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Prevalence of and trends in hyperuricemia by race and ethnicity among US adolescents, 1999–2018

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Abstract

Purpose Our objective was to ascertain the most recent prevalence and trends of hyperuricemia among adolescents, stratified by sex and race/ethnicity subgroups, as well as to investigate potential risk factors associated with hyperuricemia in US adolescents.

Methods Data were obtained from adolescents aged 12–17 years in the 1999–2018 NHANES cycles. Hyperuricemia for adolescents was defined as ≥ 5.5 mg/dL. The prevalence of hyperuricemia, along with 95% confidence intervals (CIs), was calculated for each four-year survey cycle, stratified by sex, race/ethnicity, body mass index (BMI), poverty income ratio (PIR), and parental education levels. Linear regression and logistic regression analyses were conducted independently to evaluate the linear trends in mean serum urate levels and the prevalence of hyperuricemia across the four-year cycles. Utilizing NHANES data from 2011 to 2018, we identified factors associated with mean serum urate levels and hyperuricemia through the application of linear regression and Poisson regression analyses.

Results A total of 11 264 participants were included in the analysis. In 2015–2018, the overall hyperuricemia prevalence was 32.78%, 50.7% in males, and 13.51% in females. No significant trends were identified in the prevalence of hyperuricemia from 1999 to 2002 to 2015–2018. Between 2011 and 2018, hyperuricemia was significantly more prevalent among males compared to females (prevalence ratio [PR], 3.50 [95% CI, 2.83–4.33]), non-Hispanic Asians compared to non-Hispanic Whites (PR, 1.26 [95% CI, 1.04–1.53]), and individuals with overweight (PR, 1.63 [95% CI, 1.32–2.01]) or obesity (PR, 2.45 [95% CI, 2.08–2.88]) compared to those of normal weight. There was a stronger correlation between obesity and hyperuricemia among females (PR, 4.77 [95% CI, 3.08–7.39]) than in males (PR, 2.06 [95% CI, 1.82–2.34]). Furthermore, non-Hispanic Black adolescents with obesity exhibited higher PRs (PR, 3.40 [95% CI, 2.54–4.55]) for hyperuricemia in comparison to other ethnic groups.

Conclusions This study has updated recent trends in hyperuricemia by sex and race/ethnicity among US adolescents. Our results suggest that hyperuricemia has a significant association with greater obesity in US adolescents, and the degree of correlation varies by sex and race/ethnicity.

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Keywords Adolescents, Hyperuricemia, Epidemiology, NHANES, Obesity

Introduction

In recent years, the prevalence of hyperuricemia has been increasing, particularly in economically developed countries [1]. Elevated serum uric acid levels not only contribute to the development of gout but may also be linked to an increased risk of cardiovascular disease [2–4]. Several studies have demonstrated associations between hyperuricemia in children and adolescents and cardiometabolic risk factors, including metabolic syndrome [5], obesity [6], hypertension [7], and dyslipidemia [8]. The epidemiological data obtained from the 2015–2016 National Health and Nutrition Examination Survey (NHANES) showed a prevalence of hyperuricemia of almost 20% in US adults [9]. In addition, recent studies have demonstrated racial disparities in the prevalence rates of hyperuricemia and gout [10–12]. For example, a recent nationwide study conducted in the US found that the prevalence of gout among Asians doubled between 2011 and 2018 to reach 6.6%, surpassing that of all other racial groups [11]. Correspondingly, the mean serum levels of urate also increased among Asians during the same period [11]. However, the latest prevalence of hyperuricemia among US adolescents is unknown. A previous study based on the 2007–2010 NHANES showed that the prevalence of hyperuricemia in adolescents was 10.9% [13], however, data were not available for US Asian adolescents, who represent one of the most rapidly growing ethnic minorities in the US. Furthermore, the mean serum levels of urate among adolescents remained stable between the 1966–1970 NHANES III and 2007–2010 NHANES [13]. The trends in the prevalence of hyperuricemia among US adolescents since 2010 are also unclear.

In this cross-sectional study, we evaluated the prevalence and trends of hyperuricemia over the past two decades among US adolescents, particularly the Asian population, and trends in hyperuricemia were further examined by key demographic characteristics, including sex and race/ethnicity. We also determined whether mean serum urate and hyperuricemia prevalence were different between groups defined by demographic and socioeconomic factors and obesity.

Methods

Data source

NHANES is a nationwide cross-sectional US survey that assesses the health and nutritional status of adults and children using interviews, physical examinations, and laboratory tests. This survey used a complex multistage probability design to obtain nationally representative data for the noninstitutionalized US civilian population. We combined data from five 4-year cycles of the National Health and Nutrition Examination Surveys (NHANES; 1999–2002 through 2015–2018).

Study population

We restricted the analysis to adolescents aged 12 to 17 years who completed both the NHANES interview and physical examination. Of the 13,162 adolescents in 1999–2018, we excluded 1822 subjects with missing urate data and 81 subjects with pregnancy. Therefore, the final cohort included 11,264 participants. Parental consent was obtained as the participants were aged ≤ 18 years. The Research Ethics Review Board of the National Center for Health Statistics approved the NHANES study protocol. Detailed information on the survey design and data collection process has previously been reported [14].

Assessment of sociodemographic characteristics

Sociodemographic characteristics included age, sex, race/ethnicity, educational level, and poverty-to income ratio (PIR), which were self-reported in standardized questionnaires. Race and ethnicity were categorized as follows: non-Hispanic White, non-Hispanic Black, Mexican American, non-Hispanic Asian, and others. Beginning in 2011, the NHANES included more Asian Americans to allow more detailed characterization of this group. We provided estimated prevalence values and related risk factors for Asian Americans in years when sufficient data were available. The NCHS calculated the PIR as a ratio of self- or proxy-reported family income to the federal poverty level based on family size. A PIR of less than 1.00 indicates that the family income was below the poverty level. The PIR was grouped as less than 1.30, 1.30 to 3.49, and 3.50 or greater, consistent with categories frequently used by the NCHS [15].Parental education level was dichotomized as less than high school, high-school graduate, some college, and college graduate or above [16].

Measurements and definition of hyperuricemia

Weight, height, waist circumference, and blood pressure were measured in mobile examination centers using standard protocols. Estimated glomerular filtration rate (eGFR) was computed using the bedside IDMS-traceable Schwartz equation for children as: eGFR (in mL/min/1.73 m^2) = 41.3 × (height [in m]/serum creatinine [in mg/dL]) [17]. Serum levels of urate were measured using a 917 or 704 multichannel analyzer (Hitachi, Tokyo, Japan) in 1999–2001 and a UniCel DxC 800 or DxC 660i Synchron Clinical System (Beckman Coulter, Brea, CA, USA) in 2002–2018. A colorimetric method was employed to obtain the measurements. Hyperuricemia for adolescents was defined as ≥ 5.5 mg/dL [7, 18, 19].

