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Asthma prevalence among women aged 18 to 44 in the United States: National health and nutrition examination survey 2001–2016

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ABSTRACT

Objective: To provide updated prevalence estimates of asthma and asthma medication use for women of childbearing age in the United States.

Methods: Using data from 11,383 women aged 18–44, including a subset of 1,245 pregnant women, enrolled in the National Health and Nutrition Examination Survey (2001–2016), we assessed the age-adjusted prevalence of self-reported diagnosed asthma. For women aged 18–44, we stratified by year, demographics, and other characteristics. Furthermore, we assessed asthma medication use among women aged 18–44 with asthma.

Results: After age-adjustment, 9.9% (95% confidence interval (CI) 9.2%, 10.7%) of women aged 18–44 and 10.9% (95% CI 7.2%, 14.6%) of pregnant women reported having asthma. Asthma prevalence was highest in 2015–2016 (12.0% 95% CI 9.8%, 14.3%) and lowest in 2003–2004 (8.6% 95% CI 6.4%, 10.8%). Women aged 18–44 with Medicaid or State Children's Health Insurance Program insurance coverage (16.8% 95% CI 14.5%, 19.2%), obesity (14.4% 95% CI 12.9%, 15.8%), diabetes (18.7% 95% CI 12.1%, 25.2%), hypertension (16.6% 95% CI 14.2%, 19.0%), and current smokers (12.8% 95% CI 11.4%, 14.2%) had the highest asthma prevalence. Of women with asthma, 38.3% (95% CI 34.5%, 42.1%) reported using asthma medications in the past 30 days.

Conclusions: Among women of childbearing ages, asthma burden varies across demographic and clinical characteristics and has increased in recent years.

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asthma; epidemiology; pregnancy; prescriptions; prevalence; women's health

List of abbreviations

BRFSS	Behavioral Risk Factor Surveillance System
BMI	body mass index
CIs	confidence intervals
MEC	mobile examination centers
NHIS	National Health Interview Survey
SD	standard deviation
SCHIP	State Children's Health Insurance Program

Introduction

Asthma is one of the most common chronic medical conditions affecting women of childbearing age and pregnant women in the United States (1,2). Previous estimates indicate 8.4% to 9.5% of women of childbearing age and 8.4% to 8.8% of pregnant women

have asthma; however, these estimates were reported over a decade ago using data from 2000 to 2003 (3,4). Given that national estimates from the United States indicate that from 2001 to 2010 asthma prevalence increased by 2.1% per year in adults (5), older published data on the prevalence of asthma in women of childbearing age and pregnant women may no longer be applicable.

Asthma prevalence varies according to sex and age, and national estimates indicate that after age 17 through childbearing age, asthma is more common among women than men (5). Because up to half of pregnancies in the United States may be unintended (6,7), there is a need to provide updated estimates of asthma in women of childbearing age to understand

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the potential burden of asthma during pregnancy and to identify high-risk groups.

Asthma is associated with adverse perinatal outcomes including preeclampsia, preterm birth, low birth weight, and small for gestational age (8–12). Uncontrolled or severe asthma is associated with the highest risk of several adverse perinatal outcomes, highlighting the need to properly manage asthma during pregnancy and for women who may become pregnant (10,13,14). The treatment goal for managing asthma during pregnancy is to control asthma symptoms including through adherence with indicated asthma medications (1). Inhaled short-acting beta-agonists are recommended for quick-relief of symptoms, and daily inhaled corticosteroids or inhaled corticosteroids in combination with long-acting beta-agonists are recommended for forms of persistent asthma depending on the patient's asthma severity (1). Oral corticosteroids may be indicated for severe persistent asthma and acute exacerbations (1).

The National Health and Nutrition Examination Survey (NHANES) provides ongoing nationally representative data with information on asthma diagnosis, asthma attack, asthma medication use, and demographic, clinical, and other characteristics. The purpose of our study was to update prevalence estimates of current asthma and asthma medication use among women of childbearing age in the United States and to provide stratified estimates according to certain characteristics that are associated with asthma prevalence (i.e. age, race/ethnicity, poverty, obesity, smoking) or are prevalent in the United States (i.e. diabetes, hypertension) (5,15–18). We hypothesized an increase in asthma prevalence among women of childbearing ages between 2001 and 2016 given the increase in asthma in the general population (5). We also aimed to update prevalence estimates of current asthma and asthma medication use in the subset of pregnant women.

Methods

Data source

The NHANES is an ongoing survey aimed to assess the health of individuals in the United States. Data have been collected in two-year cycles since 1999 through interviews and physical examinations and are available for public use. NHANES utilizes a complex, multistage probability sampling design to achieve a study sample representative of the civilian noninstitutionalized population in the United States (19). Certain subgroups (e.g., non-Hispanic black persons) have been

oversampled to boost the reliability and precision of estimates for these subgroups; assigned weights account for sampling probability and nonresponse (19).

