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Prevalence and Associations Between Metabolic Syndrome Components and Hyperuricemia by Race: Findings From US Population, 2011–2020

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Objective. We explored the trend in prevalence of hyperuricemia and metabolic syndrome in US populations and investigated associations between components of metabolic syndrome and hyperuricemia by race.

Methods. We analyzed data from the four most recent National Health and Nutrition Examination Survey (NHANES) cycles (2011 to March 2020), comprising 10,175 participants. Hyperuricemia is defined as serum urate >7.0 mg/dL (men) or >5.7 mg/dL (women), following the NHANES-III guideline. The definition of metabolic syndrome follows the National Cholesterol Education Program's Adult Treatment Panel III guideline. We estimated the prevalence of metabolic syndrome and hyperuricemia in each cycle and performed subgroup analyses with logistic regression to investigate the patterns of associated components of metabolic syndrome with hyperuricemia.

Results. In the most recent cycle (2017 to March 2020), the prevalence of metabolic syndrome was 45.9% and that of hyperuricemia was 20.7%. Over the 2011 to 2020 period, a significant rise in metabolic syndrome prevalence was observed among Hispanic and Asian populations, and the prevalence of hyperuricemia has increased significantly only in the Hispanic population. After adjustment for confounding factors, patients with metabolic syndrome exhibited a higher hyperuricemia in women than in men. Elevated blood pressure was the strongest factor with hyperuricemia. The association was the weakest in the Asian population. Waist circumference was the only significant factor associated with hyperuricemia in the Asian population.

Conclusion. The prevalence of metabolic syndrome has an increasing pattern, but there was no specific decadal trend in prevalence of hyperuricemia. There is an ethnicity-specific association of metabolic syndrome and hyperuricemia, especially among Asians.

INTRODUCTION

Uric acid is the metabolic end-product produced in the final step of purine metabolism.[1] Hyperuricemia is defined as a condition of increased serum uric acid (SUA) concentration over 7.0 mg/dL in men and 5.7mg/dL in women.[2] Hyperuricemia is widely known as a major cause of gout, a type of inflammatory arthritis.[3] Associations of SUA concentration with cardiovascular and renal diseases have also been reported.[4] In an umbrella review in the *British Medical Journal*, 20 meta-analyses of randomized controlled trials and 56 meta-analyses of Mendelian randomized studies found no association between SUA and health outcomes except for nephrolithiasis or gout.[5]

Metabolic syndrome is an important predictor of potential type 2 diabetes mellitus patients, increasing the risk for type 2 diabetes mellitus by ~5-fold.[6] About 20% to 30% of the adult population have metabolic syndrome, varying in different countries.[6] Metabolic syndrome is associated with insulin resistance, obesity, atherogenic dyslipidemia, and hypertension.[7] Individuals with metabolic syndrome are essentially at a twice higher risk of cardiovascular diseases compared with those without metabolic syndrome. Intriguingly, a notably high prevalence of

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SIGNIFICANCE & INNOVATIONS

- We showed the decadal trend of metabolic syndrome and hyperuricemia and investigated associations between each metabolic component and hyperuricemia.
- We showed ethnicity-specific patterns in associations between the components of metabolic syndrome and hyperuricemia, especially in the Asian population.

metabolic syndrome has been observed in individuals with gout.[8,9] Various studies have reported a positive association between hyperuricemia and metabolic syndrome in both healthy patients and patients with disease across different ethnic groups.[7]

Previous studies have shown that hyperuricemia is associated with insulin resistance.[10–12] A recent study has found that hyperinsulinemia is causally associated with hyperuricemia.[13] Given that insulin resistance is believed to affect metabolic syndrome, insulin resistance may be a causal factor for hyperuricemia.[14] However, the intricate associations between metabolic components and hyperuricemia remain not fully understood.

In this study, we hypothesized that there is an ethnicity-specific pattern in metabolic syndrome and hyperuricemia. There has been a rapid change in the prevalence of metabolic syndrome and hyperuricemia considering socioeconomic status and food consumption.[15,16] To explore this hypothesis, we used data from the National Health and Nutrition Examination Survey (NHANES) spanning from 2011 to 2020 and investigated the change in prevalence of metabolic syndrome and hyperuricemia. We analyzed the associations between each component of metabolic syndrome with hyperuricemia across different ethnic groups.

MATERIALS AND METHODS

Study population. The NHANES program includes a series of cross-sectional surveys designed to assess the health and nutritional status of adults and children in the US. In each survey cycle, a nationally representative sample of the US civilian noninstitutionalized population is selected using a complex, stratified, multistage probability cluster sampling design. For this analysis, we focused on the four most recent NHANES cycles, covering the period from 2011 to March 2020 (NHANES 2011 to March 2020).