Definition of vegetarians

We defined vegetarian diet in accordance with the methodology reported in a recent study [20]. Data from 24-hour dietary recalls over two days, pertaining to food consumption mapped to specific NHANES cycles, were obtained from the Food Patterns Equivalents Database (FPED). Respondents who reported a nonzero amount for the component "total meat, poultry, seafood, organ meats, and cured meats (ounce equivalents [oz. eq.])" on both or either of the two days of dietary recall were classified as nonvegetarians, while all others were considered vegetarians. Only one day of 24-hour dietary recall data was collected in the NHANES survey from 1999 to 2002; therefore, we do not present a percentage of vegetarians for this period.

Definitions of cardiometabolic risk factors

The cutoff values for abnormal lipid levels were as follows [21]: total cholesterol (TC) ≥ 200 mg/dL or > 5.18 mmol/L; high-density lipoprotein cholesterol (HDL-C) < 35 mg/dL or < 0.9 mmol/L; low-density lipoprotein cholesterol (LDL-C) ≥ 130 mg/dL or ≥ 3.4 mmol/L; and triglycerides (TGs) ≥ 150 mg/dL or > 1.7 mmol/L. In the Clinical Practice Guideline for Screening and Management of High Blood Pressure in Children and Adolescents published by the American Academy of Pediatrics in 2017, hypertension was defined as a systolic blood pressure and/or diastolic blood pressure ≥ 95th percentile for age, sex, and height [22]. Abnormal fasting glucose level was defined according to the recommendations of the American Diabetes Association (i.e., ≥ 100 mg/dL) [23]. Mean height and weight were used to determine the age- and sex-standardized body mass index Z-scores using the Centers for Disease Control and Prevention (2000) [24] reference population for participants aged ≤ 18 years. Based on their weight, participants were classified as follows: underweight, <5th percentile; normal weight, 5-85th percentile; overweight, 86-94th percentile; and obese, ≥95th percentile [21].

Statistical analysis

Data were analyzed from July 10, 2022, to October 30, 2023. All analyses were performed for adolescents aged 12 to 17 years separately. Characteristics of US adolescents were calculated for each 4-year NHANES cycle: 1999–2002, 2003–2006, 2007–2010, 2011–2014, and 2015–2018. Sample weights were incorporated, and data were combined across years in compliance with the NHANES Analytic and Reporting Guidelines [25]. In cases of small sizes of certain subgroups, multiple 2-year data cycles were combined. To compare continuous and categorical variables, analysis of variance and the chi-square test were used, respectively. Continuous variables are presented as means ± standard deviations (SDs), whereas categorical variables are presented as weighted percentages with 95% confidence intervals (CIs). We computed hyperuricemia prevalence and 95%CIs within each 4-year survey cycle by sex, race/ethnicity, BMI, PIR and parental education categories. Linear regression was used to assess linear trends in mean serum urate, and logistic regression was used to assess trend in hyperuricemia prevalence across the 4-year cycles.

Using NHANES data from 2011 to 2018, we determined factors associated with mean serum urate, and hyperuricemia. We used linear regression to estimate differences in mean serum urate and Poisson regression to estimate prevalence ratios (PRs) for hyperuricemia associated with age, sex, race/ethnicity, BMI, PIR and parental education. Models were conducted with adjustment for age, sex, race/ethnicity, BMI, and PIR and all factors simultaneously. Statistical analyses were performed using the "survey" package in R software (version 4.1.0; R Foundation for Statistical Computing, Vienna, Austria). Two-tailed p-values < 0.05 were considered statistically significant.

Results

Baseline characteristics of participants

The final sample size for this study was 11,264 individuals. The sample (males, 51.2%; females, 48.8%) included non-Hispanic White (58.5%), non-Hispanic Black (14.1%), Mexican American (13.3%), non-Hispanic Asian (1.9%), and other (12.2%) ethnicities. Table 1 presents the weighted sample characteristics for all 5 cycles (1999–2002 to 2015–2018) of the NHANES. In the 1999–2002 and 2015–2018 cycles, 48.9% and 48.2% of US adolescents, respectively, were females; 51.1% and 51.8%, respectively, were males; 61.6% and 53.2%, respectively, were non-Hispanic White; 14.9% and 12.9%, respectively, were non-Hispanic Black; 10.9% and 15.3%, respectively, were Mexican Amerrican; and 12.7% and 14%, respectively, were of other races (Table 1). Data for the serum levels of urate are presented in eFig. 1 in the Supplement. The mean serum levels of urate were 5.0 ± 1.2 mg/dL in all patients, 5.5 ± 1.2 mg/dL in males, and 4.4 ± 1.0 mg/dL in females. eTable 1 in the Supplement presents a comparison of the baseline demographic and clinical characteristics between the hyperuricemia and normal urate groups.

Prevalence of hyperuricemia

Data from the 2015–2018 NHANES were analyzed to estimate the most recent prevalence of hyperuricemia (Table 2). Among 1,619 adolescents (males, 51.8%; females, 48.2%), the mean age was 14.6 ± 1.7 years. The hyperuricemia prevalence was 32.8% in all participants, 50.7% in males, and 13.5% in females. Hyperuricemia was more prevalent in non-Hispanic Asians (38.9%; 95% CI: 29.5–48.4) and less prevalent in non-Hispanic Blacks

