Original Article

# Low serum high density lipoprotein is associated with the greatest risk of metabolic syndrome among U.S. adults

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A R T I C L E   I N F O

A B S T R A C T

*Aims:* Better understanding risk factors for m etabolic syndrome (MetS) will allow early targeted intervention to mitigate long term risk. We aim to determine the disparate impact of each individual MetS component on overall risk of developing MetS, stratified by sex, race/ethnicity, and age.
*Methods:* Using data from the 2003–2014 National Health and Nutrition Examination Survey (NHANES), MetS prevalence among adults (age ≥18) was stratified by sex, race/ethnicity, age, and by individual MetS components (e.g. hypertension (HTN), diabetes mellitus (DM), waist circumference, serum high density lipoprotein (HDL), serum triglycerides (TG). Mutlivariate logistic regression models were used to evaluate the disparate impact of each risk factor on MetS risk.
*Results:* Overall MetS prevalence was 33.3%, with the highest prevalence among older individuals, among women, and among Hispanics. When stratified by each individual component of MetS, low serum HDL was the strongest predictor of MetS risk overall and among both men and women, among all race/ethnic groups, and among all age groups (overall: OR 20.1, 95% CI 18.6–21.7). While presence of DM also increased an individual's risk of MetS, DM was the weakest predictor of MetS.
*Conclusions:* Among U.S. adults, low serum HDL carries the strongest risk in predicting development of MetS. This effect was seen among men and women, among all race/ethnic groups, and among all age groups, highlighting the importance of low serum HDL as a marker of MetS risk.

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## 1. Introduction

Metabolic syndrome (MetS) is a growing problem in the U.S. that has increased in tandem with the country's obesity epidemic [1,2]. While obesity alone has been linked to a host of negative health effects both immediate and chronic, MetS is emerging as a condition with similarly adverse effects on human health [3–5]. With the prevalence of MetS at 33% and likely rising [1,2,6], its importance in the American healthcare system is increasing as well. Health care costs for workers and their employers can be twice as high for people with MetS with significant decreases in quality of life and productivity [7,8]. The research performed in the National Health and Nutrition Examination Survey (NHANES) has provided an opportunity to analyze important trends in our nation's health. This study aims to evaluate the importance of individual components of the diagnostic criteria for MetS with the goal of identifying the most important risk factors for this illness. This would allow healthcare providers to implement targeted education and interventions among patients who are at greatest risk of developing MetS to prevent and mitigate long-term morbidity and mortality.

## 2. Methods

We performed a cross sectional study using data from the 2003–2014 NHANES registry, a series of cross-sectional, national, stratified, multistage sampling surveys of non-institutionalized U. S. population that are conducted in 2-year cycles. NHANES was approved by the National Center for Health Statistics institutional review board and written consent was obtained from participants. The prevalence of MetS among adults in the U.S. (age >20 years) was determined based on American Heart Association guidelines [9]. Individuals with three or more of the following criteria were

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defined as having MetS: 1) waist circumference >102 cm in men or >88 cm in women; 2) serum triglycerides >150 mg/dL; 3) high density lipoprotein <40 mg/dL in men or <50 mg/dL in women; 4) blood pressure >130/85 mmHg or currently taking anti-hypertensive medications; 5) fasting glucose > 100 mg/dL or currently on DM medications.

Using sampling weights to ensure prevalence estimates are representative of U.S. population, we further stratified prevalence estimates of MetS by sex, race/ethnicity (non-Hispanic white, blacks, Hispanics, and other race) and age groups (<40 years, 40–59 years, 60 years and over). Prevalence of MetS was also stratified by individual MetS components (e.g. hypertension (HTN), diabetes mellitus (DM), waist circumference, serum high density lipoprotein (HDL), serum triglycerides (TG)). All prevalence estimates were reported as percentages (%) and frequencies (N), with standard errors (SE). To evaluate the disparate impact of each component on MetS risk, we used multivariate logistic regression models stratified by sex, race/ethnicity, and age groups. Forward stepwise logistic regression methods included variables deemed to be biologically significant a priori (e.g. age, sex) or those variables that demonstrated significant associations ($p < 0.10$) in the univariate models. The final model included sex, age, race/ethnicity, and MetS components. Statistical significance was met with a two-tailed p-value < 0.05. Statistical analyses were performed using Stata statistical package (version 13, Stata Corporations, TX).

## 3. Results

From 2003 to 2014 the prevalence of MetS was 33.3% with significantly higher rates seen in women (35.8%) compared to men (30.7%) (Fig. 1). Race/ethnicity stratified analyses demonstrated the lowest prevalence of MetS in African Americans (32.8%) followed by non-Hispanic whites (34.0%) and Hispanics (35.8%). Age-specific analyses demonstrated that highest MetS prevalence among the oldest cohort (age ≥65 years) (47.2%) and the lowest MetS prevalence among the youngest cohort (age <40 years) (18.5%).