During NHANES interviews, participants reported information regarding age, race/ethnicity, highest level of education, family income (used to calculate ratio of income to poverty), type of health insurance, self-report of ever having diabetes, self-report of ever having hypertension, and current smoking status. The family income to poverty ratio was determined using the Department of Health and Human Services poverty guidelines (20). The eligibility threshold for some government assistance programs, including Medicaid (21), is 200% of the federal poverty level, which was the cut-point used to indicate poverty in this study. Furthermore, participants were asked to report whether a doctor or other health professional ever told them they had asthma, their age when they were first told they had asthma, and whether they still had asthma. Participants reporting that they still had asthma were asked to indicate whether they had an episode of asthma or an asthma attack during the past 12 months. Additionally, participants were queried about prescription medications used or taken in the past 30 days. For each reported medication, participants were asked to show the interviewer the prescription container. If no container was available, interviewers requested the name of the prescription. Medications were coded and classified with Lexicon Plus® drug database (Cerner Multum, Inc.). Route of medication administration was not usually specified. We assumed the route of administration to be systemic for the following reported corticosteroids that are also available in nonsystemic forms: betamethasone, hydrocortisone, methylprednisolone, triamcinolone, and the route to be oral inhalation for the following reported corticosteroids that are also available for nasal inhalation and/or administration via other routes: beclomethasone, budesonide, ciclesonide, fluticasone, mometasone. The participant's body mass index (kg/m^2) was ascertained from height and weight measurements at the NHANES mobile examination center (MEC). Pregnant women were identified by self-reported or positive pregnancy test at the MEC. Women who reported being pregnant but had a negative pregnancy test were classified as pregnant.

Asthma classification

We classified individuals as having asthma (i.e., current asthma) if they self-reported ever being told by a health professional that they had asthma and if they

reported still having asthma. We further classified individuals with asthma as having an asthma attack if they self-reported having an episode of asthma or an asthma attack during the past 12 months.

Study population

Women aged 18–44 years who participated in the 2001–2016 NHANES cycles were included in this analysis. During the 2001–2006 cycles only, pregnant women were oversampled, resulting in a smaller number of pregnant women after 2006. Due to disclosure risks, pregnant women younger than 20 or older than 44 were excluded from the 2007–2016 data. Therefore, pregnant women aged 18–44 years were included from 2001 to 2006 and pregnant women aged 20–44 years were included from 2007 to 2016. A total of 11,423 women of childbearing age, including nonpregnant and pregnant women, participated in both the interview and the physical exam. Of these women, 40 were missing a response to the current asthma or asthma attack questions and 78 had unknown pregnancy status. There were 11,383 women aged 18–44, including 1,245 pregnant women, in the final sample. No prescription data were available for 2015–2016 at the time this study was conducted.

NHANES was approved by the NHANES Institutional Review Board (IRB) and National Center for Health Statistics Ethics Review Board, and participants provided informed consent. The current study used publically available data not containing individually identifiable information and therefore did not require IRB approval.

Statistical analysis

All statistical analyses were performed in SAS 9.4 using SAS Survey procedures. Percentages and means were weighted using MEC weights to account for sampling probability and nonresponse; reported numbers were unweighted. The masked variance unit pseudo-stratum variable and the masked variance unit pseudo-primary sampling unit variable were used to account for the complex survey design in variance estimation. Relative standard errors were calculated by dividing the standard error of the estimate by the estimate multiplied by 100; values that were 0% or greater than 30% indicated a potentially unreliable prevalence estimate (19).

First, to provide a description of the study population, we stratified demographic and clinical characteristics unadjusted for age according to asthma status for all women and for the subset of pregnant women,

separately. Second, we calculated age-adjusted prevalence estimates and 95% confidence intervals (CI) for asthma and asthma attack in the past year for all women and for the subset of pregnant women, separately. Age was standardized to the 2000 United States Census because the 2000 census population is recommended as the standard population for NHANES 1999–2010 and the same standard population is needed to make comparisons across the study period (19,22). Among all women, we estimated the age-adjusted prevalence of asthma and 95% CIs for each two-year period, and we assessed linear trend and quadratic change in asthma prevalence estimates from 2001 to 2016 by testing continuous and quadratic variables. Then, we stratified asthma and asthma attack prevalence estimates among all women according to demographic and clinical characteristics. To increase precision of the stratified estimates, we used data from 2001 to 2016. We tested for differences in asthma prevalence according to characteristics, excluding those with missing values, using Wald's *f*-tests (categorical variables) and *t*-tests (continuous variable) for age-adjusted estimates, and Rao-Scott *f*-tests for age-unadjusted estimates (i.e., age and, because the age-adjusted results were unstable due to small sample size, education). We did not stratify asthma prevalence by characteristics among pregnant women because of sample size limitations.

Among all women with asthma, we calculated the age-adjusted prevalence of the use of prescription asthma medications from 2001 to 2014. We assessed asthma medications overall, class of medications (Supplementary Table 1), and controller medications (Supplementary Table 2). We tested for a difference in the prevalence of any asthma medication use in the past 30 days between nonpregnant and pregnant women with a Rao-Scott *f*-test. We did not report type of asthma medication use among pregnant women because of sample size limitations.