Among the 45,462 participants involved in the NHANES 2011 to March 2020, we excluded those aged 20 years or less and those with missing variables, resulting in a final analytical sample of 10,175 participants (Figure 1). Approval for the NHANES was obtained from the National Center for Health Statistics Research Ethics Review Board, and informed consent was secured from each participant.

The prevalence of metabolic syndrome or hyperuricemia was calculated over time and across different ethnicities, including White, Hispanic, Black, Asian, and Others. The "Others" ethnicity category was designated for participants who identified themselves as belonging to other or multiethnic groups, as outlined in NHANES manuals.

Definitions of metabolic syndrome and hyperuricemia. Metabolic syndrome was defined according to the criteria outlined in the National Cholesterol Education

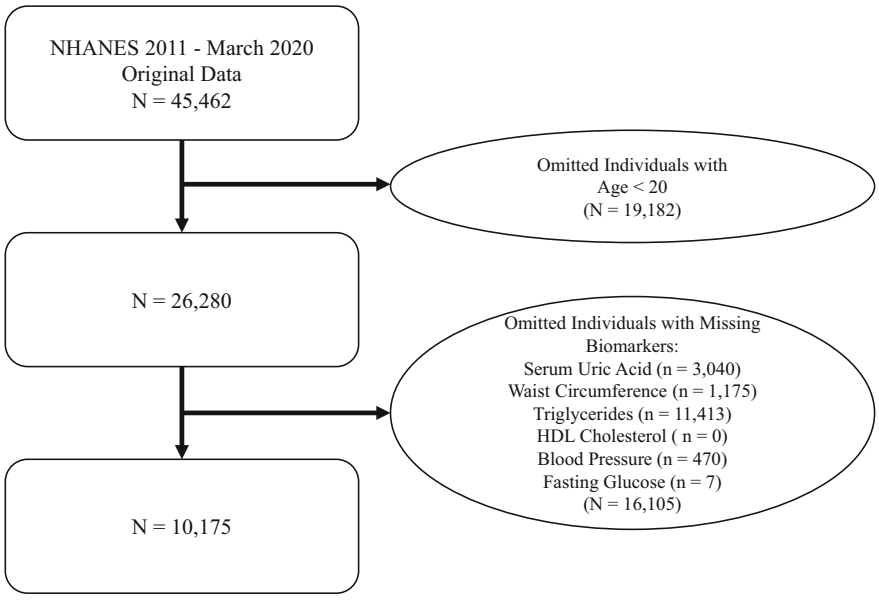

Figure 1. Flowchart of the study participants. HDL, high-density lipoprotein; NHANES, National Health and Nutrition Examination Survey.

Program's Adult Treatment Panel III, requiring the presence of at least three of the following components: waist circumference ≥102 cm in men or ≥88 cm in women (≥90 cm in Asian men or ≥80 cm in Asian women), triglyceride level ≥150 mg/dL or the use of medication to lower cholesterol, high-density lipoprotein cholesterol <40 mg/dL in men or <50 mg/dL in women or the use of medication to lower cholesterol, systolic blood pressure ≥130 mm Hg or diastolic blood pressure ≥85 mm Hg or the use of antihypertensive medications, and fasting plasma glucose level ≥100 mg/dL or the use of diabetes mellitus medications. Hyperuricemia was defined as a serum urate level exceeding 7.0 mg/dL in men and 5.7 mg/dL in women, consistent with the criteria used in a previous NHANES study and as outlined in NHANES-III manuals.[2,17]

Statistical analysis. Statistical analyses were performed using survey commands of Stata (Version 17, StataCorp) to incorporate sample weights.[18] The prevalence (%) of metabolic syndrome and hyperuricemia were initially calculated in the entire US adult population and then stratified by sex and ethnicity.

To examine trends over a decade, data from four cycles of the continuous NHANES (2011 to 2012, 2013 to 2014, 2015 to 2016, and 2017 to 2020) were used. We employed logistic regression using the midpoint from each NHANES cycle as a continuous independent variable, with metabolic syndrome and hyperuricemia prevalence modeled as a function of survey cycle.[19] Sex-specific logistic regression models were used to assess associations of metabolic syndrome components with hyperuricemia. Model 1 includes

Table 1. Metabolic syndrome and hyperuricemia prevalence in the United States, NHANES 2011 to March 2020*