Table 1 Characteristics of US adolescents, aged 12–17 years, NHANES 1999–2018

Study participant characteristic	NHANES cycle[a]					*P* value
	1999–2002	2003–2006	2007–2010	2011–2014	2015–2018	
Sample size, No.	3247 (19.4)	2942 (19.9)	1708 (20.1)	1748 (20.2)	1619 (20.5)	
Age, mean (95% CI)	14.5 (14.4,14.6)	14.5 (14.4,14.6)	14.6 (14.5,14.7)	14.5 (14.4,14.6)	14.6 (14.5,14.7)	0.258
Sex						
Female	1613, 48.9 (46.5,51.3)	1413, 48.3 (46.0,50.6)	802, 48.9 (45.5,52.2)	844, 49.5 (46.3,52.7)	790, 48.2 (44.9,51.5)	0.965
Male	1634, 51.1 (48.7,53.5)	1529, 51.7 (49.4,54.0)	906, 51.2 (47.9,54.5)	904, 50.5 (47.3,53.7)	829, 51.8 (48.6,55.1)	
Race/ethnicity						
Non-Hispanic White	828, 61.6 (57.7,65.5)	772, 64.1 (58.4,69.8)	542, 59.0 (53.5,64.5)	416, 54.8 (47.6,62.1)	482, 53.2 (46.0,60.3)	< 0.001
Non-Hispanic Black	986, 14.9 (11.3,18.4)	1041, 15.0 (11.8,18.3)	392, 14.0 (11.7,16.3)	462, 14.0 (10.0,18.0)	350, 12.9 (8.9,16.9)	
Mexican American	1199,10.9 (8.2,13.6)	948, 11.7 (8.6,14.7)	454, 13.4 (9.8,16.9)	376, 15.1 (11.0,19.3)	333, 15.3 (10.4,20.2)	
Non-Hispanic Asian[b]	NA	NA	NA	213, 4.7 (3.3,5.8)	172, 4.6 (3.0,6.3)	
Other races	234, 12.7 (9.0,16.4)	181, 9.2 (7.2,11.3)	320, 13.6 (9.9,17.4)	281, 11.4 (9.1,13.7)	282, 14.0 (12.2,15.9)	
BMI[c]						
Normal weight	1958, 64.3 (62.2,66.5)	1755, 61.6 (58.3,64.9)	979, 61.2 (58.9,63.5)	1014, 59.3 (55.5,63.2)	892, 56.5 (53.7,59.2)	0.125
Overweight	520, 14.8 (13.0,16.5)	500, 17.1 (14.8,19.4)	301, 16.5 (14.725,18.3)	285, 15.8 (13.3,18.3)	285, 17.9 (16.0,19.9)	
Obesity	655, 16.5 (15.0,18.1)	588, 17.5 (14.7,20.3)	363, 18.6 (16.3,20.8)	382, 21.5 (18.7,24.3)	385, 21.0 (18.0,24.1)	
PIR (family)[d]						
<1.30	1250, 29.1 (26.4,31.8)	1093, 25.2 (22.0,28.5)	658, 27.9 (24.7,31.2)	690, 28.7 (23.2,34.1)	545, 25.1 (21.0,29.3)	0.018
1.30–3.49	1075, 33.7 (30.5,36.9)	1092, 37.0 (33.9,40.2)	570, 32.3 (28.2,36.5)	557, 37.1 (32.8,41.4)	615, 40.2 (36.1,44.2)	
≥3.5	628, 29.9 (26.7,33.1)	645, 34.7 (30.4,39.1)	342, 33.2 (28.5,38.0)	362, 28.5 (23.3,33.7)	303, 27.8 (23.2,32.5)	
Parental Education						
Less than high school	1273, 23.7 (20.5,26.8)	935, 17.8 (15.2,20.4)	512, 19.7 (16.8,22.6)	449, 19.6 (16.0,23.2)	367, 19.3 (15.0,23.6)	< 0.001
High school graduate	744, 26.2 (23.8,28.5)	683, 25.2 (22.2,28.2)	366, 19.5 (16.9,22.2)	382, 21.0 (16.4,25.5)	606, 36.1 (31.6,40.6)	
Some college	666, 25.4 (22.2,28.6)	798, 33.4 (30.8,36.1)	471, 29.4 (26.3,32.6)	495, 30.1 (26.0,34.2)	261, 17.0 (13.3,20.9)	
College graduate or more	442, 21.9 (18.5,25.3)	419, 20.6 (17.4,23.7)	303, 27.9 (22.5,33.3)	379, 27.0 (22.8,31.3)	319, 24.2 (19.2,29.2)	
Vegetarians, n(%)						
No	NA	2798 (25.4)	1617 (25)	1615 (25)	1473 (24.7)	0.200
Yes	NA	34 (1.2)	31 (2.7)	37 (2.2)	42 (2.8)	

Abbreviations BMI, body mass index; NA, not applicable; NHANES, National Health and Nutrition Examination Survey; PIR, poverty-to-income ratio

[a] Unless otherwise indicated, data are expressed as number plus percentage (95%CI)

[b] Non-Hispanic Asian participants were not categorized in 1999–2002, 2003–2006 and 2007–2010 owing to small sample sizes

[c] Normal indicates BMI of 5th percentile to less than 85th percentile; overweight, 85th percentile to less than 95th percentile; and obesity, 95th percentile or greater. Categories were based on age- and sex-specific growth charts developed by the Centers for Disease Control and Prevention in 2000. Owing to a small sample size, children with a BMI less than the 5th percentile are not presented

[d] The PIR as a ratio of self- or proxy-reported family income to the federal poverty level based on family size. A PIR < 1.30 indicates that the family income was below 130% of the poverty level

(28.2%; 95% CI: 23.4–33.0) than other racial and ethnic subgroups. The prevalence was particularly low in non-Hispanic Black females (9.1%; 95% CI: 4.6–13.6), and obese adolescents had higher hyperuricemia prevalence than normal weight adolescents (58.2% vs. 22.3%).

Trends in the distribution of serum urate and prevalence of hyperuricemia

Among adolescents aged 12 to 17 years, mean serum urate increased from 5.06 ± 1.32 mg/dl in 1999–2002 to 5.08 ± 1.19 mg/dl in 2007–2010 and then decreased to 4.96 ± 1.27 mg/dl in 2015–2018 ($P = 0.174$ for trend from 1999 to 2002 through 2015–2018) (Fig. 1A and eTable 2 in the Supplement). The prevalence of hyperuricemia increased from 34.6% (95%CI, 32.0-37.1%) in 1999–2002 to 35.5% (95%CI, 32.8-38.2%) in 2007–2010 and then decreased to 32.8% (95%CI, 30.0-35.6%) in 2015–2018 ($P = 0.432$ for trend from 1999 to 2002 to 2015–2018) (Fig. 1B; Table 2). In male adolescents with normal weight, the prevalence of hyperuricemia decreased from 48.8% (95%CI, 44.6-53.0%) in 1999–2002 to 37.1% (95%CI, 32.3-41.9%) in 2015–2018 ($P < 0.01$ for trend from 1999 to 2002 to 2015–2018) (Table 2). During 2011–2018, The prevalence of hyperuricemia in non-Hispanic Asians increased from 35.5% in 2011–2012 to 43.9% in 2015–2016 and then decreased to 34.9% in 2017–2018 (eFig. 2 in the Supplement). eTable 3 in the Supplement show the weighted trends in prevalence of hyperuricemia by each classification of BMI for each race/ethnicity group.