Sensitivity analysis

To determine the reliability of self-report of ever being diagnosed with diabetes or hypertension and current smoking, we performed a sensitivity analysis using alternative definitions. Diabetes was redefined as self-report of current use of insulin or diabetic pills to lower blood sugar, i.e., current diabetes. Hypertension was redefined as an average systolic blood pressure (SBP) ≥ 140 or diastolic blood pressure (DBP) ≥ 90 from up to three blood pressure measurements at the MEC, or self-report of current prescription hypertension medication use (18), i.e., current hypertension. Finally, women with serum cotinine levels ≥ 10 ng/dL

Table 1. Characteristics for women aged 18–44 years and pregnant women aged 18–44 according to asthma status from NHANES 2001–2016 data.^a

	All women aged 18–44 years (N = 11,383)				Pregnant women aged 18–44 years (N = 1,245) ^b			
	n	No asthma (N = 10,298) % (95% CI)	n	Asthma (N = 1,085) % (95% CI)	n	No asthma (N = 1,110) % (95% CI)	n	Asthma (N = 135) % (95% CI)
Age (years)								
18–24	3,244	25.1 (23.6, 26.6)	373	27.2 (23.6, 30.8)	398	30.7 (26.7, 34.7)	58	38.5 (27.4, 49.6)
25–34	3,580	36.3 (35.0, 37.6)	359	35.8 (32.1, 39.4)	574	52.2 (47.5, 56.8)	67	49.25 (36.8, 62.1)
35–44	3,474	38.5 (37.0, 40.0)	353	37.1 (32.8, 41.3)	138	17.1 (13.5, 20.8)	10	*
Race/ethnicity								
Non-Hispanic White	3,818	59.8 (57.0, 62.5)	483	66.2 (62.5, 70.0)	461	52.7 (47.4, 58.0)	57	50.3 (38.1, 62.5)
Non-Hispanic Black	2,283	13.8 (12.2, 15.4)	283	14.9 (12.4, 17.5)	193	15.7 (12.5, 18.8)	34	23.0 (13.2, 32.9)
Mexican American	2,264	11.4 (9.9, 12.9)	143	6.5 (5.0, 8.0)	302	15.8 (12.8, 18.9)	22	9.5 (4.0, 15.0)
Other	1,933	15.0 (13.6, 16.4)	176	12.3 (10.0, 14.7)	154	15.8 (12.4, 19.2)	22	17.1 (8.5, 25.8)
Highest level of education								
<12th grade	2,448	16.5 (15.4, 17.6)	243	15.0 (12.5, 17.6)	303	19.7 (16.4, 23.1)	42	25.4 (15.1, 35.7)
≥ 12th grade	7,844	83.5 (82.4, 84.6)	841	84.9 (82.3, 87.4)	807	80.3 (76.9, 83.6)	93	74.6 (64.3, 84.9)
Missing	6	*	1	*	0	0	0	0
Family income to poverty ratio								
<200%	5,162	40.1 (38.4, 41.8)	603	47.3 (43.2, 51.4)	535	40.0 (35.8, 44.1)	74	51.1 (38.7, 63.5)
≥200%	4,416	54.1 (52.5, 55.7)	418	45.9 (41.6, 50.3)	509	54.6 (50.0, 59.3)	53	40.0 (27.3, 52.7)
Missing	720	5.8 (5.1, 6.5)	64	6.7 (4.4, 9.0)	66	5.4 (3.4, 7.4)	8	*
Health insurance								
No insurance	2,798	22.9 (21.6, 24.3)	213	17.7 (14.9, 20.6)	193	14.0 (11.2, 16.9)	18	12.2 (5.3, 19.1)
Medicaid/SCHIP	1,421	9.7 (8.8, 10.5)	243	16.9 (14.4, 19.4)	294	23.6 (20.1, 27.2)	38	27.9 (16.6, 39.2)
Other insurance	6,029	67.0 (65.4, 68.5)	625	64.8 (61.1, 68.5)	621	62.2 (57.7, 66.7)	79	59.9 (48.2, 71.6)
Missing	50	0.4 (0.3, 0.6)	4	*	2	*	0	0
BMI, kg/m ²								
<18.5–24.9	4,048	42.3 (40.8, 43.8)	312	30.7 (27.2, 34.2)	322	28.8 (24.8, 32.9)	30	19.1 (10.1, 28.1)
25.0–29.9	2,700	25.1 (24.0, 26.3)	224	20.6 (17.6, 23.7)	388	34.7 (30.2, 39.2)	32	23.3 (11.2, 35.4)
≥30	3,367	31.0 (29.8, 32.2)	529	46.8 (43.3, 50.4)	373	33.8 (29.3, 38.3)	72	57.3 (44.7, 69.9)
Missing	183	1.6 (1.2, 1.9)	20	*	27	*	1	*
Ever diabetes								
Yes	274	2.5 (2.2, 2.8)	61	5.1 (3.6, 6.6)	15	*	3	0.7 (0.3, 1.1)
No	10,017	97.4 (97.1, 97.8)	1,023	94.8 (93.3, 96.4)	1,094	98.1 (96.8, 99.4)	132	99.3 (98.9, 99.7)
Missing	7	*	1	*	1	*	0	0
Ever hypertension								
Yes	1,161	11.2 (10.4, 12.1)	219	20.2 (17.4, 23.1)	89	7.7 (5.3, 10.1)	20	*
No	9,101	88.5 (87.6, 89.4)	865	79.7 (76.9, 82.5)	1,018	92.0 (89.6, 94.4)	115	81.0 (69.2, 92.8)
Missing	36	0.3 (0.2, 0.4)	1	*	3	*	0	0
Current smoking								
Yes	2,026	22.1 (20.8, 23.3)	324	29.4 (26.5, 32.2)	103	9.2 (6.7, 11.8)	28	20.6 (11.1, 30.1)
No	8,155	77.5 (76.2, 78.7)	750	70.1 (67.2, 73.1)	1,000	90.5 (88.0, 93.1)	106	79.2 (69.6, 88.7)
Missing	117	0.5 (0.3, 0.6)	11	*	7	*	1	*