Characteristics	Outcome	Prevalence by cycle, % (95% CI)				
		2011–2012 (N = 2,244)	2013–2014 (N = 2,359)	2015–2016 (N = 2,118)	2017–March 2020 (N = 3,454)	*P* for trend[a]
Total population	Metabolic syndrome	42.6 (38.8–46.5)	42.4 (39.4–45.5)	48.2 (45.0–51.5)	45.9 (42.9–48.9)	0.09
	Hyperuricemia	21.4 (19.4–23.3)	20.8 (19.2–22.4)	20.4 (17.3–23.4)	20.7 (18.5–22.8)	0.67
Sex						
Men	Metabolic syndrome	43.2 (38.2–47.2)	43.1 (38.3–48.0)	50.7 (46.0–55.4)	45.2 (39.8–50.7)	0.43
	Hyperuricemia	20.3 (17.4–23.2)	20.7 (18.1–23.3)	20.7 (16.3–25.0)	19.6 (16.7–22.4)	0.67
Women	Metabolic syndrome	42.1 (37.1–47.0)	41.7 (37.6–45.9)	45.9 (41.7–50.0)	46.6 (42.6–50.6)	0.08
	Hyperuricemia	22.4 (19.4–25.4)	20.9 (18.0–23.7)	20.1 (16.8–23.5)	21.8 (19.3–24.3)	0.86
Age, y						
20–39	Metabolic syndrome	17.6 (15.0–20.3)	21.4 (16.7–26.2)	22.2 (18.0–26.4)	24.7 (20.7–28.8)	0.01[b]
	Hyperuricemia	18.7 (14.8–22.5)	15.6 (11.8–19.3)	18.0 (12.0–24.1)	17.6 (14.0–21.2)	0.97
40–59	Metabolic syndrome	47.1 (41.3–52.8)	45.3 (41.4–49.2)	52.5 (46.8–58.1)	46.8 (41.7–51.8)	0.81
	Hyperuricemia	20.1 (15.4–24.8)	21.8 (18.6–25.0)	18.6 (14.2–23.0)	18.3 (15.4–21.1)	0.29
≥60	Metabolic syndrome	70.4 (64.6–76.2)	65.2 (60.5–70.0)	69.0 (65.0–73.0)	72.0 (68.7–75.3)	0.25
	Hyperuricemia	26.9 (22.1–31.6)	26.0 (21.9–30.0)	24.8 (20.5–29.2)	27.4 (23.6–31.2)	0.78
Ethnicity						
White	Metabolic syndrome	44.7 (40.2–49.2)	44.7 (40.8–48.6)	51.2 (46.4–56.1)	47.3 (43.5–51.0)	0.24
	Hyperuricemia	22.9 (19.9–25.9)	21.9 (19.1–24.7)	21.2 (17.0–25.4)	20.4 (17.9–22.9)	0.20
Black	Metabolic syndrome	41.7 (37.6–45.8)	40.4 (35.4–45.5)	40.8 (36.8–44.8)	41.5 (36.8–46.2)	0.95
	Hyperuricemia	23.2 (18.0–28.4)	23.4 (19.7–27.1)	24.4 (21.3–26.9)	23.7 (21.4–26.0)	0.84
Hispanic	Metabolic syndrome	35.6 (30.7–40.5)	36.4 (32.2–40.7)	41.6 (37.1–46.2)	42.2 (37.6–46.8)	0.03[b]
	Hyperuricemia	12.6 (9.8–15.4)	13.5 (10.2–16.9)	17.8 (14.1–21.5)	18.2 (13.8–22.7)	0.02[b]
Asian	Metabolic syndrome	36.8 (27.5–46.1)	34.9 (28.0–41.9)	41.1 (35.2–47.0)	45.8 (40.2–51.3)	0.03[b]
	Hyperuricemia	21.0 (17.7–24.3)	24.7 (19.0–30.4)	19.5 (12.1–26.9)	23.8 (18.6–29.1)	0.63
Others	Metabolic syndrome	41.5 (26.0–56.9)	41.1 (27.6–54.6)	50.9 (39.4–62.5)	50.7 (39.6–61.7)	0.27
	Hyperuricemia	24.6 (3.2–46.1)	12.7 (3.7–21.7)	8.4 (2.5–14.3)	21.4 (12.5–30.4)	0.87

* Data were adjusted for clusters and strata of the complex sample design of the NHANES 2011 to March 2020, with incorporation of sample weights. Values are presented as weighted percentage and subgroup population in the bracket. Metabolic syndrome was defined using the NCEP ATP III guideline (any three or more of the following five factors: central obesity, raised triglycerides, reduced HDL cholesterol, raised blood pressure, raised fasting plasma glucose); hyperuricemia was defined as a serum urate level of >7.0 mg/dL in males and >5.7 mg/dL in females. HDL, high-density lipoprotein; NCEP ATP III, National Cholesterol Education Program's Adult Treatment Panel III; NHANES, National Health and Nutrition Examination Survey; 95% CI, 95% confidence interval.

[a] *P* for trend is calculated through logistic regression analysis.

