multiracial American | −.22 ± .004 | .17 ± .003 | −.61 ± .003 | −1.37 ± .006 | −.56 ± .003 | −60.7* | <.001 |
| *p* value[b] | <.001 | <.001 | <.001 | <.001 | .001 | | |
| | | | Females | | | | |
| Non-Hispanic white | .30 ± .001 | .47 ± .001 | −.38 ± .001 | −.10 ± .002 | .16 ± .001 | −46.7* | <.001 |
| Non-Hispanic black | −.03 ± .003 | −.60 ± 003 | −1.23 ± .003 | −.32 ± .004 | −.08 ± .004 | −62.5* | <.001 |
| Mexican–American | .59 ± .004 | −.06 ± .003 | −.10 ± .004 | .34 ± .005 | .77 ± .004 | +23.3* | <.001 |
| Multiracial American | .22 ± .003 | −.70 ± .003 | −.75 ± .003 | −1.77 ± .003 | .60 ± .005 | +63.3* | <.001 |
| *p* value[b] | <.001 | <.001 | <.001 | <.001 | <.001 | | |
| | | | Overall | | | | |
| | .43 ± .001 | .38 ± .001 | −.18 ± .001 | −.08 ± .001 | .03 ± .001 | −93.0* | <.001 |

Values are cardiometabolic risk factor clustering (cMetS) scores (± standard errors) and a higher score indicates worse cardiometabolic risks clustering.
*p* value; compares values 1999–2000 and 2007–2008 time points.
− and + represents in decreased and increased cMetS values in the period between 1999–2000 and 2007–2008.
[a]Compares 1999–2000 with 2007–2008.
[b]Compares racial/ethnic values (mean ± standard error) within study time point.
* Significant at $p < .001$.

MRA adolescents. To our knowledge, this is the first study to document trends in clustering of cardiometabolic risk factors in American adolescents using cMetS. cMetS is a more robust measure of clustering of cardiometabolic risk factors as compared with a measure that is based on binary classifications [16]. The use of NHANES represents a major advantage of this study because NHANES sampling schemes were representative and national in scope. Additionally, clinical and anthropometric measurements in NHANES were objective and rigorously standardized, and the training programs and quality control measures instituted in NHANES provide added credibility to the data.

The results of this study show gender and racial/ethnic differences in trends for many of the investigated cardiometabolic risk factors. Overall, both American male and female adolescents had significant increases in waist circumference, blood glucose, and HDL-C, and decreases in triglycerides, LDL-C, and MABP in the 10-year period between 1999–2000 and 2007–2008. The highest boosts in waist circumference and blood glucose were observed in NHW and MA male adolescents who gained 2.2 cm and 5.8 mg/dL, respectively, in the period between 1999–2000 and 2007–2008. With the exception of MA male adolescents, a similar trend of increased HDL-C value was observed in NHW, NHB, and MRA. For triglycerides, NHW and MRA male and female adolescents had much less improvement in the 10-year period from 1999–2000 to 2007–2008 compared with their other racial/ethnic counterparts.

Overall, a 93% decrease in cMetS was observed in the period between 1999–2000 and 2007–2008. In male and female adolescents, the highest improvement in clustering of cardiometabolic risk factors defined by decrease in mean values of cMetS between 1999–2000 and 2007–2008 occurred in NHB male and female adolescents. With the exception of NHW adolescents, all racial/ethnic groups also recorded increased values of cMetS in the study period between 2005–2006 and 2007–2008.

Our findings of gender differences in LDL-C values in adolescent are consistent with the findings of other investigators [31,32]. The lower concentration of LDL-C in males is unclear; however, this may be because of hormonal changes that are often experienced by males during puberty [32]. In this study, NHB male and female adolescents experienced a smaller decline in mean serum cholesterol levels compared with NHW male and female adolescents. This finding is consistent with that observed by Kwiterovich [32]. The more favorable cMetS in NHB male and female adolescents compared with their NHW and MA counterparts observed in this study is consistent with the findings of other investigators who defined clustering of cardiometabolic risk factors as having three or more of cardiovascular risk factors using cut-off points [33]. Using 2,436 Hispanics, whites, and black adolescents aged 12–19 years in the 2001–2002, 2003–2004, and 2005–2006 NHANES data, Johnson et al [33] observed that the prevalence of metabolic syndrome was higher in Hispanic (11.2%) and white (8.9%) individuals compared with black individuals (4.0%).