Abbreviations: BMI: body mass index; SCHIP: State-Children's Health Insurance Program.

^aNumbers are unweighted; percentages are weighted for sampling probability and nonresponse; variance estimation accounts for complex survey design.^bPregnant women are a subset of all women of childbearing ages 18–44.

*Denotes an unreliable estimate due to small sample size.

were classified as current smokers (23). Cotinine levels were only available for data before 2015. Prevalence estimates for asthma and asthma attack by these measures were repeated as previously described.

Results

Characteristics by asthma status, not adjusting for age

There were 1,085 women aged 18–44 who reported having current asthma. Women with asthma more often were in poverty and had Medicaid or State Children's Health Insurance Program (SCHIP) insurance than women without asthma. They were also more likely to be obese (BMI ≥30), have ever been diagnosed with diabetes or hypertension, and smoke

in the past 30 days (Table 1). In the subset of pregnant women, those with asthma were more likely to be obese and to smoke than those without asthma.

Age-adjusted prevalence of asthma and asthma attack in all women and in pregnant women

Age-adjusted prevalence estimates of asthma and asthma attack (Table 2) were similar to the unadjusted results (data not shown). For 2000–2016, the age-adjusted prevalence estimates for women of childbearing ages were 9.9% (95% CI 9.2%, 10.7%) for asthma and 5.4% (95% CI: 4.9%, 6.0%) for asthma attack. In the subset of pregnant women, the estimates were 10.9% (95% CI 7.2%, 14.6%) for asthma and 5.7% (95% CI: 3.2%, 8.2%) for asthma attack.

Table 2. Age-adjusted prevalence of asthma and asthma attack of women aged 18–44 years by characteristics, NHANES 2001–2016 (N = 11 383).^a

	Total	Asthma (N = 1,085)			Asthma attack (N = 585)		
		n	% Yes (% 95 CI)	p-value ^c	n	% Yes (95% CI)	p-value ^c
All women	11,383	1,085	9.9 (9.2, 10.7)	NA	585	5.4 (4.9, 6.0)	NA
Pregnant women	1,245	135	10.9 (7.2, 14.6)		74	5.7 (3.2, 8.2)	
Age (years) ^b				.52			.79
18–24	3,617	373	10.7 (9.2, 12.1)		179	5.2 (4.1, 6.3)	
25–34	3,939	359	9.8 (8.5, 11.1)		197	5.3 (4.5, 6.2)	
35–44	3,827	353	9.6 (8.5, 10.8)		209	5.7 (4.7, 6.6)	
Race/ethnicity				<.01 ^e			<.01 ^f
Non-Hispanic White	4,301	483	10.9 (9.8, 11.9)		285	6.2 (5.4, 7.1)	
Non-Hispanic Black	2,566	283	10.6 (9.3, 11.9)		140	5.4 (4.4, 6.3)	
Mexican American	2,407	143	5.9 (4.7, 7.2)		72	2.8 (1.9, 3.6)	
Other	2,109	176	8.4 (6.9, 9.8)		88	4.3 (3.2, 5.3)	
Highest level of education ^b				.26			.09
<12th grade	2,691	243	9.2 (7.6, 10.7)		132	4.7 (3.7, 5.6)	
≥ 12th grade	8,685	841	10.1 (9.3, 10.9)		452	5.6 (5.0, 6.2)	
Missing	7	1	*		1	*	
Family income to poverty ratio				<.01			<.01
<200%	5,765	603	11.6 (10.4, 12.8)		326	6.3 (5.4, 7.2)	
≥200%	4,834	418	8.6 (7.7, 9.6)		226	4.8 (4.0, 5.5)	
Missing	784	64	11.4 (7.6, 15.2)		33	5.6 (3.3, 7.9)	
Health insurance				<.01 ^g			<.01 ^g
No insurance	3,011	213	7.7 (6.4, 9.1)		119	4.2 (3.3, 5.1)	
Medicaid/SCHIP	1,664	243	16.8 (14.5, 19.2)		142	10.4 (8.3, 12.4)	
Other insurance	6,654	625	9.7 (8.8, 10.5)		324	5.2 (4.5, 5.9)	
Missing	54	4	*		0	0	
BMI, kg/m ²				<.01 ^h			<.01 ^h
<18.5–24.9	4,360	312	7.2 (6.3, 8.1)		168	3.8 (3.0, 4.5)	
25.0–29.9	2,924	224	8.3 (7.0, 9.6)		110	4.5 (3.4, 5.5)	
≥30	3,896	529	14.4 (12.9, 15.8)		298	8.3 (7.2, 9.3)	
Missing	203	20	11.9 (5.5, 18.3)		9	*	
Ever diabetes				.02			.11
Yes	335	61	18.7 (12.1, 25.2)		32	10.1 (5.0, 15.2)	
No	11,040	1,023	9.7 (8.9, 10.4)		552	5.3 (4.7, 5.9)	
Missing	8	1	*		1	*	
Ever hypertension				<.01			<.01
Yes	1,380	219	16.6 (14.2, 19.0)		128	9.7 (7.7, 11.6)	
No	9,966	865	8.9 (8.2, 9.7)		457	4.8 (4.2, 5.3)	
Missing	37	1	*		0	0	
Current smoking				<.01			<.01
Yes	2,350	324	12.8 (11.4, 14.2)		186	7.2 (6.1, 8.4)	
No	8,905	750	9.1 (8.3, 9.9)		397	4.9 (4.3, 5.6)	
Missing	128	11	*		2	*	
Age of asthma onset (mean, SD) ^d			15.5 (13.1)	<.01		15.9 (12.0)	<.01