[b] Significant *P* value.

adjustments for age and ethnicity (White, Hispanic, Black, Asian, Others). Model 2 was further adjusted for education level (less than college education, college education or more, or unknown), alcohol consumption frequency (<2 times/week, ≥2 times/week, or unknown), smoking (never, past, current, or unknown), and vigorous exercise (<3 times/week versus ≥3 times/week). Model 3 additionally considered eGFR (estimated glomerular filtration rate), obesity (body mass index [BMI] ≥25 for Asian or BMI ≥30 for other ethnicities, non-obese), and other components of metabolic syndrome. eGFR, calculated using the Modification of Diet in Renal Disease equations, eGFR = 175 × (serum creatinine)$^{-1.154}$ × (age)$^{-0.203}$ × 0.742 [if female] × 1.212 [if Black]),[20] has a known negative correlation with SUA levels, necessitating adjustment.[21,22] We further explored the interaction between metabolic syndrome components and ethnicity by adding an interaction term in regression models. Post hoc analyses, using adjusted Wald tests, were performed to assess ethnic differences in multiplicative interactions.

RESULTS

Decadal trends in the prevalence of metabolic syndrome in NHANES 2011 to March 2020. In the recent cycle (2017 to March 2020), the prevalence of metabolic syndrome in the total population was 45.9% (95% confidence interval [95% CI] 42.9%–48.9%). There is a trend of increased metabolic syndrome (Table 1). There was no significant

Table 2. Clinical characteristics of participants, NHANES 2011 to March 2020*

Characteristics	Total (N = 10,175)	Men (N = 5,017)	Women (N = 5,158)	*P* value[a]
Sex, N (%)	10,175 (100)	5,017 (49.4)	5,158 (50.6)	
Age, mean ± SD, y	48.1 ± 16.9	47.6 ± 16.8	48.6 ± 17.0	<0.01
Ethnicity, N (%)				<0.01
White	3,844 (66.1)	1,955 (66.9)	1,889 (65.3)	
Black	2,255 (10.2)	1,064 (9.0)	1,191 (11.3)	
Hispanic	2,440 (15.0)	1,178 (15.5)	1,262 (14.4)	
Asian	1,262 (5.4)	625 (5.2)	637 (5.6)	
Other	374 (3.4)	195 (3.5)	179 (3.4)	
Education, N (%)				<0.01
Less than college	4,415 (36.7)	2,305 (38.5)	2,110 (34.9)	
College or more	5,755 (63.3)	2,708 (61.5)	3,047 (65.1)	
Unknown	5 (0.0)	4 (0.0)	1 (0.0)	
Smoking status, N (%)				<0.01
Never	5,743 (55.7)	2,327 (47.8)	3,416 (63.3)	
Past	2,432 (25.9)	1,512 (31.7)	920 (20.3)	
Current	1,991 (18.4)	1,173 (20.4)	818 (16.4)	
Unknown	9 (0.0)	5 (0.0)	4 (0.0)	
Alcohol consumption frequency, N (%)				<0.01
<2/week	6,421 (62.4)	3,166 (59.6)	3,255 (65.0)	
≥2/week	1,959 (24.2)	1,287 (31.2)	672 (17.4)	
Unknown	1,795 (13.4)	564 (9.2)	1,231 (17.6)	
Regular exercise, N (%)				<0.01
<3/week	4,605 (41.7)	1,971 (35.7)	2,634 (47.6)	
≥3/week	5,570 (58.3)	3,046 (64.3)	2,524 (52.4)	
BMI, mean ± SD, kg/m^2	29.3 ± 7.0	29.0 ± 6.0	29.6 ± 7.8	<0.01
Obese, N (%)	4,405 (40.5)	2,006 (38.4)	2,399 (42.4)	0.03
eGFR, mean ± SD, mL/min/1.73 m^2	90.0 ± 23.6	89.9 ± 22.2	90.1 ± 25.0	0.70
SUA, mean ± SD, mg/dL	5.4 ± 1.4	6.0 ± 1.2	4.8 ± 1.3	<0.01
Hyperuricemia, N (%)	2,186 (20.8)	1,058 (20.2)	1,128 (21.4)	0.26
Waist circumference, mean ± SD, cm	100.0 ± 16.8	102.0 ± 15.9	98.1 ± 17.4	<0.01
Triglycerides, mean ± SD, mg/dL	111.9 ± 65.6	119.2 ± 70.8	104.8 ± 59.4	<0.01
Total cholesterol, mean ± SD, mg/dL	189.1 ± 40.6	184.9 ± 40.1	193.2 ± 40.7	<0.01
HDL-C, mean ± SD, mg/dL	54.6 ± 16.5	49.2 ± 13.6	59.8 ± 17.3	<0.01
LDL-C, mean ± SD, mg/dL	112.1 ± 35.4	111.8 ± 35.6	112.5 ± 35.2	0.46
Systolic blood pressure, mean ± SD, mm Hg	121.5 ± 16.9	123.5 ± 15.4	119.6 ± 17.9	<0.01
Diastolic blood pressure, mean ± SD, mm Hg	71.0 ± 11.8	72.2 ± 12.0	69.9 ± 11.5	<0.01
Fasting glucose, mean ± SD, mg/dL	107.5 ± 30.9	110.4 ± 33.2	104.6 ± 28.3	<0.01
Metabolic syndrome, N (%)	4,838 (45.0)	2,409 (45.5)	2,429 (44.4)	0.53