The result of this investigation indicating an overall "superior" cMetS in NHB male and female adolescents compared with NHW and MA is remarkable. Also noteworthy are the "better" lipid profiles in NHB (lower triglycerides, higher HDL cholesterol) with regard to gender, when NHB males were generally as thin as NHW, whereas NHB females were paradoxically generally heavier than NHW and MA. These findings suggest that triglycerides and HDL-C may not have the same causal influence in cardiovascular diseases as other factors of cardiometabolic risk clustering among NHB compared with NHW and MA. This observation calls into question whether even the same set of cardiometabolic risk factors should be used for defining metabolic syndrome in NHW, NHB, MA, and MRA.

The improvements in HDL-C, LDL-C, triglycerides, and MABP in adolescents in the period between 1999–2000 and 2007–2008 as shown in this investigation are accomplishments to be celebrated in an age of cardiovascular risk and disease. It is overreaching to link the observed improvements in HDL-C, LDL-C, triglycerides, and MABP in adolescents to adult cardiovascular diseases. However, the observed improvement in MABP is laudable because an analysis of 2–17-year-old American adolescents by Ford et al [34] using NHANES showed that mean systolic blood pressure increased by 2.2 mm Hg among adolescents 8–17 years of age, whereas mean concentrations of LDL-C, total cholesterol, and HDL-C were relatively unchanged in the period between 1988–1994 and 1999–2000. It is difficult to attribute improvements in HDL-C, LDL-C, triglycerides, and MABP in the period

between 1999–2000 and 2007–2008 to secular increase in mean BMI and decrease in physical activities in U.S. adolescents [35]. Evidence suggests that BMI and physical activity explains only a small amount of the variance in cardiometabolic risk factors during adolescence [36-37]. A rigorous epidemiologic investigation of behavioral correlates of these lipids and blood pressure changes in adolescents is therefore warranted. The observed decreased in triglycerides that is at variance with weight increase over the time span in this study is not clear. Understanding whether studied participants are eating too much of healthier foods, or exercising to the point of keeping their triglyceride levels normal also deserves further investigation.

### *Study limitations*

Some important limitations must be taken into account in the interpretation of the results from this investigation. First, pubertal stage variations were not included in the derivation of cMetS because they were not available in NHANES. It has been suggested that pubertal and maturity-related (age, race/ethnicity, gender) stage variations are important in the development of individual cardiovascular risk factors. In this study, we controlled for age, race/ethnicity, and gender in the computation of cMetS. Second, the influence of sexual maturation in the observed improvements in HDL-C, LDL-C, triglycerides, and MABP was not determined. Studies indicate that sexual maturation is associated with changes in body size and adiposity, and adiposity and height affect blood pressure and others factors of MetS [38,39]. Third, it is noteworthy that lipid profile results from 1999–2000 to 2007–2008 are well within the normal accepted ranges for total cholesterol, HDL-C, LDL-C, and triglyceride. One issue with NHANES data is that we do not know the presence of comorbidities in the studied participants, except that the sample did not contain a large number of subjects with BMIs $>$ 95%.

### *Significance of findings*

Previous studies have demonstrated that cMetS has a strong predictive validity in estimating clustering of cardiometabolic risk factors in youths [40]. Because cMetS tracks down from childhood/adolescence into adulthood [8], early identification of factors that are associated with cMetS may help in designing public health programs for forestalling cMetS-associated sequelae. The ultimate net value of cMetS compared with the dichotomized definition of clustering of cardiometabolic risk factors is unclear.

## Conclusion

Because clustering of cardiometabolic risk factors is predictive of adult health status, early lifestyle intervention in childhood/adolescents may help to slow down the progress and delay or prevent the onset of cardiovascular diseases in adulthood.

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