Abbreviations: BMI: body mass index; CI: confidence interval; NA: not applicable; SCHIP: State-Children's Health Insurance; SD: standard deviation.

^aNumbers are unweighted; percentages and means are weighted for sampling probability and nonresponse; variance estimation accounts for complex survey design.^bAge and education (due to small sample size) unadjusted for age.^cComparisons by each characteristic, excluding those with missing values.^d16 women with missing asthma were missing age of asthma onset; 6 women with an asthma attack were missing age of asthma onset.^eSignificant differences observed for all racial/ethnic groups except non-Hispanic Whites versus non-Hispanic Blacks.^fSignificant differences observed for all racial/ethnic groups except non-Hispanic White versus non-Hispanic Black, and non-Hispanic Black versus other.^gSignificant differences observed for women with Medicaid/SCHIP versus no insurance, no insurance versus other insurance, and Medicaid/SCHIP versus other insurance.^hSignificant differences observed between obese women (≥30 kg/m²) and the other two BMI categories (<18.5–24.9 and 25.0–29.9 kg/m²).

*Denotes an unreliable estimate due to small sample size.

Age-adjusted asthma prevalence by year among all women

There was a statistically significant linear increase in asthma prevalence during the study period ($p < .01$); there was no evidence of a quadratic trend ($p = .29$). Asthma prevalence was lowest in the years 2003–2004 (8.6% 95% CI 6.4%, 10.8%) and highest in the years 2015–2016 (12.0% 95% CI 9.8%, 14.3%) (Figure 1).

Age-adjusted prevalence of asthma and asthma attack by characteristics among all women

Compared with Mexican American women and women in the other race/ethnicity group, non-Hispanic White and non-Hispanic Black women had the highest prevalence of asthma at 10.9% (95% CI 9.8%, 11.9%) and 10.6% (95% CI 9.3%, 11.9%), respectively (Table 2). Compared to women with other insurance or without insurance, women with

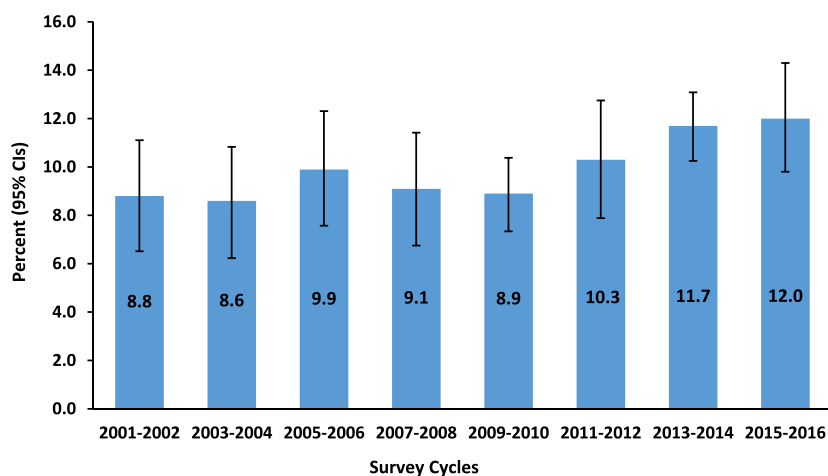


Figure 1. Age-adjusted asthma prevalence by two-year intervals among women aged 18–44 years using NHANES data from 2001 to 2016 ($N = 11,383$). Percentages are weighted for sampling probability and nonresponse; variance estimation accounts for complex survey design. $p < .01$ for linear increase. Abbreviation: CI, confidence interval.