* Data were adjusted for clusters and strata of the complex sample design of the NHANES 2011 to March 2020, with incorporation of sample weights. Values are presented as weighted mean ± SD or unweighted n (weighted %). BMI, body mass index; eGFR, estimated glomerular filtration rate; HDL-C, high-density lipoprotein cholesterol; LDL-C, low-density lipoprotein cholesterol; NHANES, National Health and Nutrition Examination Survey; SUA, serum uric acid.

[a] For continuous variables, *P* values are calculated through independent *t*-test, and for categorical variables, *P* values are calculated through chi-squared test.

difference in the prevalence of metabolic syndrome between men and women (45.2% vs 46.6%; $P = 0.71$). The highest prevalence of metabolic syndrome was observed among individuals categorized as "Others" ethnicity (50.7%), followed by White (47.3%) and Asian (45.8%) participants (Table 1). There was a statistically significant increase in the prevalence of metabolic syndrome among those aged 20 to 39 years across 5 NHANES cycles (from 17.6% to 24.7%; $P = 0.01$ for trend). The prevalence of metabolic syndrome significantly increased across five NHANES cycles in the Hispanic (from 35.6% to 42.2%; $P = 0.03$ for trend) and Asian (from 36.8% to 45.8%; $P = 0.03$ for trend) populations (Supplementary Figure 1).

Decadal trends of hyperuricemia prevalence in the NHANES 2011 to March 2020. In the most recent cycle (2017 to March 2020), the prevalence of hyperuricemia in the total population was 20.7% (95% CI 18.5%–22.8%). There was no significant difference in its prevalence between men and women (19.6% vs 21.8%; $P = 0.19$). The highest prevalence of hyperuricemia was observed in the age group of 60 years and over. Throughout the study period, the prevalence of hyperuricemia in the total population did not exhibit statistically significant changes ($P = 0.67$ for trend). However, there was a significant increase in the prevalence of hyperuricemia specifically among the Hispanic population (from 12.6% to 18.2%; $P = 0.02$ for trend; see Table 1).

Population demographics. Clinical characteristics of the whole study population according to sex are shown in Table 2. The mean age was 48.1 years. Women account for 50.6% of the participants. Mean SUA level, triglycerides, blood pressure, and fasting glucose were higher in men than in women. Mean BMI and high-density lipoprotein (HDL) cholesterol were higher in women than in men. The mean ± BMI was different across the different ethnic groups: 29.2 ± 5.2 in the White, 30.0 ± 8.1 in the Hispanic, 30.9 ± 11.6 in the Black, 25.0 ± 7.1 in the Asian, and 29.5 ± 7.4 in the Others populations (data not shown). The number of patients with metabolic syndrome and hyperuricemia was higher among women than among men.

Associations of metabolic components with hyperuricemia by sex. The SUA level was found to be significantly higher in individuals with metabolic syndrome compared with those in the normal group (5.83 ± 1.49 [N = 4,848] vs 5.14 ± 1.31 [N = 5,337], $P < 0.01$; Supplementary Figure 2). In quartile analysis, there was an increasing trend in prevalence of metabolic syndrome in higher SUA quartile groups (Supplementary Table 1). Furthermore, the metabolic syndrome group demonstrated a higher prevalence of hyperuricemia than the normal group (27.4% vs 14.2% in men, 34.1% vs 11.2% in women). The association was more pronounced in women than in men (see Tables 3 and 4). In men, the groups with central obesity (high waist circumference), high triglycerides, and elevated blood pressure exhibited higher odds of hyperuricemia compared with the normal group (Table 3). For women, the groups with central obesity, low HDL cholesterol, elevated blood pressure, and high fasting glucose had higher odds of hyperuricemia than the normal group (Table 4). Among the components of metabolic syndrome, central obesity and elevated blood pressure

Table 3. Associations of metabolic syndrome components with hyperuricemia in men, NHANES 2011 to March 2020*