MetS prevalence was further stratified by individuals who met individual components of the diagnostic criteria (Fig. 2). For example, 53.8% of people who had enlarged waist circumference were positive for MetS, whereas MetS prevalence was 6.6% among individuals who did not have enlarged waist circumference, $p < 0.01$. Similar patterns were observed for HTN (65.4% MetS prevalence among patients with HTN vs 16.7% MetS prevalence among individuals without HTN, $p < 0.01$), TG (60.5% MetS prevalence among individuals with elevated TG vs 17.0% MetS prevalence among individuals with normal TG, $p < 0.01$), HDL (70.1% MetS prevalence among individuals with low HDL vs 19.8% among individuals with normal HDL, $p < 0.01$), and DM (67.1% MetS prevalence among individuals with DM vs. 20.2% MetS prevalence among individuals without DM, $p < 0.05$) (Fig. 2).

The impact of each MetS component on overall risk of developing MetS was evaluated with multivariate logistic regression models. Overall, an HDL level less than 40 in men or less than 50 in women demonstrated the greatest impact on risk of MetS (OR, 20.1, 95% CI 18.6-21.7) (Table 1). To further understand the disparate impact of each MetS component on overall risk of developing MetS, we additionally stratified our regression analyses by sex, age, and race/ethnicity to understand if the impact of each component varied by these subgroups (Table 1). Despite stratification by sex, race/ethnicity, or age, low HDL levels remained one of the greatest factors contributing to MetS risk (Table 1).

## 4. Discussion

Our current study utilizing the most recent version of the U.S. NHANES data specifically evaluated the disparate impact of individual risk factors on overall risk of MetS. Overall, decreased HDL levels demonstrated the greatest impact on risk of MetS across all groups analyzed.

While the prevalence of MetS increased with increasing age, our study demonstrated that the impact of individual risk factors on risk of MetS decreased among the older aged cohort. The odds ratios for the two most predictive criteria (low HDL and increased waist circumference) are roughly twice as large for the youngest
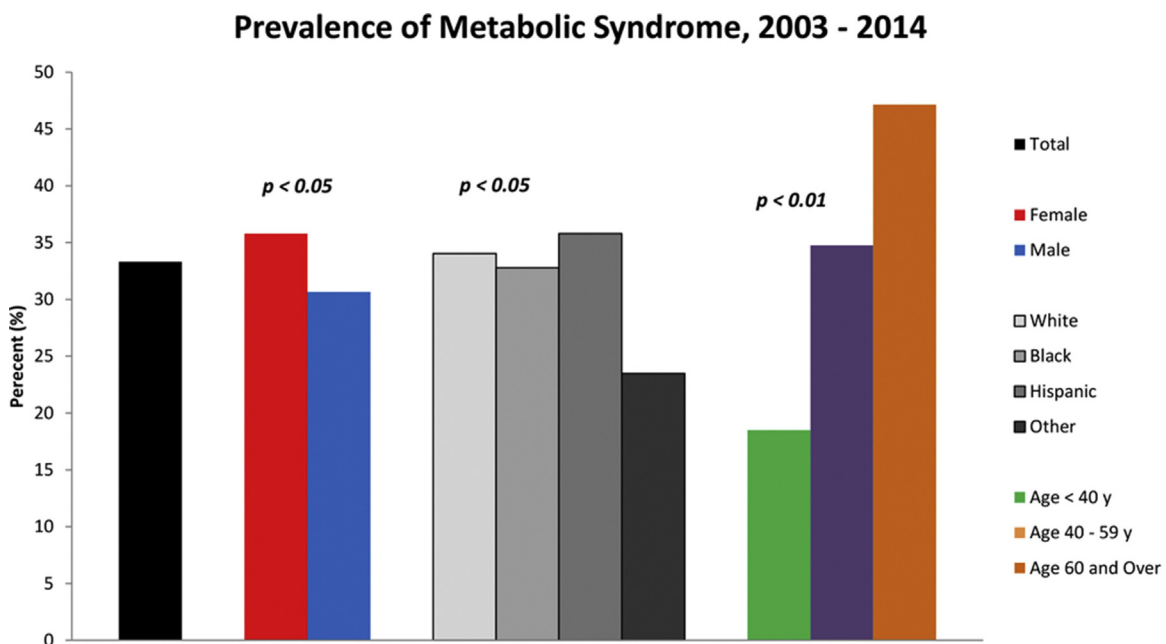


**Fig. 1.** Prevalence of Metabolic Syndrome among U.S. adults, 2003–2014.