Table 2 Trends in prevalence of hyperuricemia among US adolescents, NHANES 1999–2018

	NHANES Years					
	1999–2002	**2003–2006**	**2007–2010**	**2011–2014**	**2015–2018**	***P* for trend[a]**
Overall	34.6 (32.0,37.1)	32.9 (30.2,35.5)	35.5 (32.8,38.2)	32.5 (29.8,35.1)	32.8 (30.0,35.6)	0.432
Race/ethnicity						
Non-Hispanic White	35.8 (32.0,39.6)	34.4 (30.8,38.1)	39.2 (34.8,43.5)	34.1 (29.8,38.5)	32.4 (27.5,37.4)	0.25
Non-Hispanic Black	25.6 (22.6,28.5)	26.1 (23.0,29.2)	27.3 (23.1,31.5)	27.3 (21.8,32.9)	28.2 (23.4,33.0)	0.894
Mexican American	36.6 (32.8,40.4)	32.5 (29.5,35.6)	30.2 (25.6,34.7)	31.7 (27.2,36.2)	33.3 (28.4,38.2)	0.368
Non-Hispanic Asian[b]	NA	NA	NA	36.6 (30.1,43.1)	38.9 (29.5,48.4)	0.689
Other races	37.3 (29.1,45.4)	33.4 (25.7,41.0)	33.5 (27.9,39.0)	30.3 (24.5,36.2)	35.8 (28.8,42.7)	0.678
BMI[c]						
Normal weight	27.4 (24.5,30.4)	26.2 (22.9,29.5)	28.2 (24.7,31.8)	25.4 (21.9,28.9)	22.3 (19.5,25.1)	0.108
Overweight	39.4 (31.8,46.9)	37.3 (32.2,42.4)	39.5 (31.5,47.5)	37.8 (27.9,47.8)	37.9 (30.8,45.0)	0.989
obesity	62.7 (56.6,68.8)	54.6 (49.1,60.2)	58.8 (52.5,65.1)	51.5 (44.2,58.8)	58.2 (52.3,64.0)	0.143
PIR[d]						
<1.30	31.5 (26.8,36.1)	30.4 (26.8,33.9)	38.4 (32.5,44.2)	30.8 (26.5,35.0)	33.6 (30.0,37.2)	0.08
1.30–3.49	36.1 (32.7,39.5)	33.2(28.5,38.0)	33.7 (28.4,39.1)	30.2 (26.6,33.9)	35.3 (31.1,39.6)	0.373
≥3.5	34.8 (30.9,38.8)	34.2 (29.9,38.4)	36.7 (31.5,41.9)	37.3 (32.3,42.4)	27.9 (20.1,35.8)	0.168
Parental education level						
Less than high school	33.9 (30.0,37.7)	31.4 (27.1,35.7)	32.3 (27.5,37.1)	29.2 (22.8,35.7)	32.2 (25.4,38.9)	0.786
High school graduate	34.0 (27.9,40.1)	30.9 (27.9,33.9)	40.5 (35.3,45.6)	32.0 (25.3,38.7)	37.0 (31.2,42.9)	0.156
Some college	36.9 (31.8,41.9)	33.4 (29.5,37.4)	37.7 (32.4,43.0)	32.2 (26.9,37.4)	35.2 (27.9,42.5)	0.527
College graduate or more	33.4 (28.4,38.4)	33.5 (25.2,41.8)	31.9 (25.8,38.0)	35.5 (29.4,41.6)	25.2 (20.1,30.2)	0.167
Male	55.6 (52.0,59.2)	51.8 (48.3,55.3)	53.6 (49.8,57.4)	49.3 (45.9,52.8)	50.7 (46.1,55.3)	0.186
Race/ethnicity						
Non-Hispanic White	57.3 (52.5,62.2)	53.9 (49.0,58.9)	56.8 (51.0,62.5)	52.2 (47.0,57.4)	47.8 (40.0,55.5)	0.158
Non-Hispanic Black	39.8 (36.1,43.4)	41.6 (36.7,46.6)	46.5 (40.4,52.6)	39.7 (31.5,48.0)	47.4 (39.6,55.1)	0.293
Mexican American	58.3 (52.3,64.3)	52.4 (48.2,56.6)	46.8 (40.7,52.9)	47.6 (40.9,54.4)	54.3 (45.7,62.9)	0.117
Non-Hispanic Asian	NA	NA	NA	56.6 (47.2,66.0)	63.2 (52.2,74.3)	0.381
Other races	64.2 (53.1,75.4)	52.9 (44.7,61.1)	53.4 (45.1,61.6)	48.1 (38.8,57.4)	57.3 (45.2,69.3)	0.279
BMI						
Normal weight	48.8 (44.6,53.0)	42.8 (38.5,47.1)	45.2 (41.5,49.0)	42.2 (37.7,46.6)	37.1 (32.3,41.9)	0.005
Overweight	63.9 (54.7,73.1)	62.4 (55.5,69.3)	63.5 (52.5,74.6)	50.6 (38.3,62.9)	65.5 (55.5,75.6)	0.22
obesity	81.9 (74.6,89.2)	76.3 (70.8,81.8)	75.3(68.2,82.4)	77.1 (69.0,85.1)	82.0 (76.0,87.9)	0.497
PIR						
<1.30	51.3 (44.6,58.1)	48.9 (44.2,53.7)	55.4 (48.1,62.8)	50.8 (44.6,57.1)	53.1 (47.5,58.7)	0.65
1.30–3.49	58.5 (52.9,64.1)	52.0 (45.7,58.2)	53.2 (45.8,60.7)	45.3 (39.2,51.3)	51.2 (44.7,57.6)	0.096
≥3.5	55.3 (49.2,61.3)	53.1 (46.7,59.5)	54.3 (45.8,62.8)	52.5 (45.3,59.8)	45.9 (34.5,57.4)	0.546
Parental education level						
Less than high school	56.5 (51.8,61.2)	52.0 (45.9,58.1)	48.2 (42.4,54.0)	46.1 (37.4,54.8)	52.8 (42.6,63.0)	0.273
High school graduate	58.8 (50.5,67.2)	47.6 (42.7,52.5)	56.2 (49.3,63.1)	50.4 (42.2,58.5)	53.8 (45.4,62.2)	0.276
Some college	56.8 (49.6,63.9)	51.9 (45.5,58.4)	58.5 (51.1,65.9)	48.0 (42.8,57.1)	52.2 (43.3,61.1)	0.421
College graduate or more	51.1 (44.4,57.8)	55.1 (45.6,64.6)	48.7 (39.9,57.5)	45.0 (41.7,58.2)	43.8 (34.3,53.3)	0.522
Female	12.6 (9.8,15.5)	12.6 (9.9,15.3)	16.6 (13.7,19.6)	15.3 (10.8,19.9)	13.5 (10.9,16.1)	0.307
Race/ethnicity						
Non-Hispanic White	13.1 (9.0,17.2)	13.7 (9.4,18.0)	20.7 (15.6,25.8)	17.2 (10.1,24.4)	15.2 (10.3,20.0)	0.234
Non-Hispanic Black	10.4 (7.6,13.2)	9.3 (7.2,11.4)	8.9 (5.5,12.3)	12.2 (8.0,16.4)	9.1 (4.6,13.6)	0.663
Mexican American	11.5 (8.6,14.4)	10.0 (7.2,12.7)	12.5 (7.6,17.4)	13.5 (9.8,17.3)	13.5 (8.8,18.2)	0.672
Non-Hispanic Asian	NA	NA	NA	15.5 (7.7,23.4)	16.5 (6.7,26.3)	0.88
Other races	13.7 (4.9,22.4)	13.2 (4.0-22.4)	11.0 (4.2,17.7)	11.3 (4.2,18.5)	10.4 (5.0,15.9)	0.961
BMI						
Normal weight	6.7 (3.9,9.6)	9.1 (5.9,12.4)	11.5 (6.9,16.0)	8.9 (4.9,12.9)	5.9 (2.3,9.5)	0.259
Overweight	13.2 (6.6,19.9)	9.2 (4.8,13.7)	14.7 (9.0,20.3)	20.7 (9.1,32.3)	18.0 (9.5,26.4)	0.264
obesity	39.0 (31.7,46.3)	29.2 (20.6,37.9)	39.0 (30.3,47.7)	29.4 (19.4,39.4)	30.4 (23.5,37.3)	0.269
PIR						