Men (N = 5,017)	Prevalence of hyperuricemia, % (95% CI)	Odds ratio (95% CI)			
		Unadjusted	Model 1[a]	Model 2[b]	Model 3[c]
Normal	14.2 (12.1–16.5)	1.00 (ref)	1.00 (ref)	1.00 (ref)	1.00 (ref)
Metabolic syndrome	27.4 (24.8–30.2)	2.29 (1.80–2.92)	2.65 (2.04–3.44)	2.68 (2.05–3.49)	2.06 (1.54–2.75)[d,e]
Normal	13.4 (11.5–15.5)	1.00 (ref)	1.00 (ref)	1.00 (ref)	1.00 (ref)
Central obesity	27.4 (24.9–30.1)	2.45 (1.96–3.05)	2.53 (1.85–2.99)	2.59 (2.04–3.30)	1.69 (1.24–2.31)[e]
Normal	16.8 (14.7–19.1)	1.00 (ref)	1.00 (ref)	1.00 (ref)	1.00 (ref)
High triglycerides	25.1 (22.3–28.2)	1.67 (1.32–2.11)	1.74 (1.35–2.25)	1.72 (1.33–2.20)	1.56 (1.11–2.17)[e]
Normal	18.6 (16.6–20.8)	1.00 (ref)	1.00 (ref)	1.00 (ref)	1.00 (ref)
Low HDL cholesterol	22.7 (20.2–25.3)	1.28 (1.05–1.57)	1.30 (1.06–1.59)	1.33 (1.08–1.64)	0.78 (0.60–1.02)
Normal	15.7 (13.4–17.7)	1.00 (ref)	1.00 (ref)	1.00 (ref)	1.00 (ref)
Elevated blood pressure	25.9 (23.5–28.4)	1.87 (1.57–2.23)	2.07 (1.70–2.53)	2.06 (1.69–2.52)	1.66 (1.33–2.08)[e]
Normal	17.1 (14.8–19.8)	1.00 (ref)	1.00 (ref)	1.00 (ref)	1.00 (ref)
High fasting glucose	22.0 (20.0–24.2)	1.37 (1.11–1.69)	1.41 (1.13–1.76)	1.41 (1.13–1.75)	1.09 (0.86–1.39)

* Data were adjusted for clusters and strata of the complex sample design of the NHANES 2011 to March 2020, with incorporation of sample weights. Values are presented with range within 95% CI in the bracket. BMI, body mass index; HDL, high-density lipoprotein; NHANES, National Health and Nutrition Examination Survey; ref, reference; 95% CI, 95% confidence interval.
[a] Model 1: adjusted for age and ethnicity.
[b] Model 2: adjusted for model 1 covariates plus education level (less than college, college or more, unknown), smoking status (never, past, current, unknown), alcohol consumption frequency (<2, ≥2 times/week, unknown), regular exercise (<3, ≥3 times/week).
[c] Model 3: adjusted for model 2 covariates plus estimated glomerular filtration rate, obesity (obese: BMI ≥25 for Asian or BMI ≥30 for the other ethnicities, nonobese), and all the other components of metabolic syndrome.
[d] Model 3 for overall associations with metabolic syndrome: model 3 without components of metabolic syndrome.
[e] Significant *P* value.

Table 4. Associations of metabolic syndrome components with hyperuricemia in women, NHANES 2011 to March 2020*

Women (N = 5,158)	Prevalence of hyperuricemia, % (95% CI)	Odds ratio (95% CI)			
		Unadjusted	Model 1[a]	Model 2[b]	Model 3[c]
Normal	11.2 (9.6–13.0)	1.00 (ref)	1.00 (ref)	1.00 (ref)	1.00 (ref)
Metabolic syndrome	34.1 (31.8–36.5)	4.11 (3.42–4.95)	3.70 (3.12–4.40)	3.84 (3.23–4.57)	2.79 (2.32–3.36)[d,e]
Normal	7.4 (5.7, 9.5)	1.00 (ref)	1.00 (ref)	1.00 (ref)	1.00 (ref)
Central obesity	27.1 (25.4–29.0)	4.70 (3.54–6.24)	4.23 (3.22–5.54)	4.22 (3.21–5.55)	1.94 (1.44–2.62)[e]
Normal	16.0 (14.1–18.1)	1.00 (ref)	1.00 (ref)	1.00 (ref)	1.00 (ref)
High triglycerides	32.5 (29.6–35.6)	2.53 (2.01–3.19)	2.12 (1.70–2.65)	2.14 (1.69–2.69)	1.27 (0.98–1.63)
Normal	14.7 (12.7–16.9)	1.00 (ref)	1.00 (ref)	1.00 (ref)	1.00 (ref)
Low HDL cholesterol	30.5 (27.9–33.2)	2.55 (2.02–3.21)	2.34 (1.86–2.94)	2.40 (1.89–3.06)	1.40 (1.08–1.81)[e]
Normal	13.1 (11.4–14.9)	1.00 (ref)	1.00 (ref)	1.00 (ref)	1.00 (ref)
Elevated blood pressure	33.9 (31.5–36.4)	3.41 (2.81–4.14)	3.02 (2.44–3.74)	3.06 (2.47–3.79)	2.12 (1.63–2.75)[e]
Normal	14.1 (12.3–16.2)	1.00 (ref)	1.00 (ref)	1.00 (ref)	1.00 (ref)
High fasting glucose	29.4 (27.1–31.8)	2.53 (2.07–3.08)	2.15 (1.79–2.59)	2.16 (1.80–2.60)	1.34 (1.10–1.65)[e]