Medicaid/SCHIP insurance coverage had a higher prevalence of asthma (16.8% (95% CI 14.5%, 19.2%)) and asthma attack in the past year (10.4% (95% CI 8.3%, 12.4%)). Compared with lower BMI categories, asthma (14.4% (95% CI 12.9%, 15.8%)) and asthma attack prevalence (8.3% (95% CI 7.2%, 9.3%)) were highest for women with a BMI ≥ 30 , kg/m². Women reporting ever having hypertension had a higher prevalence of asthma (16.6% 95 CI 14.2%, 19.0%) and asthma attack (9.7% 95% CI 7.7%, 11.6%) compared with normotensive women. In the sensitivity analysis, asthma and asthma attack estimates were similar to the primary analysis for women with current diabetes medication use and with serum cotinine ≥ 10 ng/mL (Supplementary Tables 3 and 4). However, the prevalence estimates in the sensitivity analysis were not statistically different according to current hypertension.

Age-adjusted prevalence of asthma medication use among all women with asthma

A total of 38.3% (95% CI 34.5%, 42.1%) of women with asthma reported using any type of asthma medication in the past 30 days, and 19.9% (95% CI 16.8%, 23.1%) reported using any controller medication (Table 3). The most commonly reported medications were short-acting beta-agonists (28.2% (95% CI 24.8%, 31.6%)), followed by inhaled corticosteroid/long-acting beta-agonist combinations and leukotriene modifiers.

Age-adjusted prevalence of asthma medications in nonpregnant and pregnant women with asthma

The age-adjusted prevalence estimates for any asthma medication use in the past 30 days was 38.1% (95% CI

33.9%, 42.4%) (Table 3) for nonpregnant women and was 29.3% (95% CI 10.8%, 47.8%) (unstable estimate because of small sample size) for pregnant women, although the estimates were not significantly different ($p = .26$).

Discussion

According to NHANES data from 2001 to 2016, 9.9% of women aged 18–44 (including pregnant women) in the United States had current asthma and 5.4% had an asthma attack in the past year. In the subset of pregnant women, 10.9% had current asthma and 5.7% had an asthma attack in the past year.

Asthma prevalence among all women 18–44 years of age increased during the study period, and by 2015–2016, 12.0% of women aged 18–44 had asthma. Women of childbearing ages who had Medicaid/SCHIP health insurance coverage, obesity, or who reported ever being diagnosed with hypertension or diabetes, or current smoking had the highest prevalence of asthma and asthma attack in the past year.

The results of the current study together with data from earlier time periods indicate a temporal trend of increasing asthma prevalence among women of childbearing ages in the United States. In an earlier study using NHANES II and III data among women of childbearing ages, Kwon et al. reported lower asthma prevalence estimates of 2.9% (95% CI 1.6, 4.2%) in 1976–1980 and of 5.8% (95% CI 4.0%, 7.6%) in 1988–1994, age-adjusted to the 1980 United States Census (3). Between the 1980 Census and the 2000 Census, there were shifts in age and race/ethnicity composition of the United States population (22,24). Specifically, there was a relative ‘aging’ of the

Table 3. Age-adjusted prevalence of asthma medications reported by women 18–44 years of age with asthma from NHANES 2001–2014 ($N=944$; $n=758$ nonpregnant women, $n=126$ pregnant women, $n=60$ women with unknown pregnancy status).^{a,b}

Asthma medications	<i>N</i>	% (95% CI)
Any asthma medication ^{c,d}	349	38.3 (34.5, 42.1)
Any asthma medication: nonpregnant women ^e	289	38.1 (33.9, 42.4)
Any asthma medication: pregnant women ^e	39	29.3 (10.8, 47.8)*
Any controller medication ^f	162	19.9 (16.8, 23.1)
Short-acting beta-agonists	282	28.2 (24.8, 31.6)
Inhaled corticosteroids/Long-acting beta-agonist combinations	73	8.1 (6.0, 10.2)
Leukotriene modifiers	61	7.9 (5.8, 10.1)
Inhaled corticosteroids	49	5.6 (3.7, 7.5)
Systemic corticosteroids	31	3.4 (2.1, 4.7)
Long-acting beta-agonists	12	1.3 (0.3, 2.3)*
Other ^g	21	2.0 (1.0, 2.9)

^aNumbers are unweighted; percentages are weighted for sampling probability and nonresponse; variance estimation accounts for complex survey design.

^bNo prescription data were available for survey years 2015–2016 at the time this study was conducted.