Table 2 (continued)

	NHANES Years					
	1999–2002	**2003–2006**	**2007–2010**	**2011–2014**	**2015–2018**	***P* for trend[a]**
<1.30	11.3 (7.9,14.7)	12.4 (8.3,16.5)	19.7 (13.2,26.2)	10.6(6.8,14.4)	16.3 (11.8,20.9)	0.026
1.30–3.49	12.7 (7.8,17.7)	12.6 (6.6,18.5)	14.7 (9.6,19.8)	16.1 (9.5,22.6)	15.8 (10.5,21.1)	0.85
≥3.5	13.2 (9.1,17.3)	13.0 (8.2,17.8)	17.5 (10.7,24.4)	20.1 (12.8,27.4)	8.7 (3.6,13.8)	0.076
Parental education level						
Less than high school	11.2 (6.3,16.0)	11.8 (7.4,16.2)	14.7 (8.2,21.2)	11.3 (5.5,17.2)	16.6 (10.4,22.9)	0.55
High school graduate	12.9 (7.0,18.8)	9.8 (5.37,14.2)	22.0 (13.4,30.6)	15.4 (8.5,22.3)	16.1 (11.4,20.8)	0.13
Some college	12.5 (8.2,16.7)	12.4 (6.9,17.8)	16.4 (10.8,21.9)	13.3 (8.3,18.4)	15.4 (6.1,24.6)	0.804
College graduate or more	13.6 (7.9,19.3)	14.4 (6.9,22.0)	15.5 (8.6,22.3)	20.5 (10.9,30.2)	5.6 (1.4,9.9)	0.054

Data are presented incorporating sample weights and adjusted for clusters and strata of the complex sample design of the NHANES1999-2018

[a] P value for trend in prevalence of hyperuricemia across all survey years

[b] Non-Hispanic Asians were not presented in 1999–2002, 2003–2006, and 2007–2010 due to small sample sizes

[c] Body mass index was categorized as normal (body mass index 5th percentile to <85th percentile), overweight (body mass index 85th percentile to <95th percentile) and obese (body mass index ≥95th percentile) based on age- and sex-specific growth charts developed by the Centers for Disease Control and Prevention in 2000. Due to a small sample size, children with a body mass index <5th percentile are not presented

[d] The PIR as a ratio of self- or proxy-reported family income to the federal poverty level based on family size. A PIR <1.30 indicates that the family income was below 130% of the poverty level

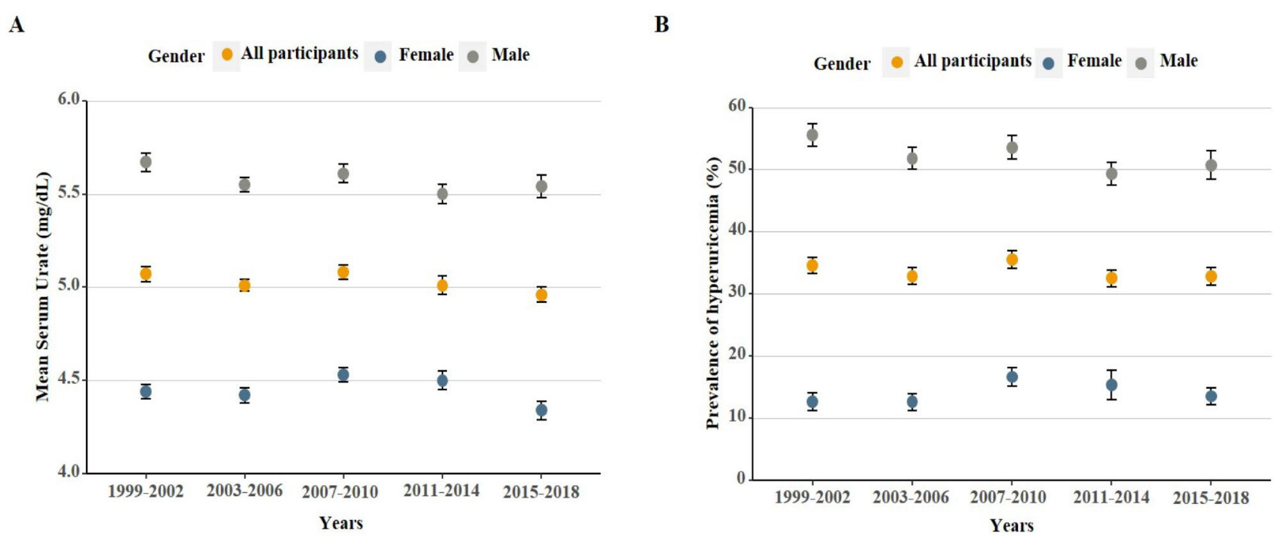

Fig. 1 Trends in Mean Serum Urate levels and Hyperuricemia Prevalence Among US Adolescents. Adolescents were aged 12 to 17 years. Data are from the 1999–2002 to 2015–2018 cycles of the National Health and Nutrition Examination Survey (NHANES). Error bars represent 95%CIs

Factors associated with serum urate levels in NHANES 2011–2018

Among adolescents aged 12 to 17 years, serum urate was 1.26 (95%CI, 1.23–1.28) mg/dl higher among males compared with females, 1.08 (95%CI, 1.05–1.11) mg/dl higher among those with overweight and 1.22 (95%CI, 1.19 to 1.26) mg/dl higher among those with obesity compared with normal weight, 0.94 (95%CI, 0.91–0.97) mg/dl lower among non-Hispanic Black compared with non-Hispanic White participants and 1.04 (95%CI, 1.00-1.07) mg/dl higher among non-Hispanic Asian compared with non-Hispanic White participants. While in female adolescents, the difference disappeared between non-Hispanic Asian and non-Hispanic White participants (eTable 4 in the Supplement).