* Data were adjusted for clusters and strata of the complex sample design of the NHANES 2011 to March 2020, with incorporation of sample weights. Values are presented with range within 95% CI in the bracket. BMI, body mass index; HDL, high-density lipoprotein; NHANES, National Health and Nutrition Examination Survey; ref, reference; 95% CI, 95% confidence interval.
[a] Model 1: adjusted for age and ethnicity.
[b] Model 2: adjusted for model 1 covariates plus education level (less than college, college or more, unknown), smoking status (never, past, current, unknown), alcohol consumption frequency (<2, ≥2 times/week, unknown), regular exercise (<3, ≥3 times/week).
[c] Model 3: adjusted for model 2 covariates plus estimated glomerular filtration rate, obesity (obese: BMI ≥25 for Asian or BMI ≥30 for the other ethnicities, nonobese), and all the other components of metabolic syndrome.
[d] Model 3 for overall associations with metabolic syndrome: model 3 without components of metabolic syndrome.
[e] Significant *P* value.

displayed the strongest associations with hyperuricemia in men and women, respectively.

Ethnic difference for the association between metabolic syndrome and hyperuricemia. In all ethnic groups, those with metabolic syndrome had higher odds of hyperuricemia than normal controls. The odds ratio (OR) is 2.51 (95% CI 2.03–3.11) in the White, 1.77 (95% CI 1.36–2.31) in the Black, 2.38 (95% CI 1.67–3.40) in the Hispanic, 1.67 (95% CI 1.12–2.47) in the Asian, and 5.13 (95% CI 2.25–11.69) in the Others populations (Table 5). In the fully adjusted model, elevated blood pressure exhibited the strongest association with hyperuricemia in the White, Hispanic, and Black groups (Table 5). In Asians, central obesity was the most significant factor associated with hyperuricemia. We observed diminished association of elevated blood pressure with hyperuricemia in Asians through regression analysis with interaction terms (data not shown).

Table 5. Association of metabolic syndrome components with hyperuricemia by ethnicity, NHANES 2011 to March 2020*

	Fully adjusted[a] (model 3), odds ratio (95% CI)				
	White, N = 3,844	Black, N = 2,255	Hispanic, N = 2,440	Asian, N = 1,262	Others, N = 374
Normal	1.00 (ref)	1.00 (ref)	1.00 (ref)	1.00 (ref)	1.00 (ref)
Metabolic syndrome[b]	2.51 (2.03–3.11)[c]	1.77 (1.36–2.31)[c]	2.38 (1.67–3.40)[c]	1.67 (1.12–2.47)[c]	5.13 (2.25–11.69)[c]
Normal	1.00 (ref)	1.00 (ref)	1.00 (ref)	1.00 (ref)	1.00 (ref)
Central obesity	1.58 (1.21–2.05)[c]	1.25 (0.90–1.74)	1.61 (1.08–2.39)[c]	2.28 (1.59–3.27)[c]	1.00 (0.31–3.20)
Normal	1.00 (ref)	1.00 (ref)	1.00 (ref)	1.00 (ref)	1.00 (ref)
High triglycerides	1.44 (1.06–1.96)[c]	1.16 (0.76–1.76)	1.56 (1.08–2.26)[c]	1.30 (0.87–1.95)	3.05 (1.23–7.59)[c]
Normal	1.00 (ref)	1.00 (ref)	1.00 (ref)	1.00 (ref)	1.00 (ref)
Low HDL cholesterol	0.97 (0.75–1.25)	1.16 (0.80–1.69)	1.11 (0.82–1.49)	1.12 (0.74–1.71)	2.26 (0.99–5.14)
Normal	1.00 (ref)	1.00 (ref)	1.00 (ref)	1.00 (ref)	1.00 (ref)
Elevated blood pressure	2.04 (1.61–2.58)[c]	1.46 (1.05–2.03)[c]	2.01 (1.39–2.90)[c]	1.24 (0.89–1.72)	1.94 (0.86–4.42)
Normal	1.00 (ref)	1.00 (ref)	1.00 (ref)	1.00 (ref)	1.00 (ref)
High fasting glucose	1.22 (0.97–1.53)	1.42 (1.08–1.88)[c]	1.23 (0.89–1.70)	1.37 (0.99–1.90)	1.81 (0.75–4.37)