^cAny asthma medication includes betamethasone, hydrocortisone, methylprednisolone, prednisone, triamcinolone, beclomethasone, budesonide, ciclesonide, fluticasone, mometasone, budesonide/formoterol combination, fluticasone/salmeterol combination, mometasone/formoterol combination, formoterol, salmeterol, montelukast, zafirlukast, albuterol, levalbuterol, metaproterenol, pirbuterol, albuterol/ipratropium combination, cromolyn, ipratropium, theophylline, tiotropium.

^d21 women who reported any asthma medication had missing pregnancy status.

^e p -value = .26 for Rao-Scott f -test comparing nonpregnant and pregnant women.

^fAny controller includes inhaled corticosteroids (ICS), ICS/long-acting beta-agonist combinations, leukotriene modifiers, long-acting beta-agonists, cromolyn, theophylline, tiotropium.

^gOther includes medications from classes observed among <10 women (i.e., albuterol/ipratropium combination, cromolyn, ipratropium, theophylline, tiotropium).

*Denotes a potentially unreliable estimate due to small sample size.

population with a higher proportion of women in the 35–44 year old age groups in the 2000s compared with 1980s. Additionally, the proportion of Hispanic women among women of childbearing age doubled, while the proportion of non-Hispanic White women decreased (22,24). Given the slightly higher burden of asthma among younger individuals and non-Hispanic White women, both demographic trends may have been expected to lower prevalence estimates in the current study relative to previous studies. Thus, the higher asthma prevalence observed in the current study compared with the earlier studies is likely attributable to other factors and requires further exploration. Kwon et al. reported asthma prevalence estimates unadjusted for age from the 2001–2003 National Health Interview Survey (NHIS) of 8.4% (95% CI 8.0%, 8.8%) and the 2000–2003 Behavioral Risk Factor Surveillance System (BRFSS) of 9.5% (95% CI 9.3%, 9.7%) (4).

Similar to asthma, the prevalence of other chronic diseases in women of childbearing age have increased in recent years and are associated with maternal and infant morbidity (25–31). Specifically, among women of child-bearing age, there has been an increase in the prevalence of obesity, diabetes, and hypertension (25–27). Our study found higher asthma prevalence among women with obesity, diabetes, and hypertension, which highlights the need for prevention of chronic conditions before pregnancy and management

of multiple chronic conditions during pregnancy among some women with asthma.

Among pregnant women, Kwon et al. reported an age-adjusted asthma prevalence of 5.8% (95% CI 4.0%, 7.6%) in 1988–1994 NHANES III data (3). Age-unadjusted BRFSS estimates from 2000 to 2003 and NHIS estimates from 2001 to 2003 were 8.4% (95% CI 7.4%, 9.5%) and 8.8% (95% CI 7.0%, 11.0%), respectively (4). Using national hospital discharge data from over 7.5 million deliveries between 2003 and 2011, Baghlaf et al. found only 2.9% of pregnant women had a diagnosis of asthma (12). This may have been an underestimate as it was based on data from the delivery hospitalization only and may not have fully captured women with mild or well-controlled asthma.

Although not statistically significant, the prevalence of asthma medication use was higher in nonpregnant women compared with pregnant women. Discontinuation of asthma medications in the first trimester is common, with a reported 54% decline in oral corticosteroid prescriptions (32).

We found that approximately one third of women with asthma reported using an asthma medication in the past 30 days. Short-acting beta-agonists were the most commonly used asthma medications. Analyzing NHANES data from 1999 to 2006, Tinker and colleagues reported albuterol, a short-acting beta-agonist, as one of the most frequent prescription medications used by nonpregnant women (including women with

and without asthma) of childbearing ages (33). Using health care claims databases from 2001 to 2007, Hansen et al. found that among pregnant women with asthma, 63% had a pharmacy dispensing for any asthma medication (34). Hansen et al. relied on medication dispensings and therefore their results may have overestimated actual asthma medication use (34). Whereas in the current study, asthma medication use was likely underestimated as it relied on patient recall and was only reported for the past 30 days.

In addition to potential underestimation of asthma medication use, our study had other limitations. First, it is possible there was a lower participation response in pregnant women vs. nonpregnant women in our study. This could lead to bias in asthma prevalence estimates in the subset of pregnant women if participation differed by pregnancy and asthma status. Second, asthma was based on self-report of health professional-diagnosed asthma and could not be confirmed. This could result in underestimation of asthma prevalence and, if differential by certain characteristics, may explain some of the lower stratified estimates, e.g., among Mexican American women or among women with no insurance. Results could differ if clinical data were available. Third, the small sample size of pregnant women prevented us from estimating asthma prevalence among pregnant women by year, demographic and clinical characteristics, and asthma medication use by class. Fourth, although asthma prevalence was higher in 2015–2016 (12.0%) than across all survey years (9.9%), we combined survey years 2001–2016 to increase sample size for asthma prevalence estimates stratified by demographic and clinical characteristics and for medication prevalence estimates. As such, temporal variations in stratified prevalence estimates and medication use across the study period cannot be identified, and some of the stratified prevalence estimates are expected to underestimate asthma burden in more recent years. Fifth, we were unable to assess changes in asthma and asthma medication during pregnancy given that the data were cross-sectional. Sixth, data were not available to stratify asthma prevalence according to asthma severity. Finally, the route of administration was unknown for corticosteroids, and assumptions had to be made. Thus, prevalence estimates for inhaled corticosteroid and systemic corticosteroid use may be different, had we had information on route of administration.