Factors associated with hyperuricemia in NHANES 2011–2018

Among adolescents aged 12 to 17 years, hyperuricemia was more prevalent in males compared to females (PR, 3.50 [95% CI, 2.83–4.33]), non-Hispanic Asians compared to non-Hispanic Whites (PR, 1.26 [95% CI, 1.04–1.53]), and those with overweight (PR, 1.63 [95% CI, 1.32–2.01]) or obesity (PR, 2.45 [95% CI, 2.08–2.88]) relative to individuals of normal weight; conversely, it was less common among non-Hispanic Blacks compared to non-Hispanic Whites (PR, 0.74 [95% CI, 0.63–0.87]) (Table 3). There was a stronger correlation between obesity and hyperuricemia among females (PR, 4.77 [95% CI, 3.08–7.39]) than in males (PR, 2.06 [95% CI, 1.82–2.34]). Furthermore, we evaluated race/ethnicity-stratified

Table 3 Factors associated with hyperuricemia among US adolescents in 2011–2018

Study participant characteristic	PR (95% CI)			
	Model 1[a]		Model 2[b]	
	Mean difference (95% CI)	*P* value	Mean difference (95% CI)	*P* value
Sex				
Female	0 [Reference]	NA	0 [Reference]	NA
Male	3.54 (2.88–4.35)	< 0.001	3.50 (2.83–4.33)	< 0.001
Race/ethnicity				
Non-Hispanic White	0 [Reference]	NA	0 [Reference]	NA
Non-Hispanic Black	0.83 (0.7-1)	0.05	0.74 (0.63–0.87)	< 0.001
Mexican American	0.98 (0.85–1.12)	0.76	0.91 (0.78–1.07)	0.26
Non-Hispanic Asian	1.11 (0.93–1.33)	0.24	1.26 (1.04–1.53)	0.02
Other races	1.02 (0.85–1.22)	0.86	0.96 (0.79–1.18)	0.72
BMI[c]				
Normal weight	0 [Reference]	NA	0 [Reference]	NA
Overweight	1.61 (1.32–1.96)	< 0.001	1.63 (1.32–2.01)	< 0.001
Obesity	2.38 (2.05–2.76)	< 0.001	2.45 (2.08–2.88)	< 0.001
PIR (family)[d]				
≥3.5	0 [Reference]	NA	0 [Reference]	NA
1.30–3.49	1.04 (0.86–1.25)	0.694	0.95 (0.77–1.16)	0.58
<1.30	1.03 (0.87–1.23)	0.71	0.94 (0.75–1.17)	0.55
Parental education level				
College graduate or more	0 [Reference]	NA	0 [Reference]	NA
Some college	1.12 (0.92–1.37)	0.26	1.03 (0.83–1.29)	0.78
High school graduate	1.17 (0.95–1.44)	0.14	1.08 (0.84–1.4)	0.53
Less than high school	1.02 (0.83–1.26)	0.82	0.94 (0.73–1.22)	0.65
Female				
Race/ethnicity				
Non-Hispanic White	0 [Reference]	NA	0 [Reference]	NA
Non-Hispanic Black	0.65 (0.42–0.99)	0.05	0.5 (0.33–0.76)	0.002
Mexican American	0.83 (0.58–1.17)	0.27	0.82 (0.57–1.18)	0.285
Non-Hispanic Asian	0.99 (0.62–1.58)	0.97	1.33 (0.77–2.3)	0.306
Other races	0.65 (0.41–1.05)	0.08	0.62 (0.38–1.01)	0.057
BMI[c]				
Normal weight	0 [Reference]	NA	0 [Reference]	NA
Overweight	2.68 (1.6–4.47)	< 0.001	2.84 (1.69–4.78)	< 0.001
Obesity	4.33 (2.81–6.67)	< 0.001	4.77 (3.08–7.39)	< 0.001
PIR (family)[d]				
≥3.5	0 [Reference]	NA	0 [Reference]	NA
1.30–3.49	1.17 (0.81–1.69)	0.388	0.94 (0.58–1.5)	0.778
<1.30	1.06 (0.74–1.52)	0.733	0.77 (0.47–1.25)	0.284
Parental education level				
College graduate or more	0 [Reference]	NA	0 [Reference]	NA
Some college	1.11 (0.69–1.79)	0.67	0.88 (0.53–1.47)	0.621
High school graduate	1.28 (0.77–2.11)	0.33	1.06 (0.57–1.95)	0.853
Less than high school	1.18 (0.69–2.02)	0.54	1.05 (0.55–2.03)	0.873
Male				
Race/ethnicity				
Non-Hispanic White	0 [Reference]	NA	0 [Reference]	NA
Non-Hispanic Black	0.84 (0.71–0.99)	0.04	0.77 (0.67–0.88)	< 0.001
Mexican American	1.01 (0.87–1.17)	0.93	0.89 (0.76–1.02)	0.1
Non-Hispanic Asian	1.14 (0.98–1.31)	0.08	1.24 (1.06–1.45)	0.008
Other races	1.07 (0.89–1.28)	0.46	1 (0.85–1.17)	0.971
BMI[c]				

Table 3 (continued)

Study participant characteristic	PR (95% CI)			
	Model 1[a]		Model 2[b]	
	Mean difference (95% CI)	*P* value	Mean difference (95% CI)	*P* value
Normal weight	0 [Reference]	NA	0 [Reference]	NA
Overweight	1.44 (1.22–1.7)	< 0.001	1.46 (1.21–1.75)	< 0.001
Obesity	2.05 (1.83–2.29)	< 0.001	2.06 (1.82–2.34)	< 0.001
PIR (family)[d]				
≥3.5	0 [Reference]	NA	0 [Reference]	NA
1.30–3.49	1.01 (0.85–1.2)	0.89	0.98 (0.82–1.16)	0.782
<1.30	1.09 (0.94–1.26)	0.28	1.04 (0.86–1.26)	0.696
Parental education level				
College graduate or more	0 [Reference]	NA	0 [Reference]	NA
Some college	1.11 (0.93–1.34)	0.24	1.02 (0.83–1.25)	0.837
High school graduate	1.14 (0.96–1.37)	0.14	1.05 (0.86–1.29)	0.63
Less than high school	1.07 (0.88–1.31)	0.49	0.96 (0.77–1.21)	0.729