* Data were adjusted for clusters and strata of the complex sample design of the NHANES 2011 to March 2020, with incorporation of sample weights. Values are presented with range within 95% CI in the bracket. BMI, body mass index; HDL, high-density lipoprotein; NHANES, National Health and Nutrition Examination Survey; ref, reference; 95% CI, 95% confidence interval.
[a] Adjusted for sex, age, education level (less than college, college or more, unknown), smoking status (never, past, current, unknown), alcohol consumption frequency (<2, ≥2 times/week, unknown), regular exercise (<3, ≥3 times/week), obesity (obese: BMI ≥25 for Asian or BMI ≥30 for the other ethnicities, nonobese), and estimated glomerular filtration rate and all the other components of metabolic syndrome.
[b] Overall associations with metabolic syndrome: fully adjusted model without components of metabolic syndrome.
[c] Significant *P* value.

DISCUSSION

In this study, we examined the decadal trend of metabolic syndrome and hyperuricemia, along with exploring the associations between metabolic components and hyperuricemia. Hyperuricemia exhibited significantly higher prevalence in individuals with metabolic syndrome compared with healthy individuals. Hyperuricemia and metabolic syndrome were more closely related to each other in women than in men. We also showed that the association between hyperuricemia and metabolic syndrome was the least in the Asian group among different ethnic groups.

In US adults, we found an increasing trend of metabolic syndrome prevalence in the Hispanic and Asian groups. Notably, in the Hispanic population, both the prevalence of metabolic syndrome and hyperuricemia exhibited an increasing trajectory, but the pattern was not mirrored in the Asian group. In the Hispanic group, the associations between metabolic syndrome components and hyperuricemia have a similar pattern as those in the White population. In both groups, elevated blood pressure (BP) stood out as the most notable risk factor for hyperuricemia. Meanwhile, among the Asian population, central obesity took on a significant role as the primary risk factor. In nonobese Asians, there was no significant association between hyperuricemia and metabolic syndrome. However, central obesity retained its significance as a risk factor in nonobese Asians.

This study has two strengths. First, we investigated decadal changes of hyperuricemia and metabolic syndrome by ethnic group. Second, we investigated racial differences in hyperuricemia and metabolic syndrome for the first time. Although previous studies also had interest in the specific associations between metabolic syndrome components and hyperuricemia, no other studies investigated difference in patterns of association across the different ethnic groups.[23–25] Our findings suggest ethnicity-specific patterns in the associations between metabolic syndrome components and hyperuricemia, with a particular emphasis on the Asian group. To our best knowledge, there are only three Asian studies investigating association between metabolic syndrome components and hyperuricemia.

First, in the military cohort of Taiwan (N = 7,504), central obesity (OR 2.85, 95% CI 2.55–3.18) showed the strongest associations with hyperuricemia among the components, including elevated BP (OR 1.59, 95% CI 1.42–1.77).[25] It showed an even higher OR than metabolic syndrome (OR 2.61, 95% CI 2.26–3.01). The study used the same definition for hyperuricemia (SUA >7.0 mg/dL for men and >5.7 mg/dL for women) and metabolic syndrome as in our study. Second, in Taiwan Biobank data (N = 21,030), central obesity has an equivalent effect as elevated BP (OR 1.18, 95% CI 1.13–1.23 vs 1.17, 95% CI 1.12–1.22).[26] They used the definition of hyperuricemia as >7.0 mg/dL in men and >6.0 mg/dL in women. Third, in a Tibetan cohort (N = 307), central obesity has an equivalent effect as elevated BP (OR 2.53, 95% CI 1.41–4.53 vs 2.61, 95% CI 1.37–4.97).[27] They used the definition of hyperuricemia as >420 μmol/L (7.06 mg/dL) in men, >360 μmol/L (6.05 mg/dL) in women.

Despite these findings, our study has limitations. First, the cross-sectional nature of our design constrains our capacity to establish causality definitively. Therefore, further Mendelian randomization study or prospective cohort study is required to verify the causality between metabolic syndrome and hyperuricemia. Second, we have a limited sample size, given the lower participation of fasting blood tests in NHANES. Third, during the COVID-19 pandemic (2017 to March 2020), a measurement unit of 3.2 years is used instead of the standard 2 years. Lastly, the definition of hyperuricemia adheres to NHANES-III guidelines, which are outdated. An updated definition is required for future studies.[17]

In conclusion, we found that prevalence of metabolic syndrome has increasing pattern, but there was no specific decadal trend in prevalence of hyperuricemia. Also, we found an ethnicity-specific association of metabolic syndrome and hyperuricemia, especially in Asians.

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AUTHOR CONTRIBUTIONS

All authors were involved in drafting the article or revising it critically for important intellectual content, and all authors approved the final version to be published. Dr Cho had full access to all of the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis.

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