Abbreviations BMI, body mass index (calculated as weight in kilograms divided by height in meters squared); NA, not applicable; PIR, poverty-to-income ratio; PR, prevalence ratio

[a] Adjusted for age, sex, and race/ethnicity

[b] Adjusted for variables in model 1, BMI, and PIR

[c] Normal indicates BMI of 5th percentile to less than 85th percentile; overweight, 85th percentile to less than 95th percentile; and obesity, 95th percentile or greater. Categories were based on age- and sex-specific growth charts developed by the Centers for Disease Control and Prevention in 2000. Owing to a small sample size, children with a BMI less than the 5th percentile are not presented

[d] The PIR as a ratio of self- or proxy-reported family income to the federal poverty level based on family size. A PIR < 1.30 indicates that the family income was below 130% of the poverty level

models for obesity measures (Fig. 2 and eTable 5 in the Supplement). After adjusting for age, sex, and PIR, higher BMI emerged as an independent risk factor for hyperuricemia within each race/ethnicity group; notably, non-Hispanic Black adolescents with obesity exhibited higher prevalence ratios (PRs) (PR, 3.40 [95% CI, 2.54–4.55]) for hyperuricemia compared to other ethnic groups.

Discussion

To the best of our knowledge, this is the first study to examine the national hyperuricemia prevalence among US adolescents, including Asians, according to race/ethnicity. The overall prevalence among US adolescents in 2015–2018 was 32.8%; it was significantly higher in males than females. It was highest among non-Hispanic Asian adolescents and lowest in non-Hispanic Black adolescents. In addition, in adolescents it has remained stable over the past two decades. Among all of the components tested, hyperuricemia correlated best with obesity in all racial/ethnic and sex groups.

The prevalence of hyperuricemia varies across countries. A cross-sectional analysis of the 1999–2006 NHANES data showed that the proportion of children and adolescents aged 12–17 years with urate≥5.5 mg/dL was 34% [18]; our results are in line with those data. Meanwhile, a study that analyzed NHANES data from 2007 to 2010 demonstrated a prevalence of hyperuricemia of 10.9% [13]. A large pooled cross-sectional study found that the overall prevalence of hyperuricemia was 23.3% among Chinese children and adolescents aged 3–19 years during 2009–2019, with prevalence rates of 35.5% for those aged 12–15 years and 31.7% for those aged 16–19 years, which hyperuricemia was defined as serum urate>7 mg/dL in boys and >6 mg/dL in girls [26]. Using a cut-off of urate levels of 5.5 mg/dL, the prevalence of hyperuricemia was 10.3% among Brazilian children and adolescents aged 6–17 years [27]. These differences in prevalence rates can be explained by differences in age, sex, race/ethnicity, regions, lifestyle factors, and diagnostic criteria among the study populations.

The prevalence of hyperuricemia varied according to sex and race/ethnicity. Consistent with most previous studies [28, 29], the rate in our study was significantly higher in males than females. Moreover, hyperuricemia was more common in non-Hispanic Asians and less prevalent in non-Hispanic Blacks. The higher urate levels in non-Hispanic Asians are surprising, given the association between urate and obesity [30], which is lower in non-Hispanic Asians than non-Hispanic Blacks [31]. A recent study found that Asian adults had the highest prevalence of gout among US racial and ethnic group, in line with the UK Biobank study [11]. Urate is affected by multiple modifiable factors, such as BMI, alcohol consumption, diet, and diuretic use [32], as well as non-modifiable factors such as genetic background [33]. Epidemiological studies have confirmed that both genetic background and environmental factors are important risk factors for hyperuricemia. A recent genetic analysis demonstrated

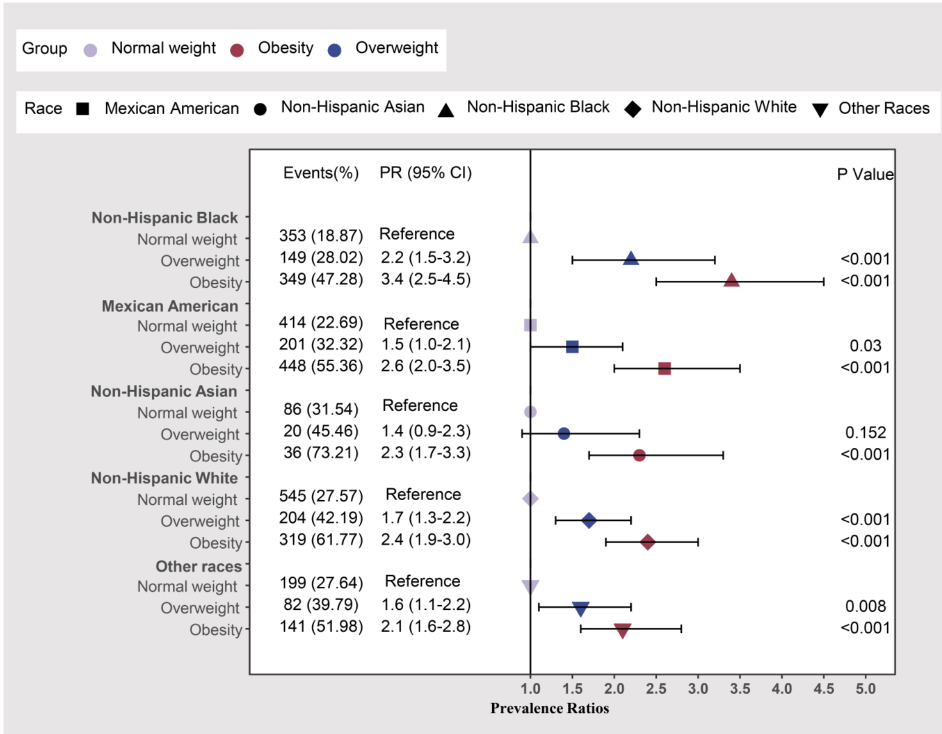

Fig. 2 Adjusted prevalence ratios (PRs) (95% CI) of Hyperuricemia Among US Adolescents Stratified by Race/ethnicity and Obesity in NHANES 2011–2018. Data from 2011 to 2018 National Health and Nutrition Examination Survey (NHANES). Beginning in 2011, the NHANES included more Asian Americans to allow more detailed characterization of this group. Models were conducted with adjustment for age, sex, and PIR simultaneously

that Han-Chinese and Japanese populations had higher prevalence rates of validated risk alleles for hyperuricemia than Europeans, suggesting that the high prevalence of hyperuricemia in Asians has a genetic basis [34]. Moreover, an epidemiological analysis of Chinese adolescents aged 13–19 years showed that the overall prevalence of hyperuricemia was 60.5% (males, 82.1%; females, 38.4%) [28], which is significantly higher than our results for Asians living in the US. The significant differences in the hyperuricemia prevalence among populations of the same ethnicity residing in different regions suggests that complex genetic and environmental factors influence the occurrence of hyperuricemia.

The prevalence of hyperuricemia differs between adults and adolescents. In adults, it is lower in Mexican Americans than non-Hispanic Whites, and higher in non-Hispanic Blacks [9]. Among adolescents, Blacks had the lowest prevalence of hyperuricemia. The reason for this pattern of prevalence is uncertain. Comorbidities, such as metabolic syndrome, as well as socioeconomic factors and medications may explain the differences in hyperuricemia prevalence between adults and adolescents.

A previous study based on NHANES data found no significant changes in mean urate among adolescents over the past 40 years (between 1966 and 1970 and 2007–2010) [13]. Our results are consistent with that finding. We found that the overall prevalence of hyperuricemia in adolescents has remained stable over the previous two decades (between 1999 and 2002 and 2015–2018). Similarly, the rate in adults remained stable between 2007 and 2016 [9]. In adolescents, this may be related to the plateauing trends of obesity in the US over this time period (between 2005 and 2006 and 2013–2014) [35], as obesity is strongly associated with hyperuricemia [6, 36]. In our study, higher serum urate levels and a higher prevalence of hyperuricemia were present in those with overweight or obesity compared with normal weight among adolescents. Obesity increases the activity of xanthine oxidase in the adipose tissues and would result in higher urate production and lower urate renal clearance [37]. However, as mentioned previously, Black adolescents have a higher prevalence of obesity and a lower prevalence of hyperuricemia, whereas Asian adolescents have a lower prevalence of obesity [31] and a higher prevalence of hyperuricemia. These results suggest that race/ethnicity and obesity may both be important factors affecting urate levels.

Strengths of this analysis include the use of a large, nationally representative data set with objective data collected during 20 years. Our results are subject to several limitations. First, the outcomes that were assessed relied on self-reported information. However, previous analyses suggest that self-reported outcomes in the NHANES are a valid tool for assessing prevalence [38, 39]. Second, hyperuricemia was defined based on a single urate measurement rather than two or more measurements, which may have led to overestimation of the urate level. Third, due to the cross-sectional nature of the NHANES, causality cannot be inferred. Further research is needed to establish the causal relationships between hyperuricemia and obesity in the United States. Fourth, our analysis did not consider potential confounding factors, such as dietary patterns, history of alcohol consumption, and levels of physical activity. It is important to note that the data collected by NHANES have certain limitations, including small sample sizes and variations in data collection methods across different years (e.g., surveys on vegetarians), which may restrict its applicability in statistical analyses. These unmeasured confounding factors may potentially impact the prevalence and distribution of hyperuricemia. Finaly, despite pooling data across several survey years, the sample sizes for certain subgroups (such as Asian individuals) were small, thereby limiting the power to detect statistically significant differences and resulting in wider confidence intervals and point estimates. NHANES commenced data collection on Asian Americans in 2011. The relatively small sample size may lead to biased estimates of prevalence rates for hyperuricemia, thus caution should be exercised when interpreting the findings on the prevalence and trend of hyperuricemia in the Asian population. Furthermore, the observed discrepancies between numerical values and their corresponding percentages could stem from the application of weighted statistical analysis.

Conclusion

In this large, nationally representative study from US, we present data on the prevalence rates of hyperuricemia from 1999 to 2018. Our study demonstrates that the prevalence of hyperuricemia in adolescents has remained stable over the past two decades, probably due to the relative stability of its associated risk factors. Nonetheless, significant sex and racial disparities persist in the prevalence of hyperuricemia, with varying degrees of correlation to obesity across different sex and racial populations. in Key point. Please check and confirm.

This study suggests that obesity may be the factor most associated with hyperuricemia in adolescents. Healthcare professionals must adopt proactive strategies to prevent childhood obesity, while public health agencies should focus on promoting healthy diets and obesity prevention initiatives, as these efforts may contribute to a reduction in the prevalence of hyperuricemia among adolescents. Additional prospective studies are necessary to clarify the causal relationship between urate levels and obesity. We anticipate that future efforts will prioritize the recognition of elevated urate levels in adolescents, and that race- and sex-specific diagnostic criteria will be established to improve management and mitigate potential related complications.

Abbreviations

BMI	Body Mass Index
BMIZ	Body Mass Index Z score
DBP	Diastolic Blood Pressures
FPG	Fasting Plasma Glucose
HDL-C	High Density Lipoprotein Cholesterol
HUA	Hyperuricemia
LDL-C	Low Density Lipoprotein Cholesterol
NHANES	National Health and Nutrition Examination Survey
PIR	Poverty-to-income Ratio
SBP	Systolic Blood Pressures
SUA	Serum Urate
TC	Total Cholesterol
TG	Triglycerides
WC	Waist Circumference

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s13075-024-03427-1.

Supplementary Material 1: eFigure 1. Distribution of Serum Concentrations of Urate Among 11264 Participants Aged 12 to 17 Years, NHANES 1999-2018. eFigure2. Trends in Hyperuricemia Prevalence by Race/Ethnicity Among US Adolescents, NHANES 2011-2018.

Supplementary Material 2: eTable 1. Demographic and General Clinical Characteristics of US Adolescents with and without Hyperuricemia, NHANES 2011-2018. eTable 2. Mean Serum Urate Among US Adolescents, NHANES 1999-2018. eTable 3. Trends in Prevalence of Hyperuricemia Among US Adolescents by Race/Ethnicity and Obesity, NHANES 1999-2018. eTable 4. Factors Associated with Serum Urate Among US Adolescents in 2011-2018. eTable 5. Factors Associated with Hyperuricemia by Race/Ethnicity and Obesity Among US Adolescents in 2011-2018.

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Author contributions

Kaifeng Guo, Yali Han and Haibing Chen designed the research. Kaifeng Guo, Yali Han, Shuang Liu, Hang Sun, Xiaojing Lin, Shaoling Yang, Yining Gao and Haibing Chen conducted the research. Yali Han performed statistical analysis. Kaifeng Guo wrote the paper. Kaifeng Guo, Yali Han, Shuang Liu and Haibing Chen revised the paper. Haibing Chen are the guarantors of this work and, as such, had full access to all the data in the study and take responsibility for the integrity of the data and the accuracy of the data analysis.

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Data availability

No datasets were generated or analysed during the current study.

Declarations

Ethical approval

The Research Ethics Review Board of the National Center for Health Statistics approved the NHANES study protocol. This analysis was considered exempt from ethical approval by our institution's institutional review board because the dataset used in the analysis was fully de-identified.

Competing interests
The authors declare no competing interests.

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