Conclusions/key findings

The findings of the current study highlight differences in the burden of asthma across time, demographic,

and clinical characteristics among women of childbearing age. Women who were enrolled in Medicaid/SCHIP health insurance coverage, were obese, had diabetes or were smokers had the highest asthma attack prevalence and may represent groups that would benefit from asthma management and medication adherence efforts. The suggested trend towards less asthma medication use among pregnant women compared with nonpregnant women highlights the role primary care, obstetricians, and asthma specialists have in counseling women on asthma medication use during pregnancy and monitoring patient's asthma treatment before and during pregnancy. Uncontrolled or untreated asthma increases pregnancy risks (10,13,14), and prenatal care can provide an opportune time to ensure women with preexisting asthma obtain appropriate treatment and receive routine asthma care.

Declaration of interest

The authors report no conflicts of interest. The authors alone are responsible for the content and writing of the paper.

Author's contribution

Study conception and design: Flores, Bandoli, Chambers, Schatz and Palmsten. Acquisition of data: Flores. Analysis of data: Flores, Bandoli and Palmsten. Interpretation of results: Flores, Bandoli, Chambers, Schatz and Palmsten. Critical revision of the manuscript: Flores, Bandoli, Chambers, Schatz and Palmsten. All authors have approved the final version of the manuscript.

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Supplementary Table 1: Asthma medications observed among women aged 18-44 years using NHANES data from 2001-2014.

Classification	Medication
Combination bronchodilator	Albuterol/ipratropium
ICS/Long-acting beta-agonist combination	Budesonide/formoterol
ICS/Long-acting beta-agonist combination	Fluticasone/salmeterol
ICS/Long-acting beta-agonist combination	Mometasone/ formoterol
Inhaled corticosteroid	Beclomethasone ^a
Inhaled corticosteroid	Budesonide ^a
Inhaled corticosteroid	Ciclesonide ^a
Inhaled corticosteroid	Fluticasone ^a
Inhaled corticosteroid	Mometasone ^a
Leukotriene modifier	Montelukast
Leukotriene modifier	Zafirlukast
Long-acting anti-cholinergic	Tiotropium
Long-acting beta-agonist	Formoterol
Long-acting beta-agonist	Salmeterol
Short-acting anti-cholinergic	Ipratropium
Short-acting beta-agonist	Albuterol
Short-acting beta-agonist	Levalbuterol
Short-acting beta-agonist	Metaproterenol
Short-acting beta-agonist	Pirbuterol
Systemic corticosteroid	Betamethasone ^b
Systemic corticosteroid	Hydrocortisone ^b
Systemic corticosteroid	Methylprednisolone ^b
Systemic corticosteroid	Prednisone or Prednisolone
Systemic corticosteroid	Triamcinolone ^b
Other	Cromolyn
Other	Theophylline

^a Route of beclomethasone, budesonide, ciclesonide, fluticasone, and mometasone are unknown and assumed to be oral inhalation.

^b Route of betamethasone, hydrocortisone, methylprednisolone, and triamcinolone are unknown and assumed to be systemic.

Supplementary Table 2: Controller asthma medications observed among women aged 18-44 years using NHANES data from 2001-2014.

Controller medication classification

Inhaled corticosteroid^a
ICS/Long-acting beta-agonist combination
Leukotriene modifiers
Long-acting beta-agonist
Cromolyn
Theophylline
Tiotropium

^a Includes beclomethasone, budesonide, ciclesonide, fluticasone, and mometasone and route for these medications are unknown and assumed to be oral inhalation.

Supplementary Table 3. Sensitivity analysis of age-adjusted prevalence of asthma and asthma attack of women aged 18-44 years by current diabetes and current hypertension, NHANES 2001-2016 (N=11,383).^a

	Total	Asthma (N =1,085)			Asthma attack (N = 585)		
		n	% Yes (% 95 CI)	p-value ^e	n	% Yes (95% CI)	p-value ^e
Current diabetes medication use ^b				0.01			0.06
Yes	270	53	22.0 (13.9, 30.2)		30	12.7 (6.0, 19.4)	
No	11,113	1,032	9.7 (8.9, 10.4)		555	5.3 (4.7, 5.9)	
Current hypertension ^c				0.16			0.11
Yes	812	117	14.6 (9.6, 19.5)		71	10.0 (5.2, 14.8)	
No	9,934	919	9.6 (8.7, 10.4)		487	5.1 (4.5, 5.7)	
Missing	637	49	6.8 (4.6, 9.0)		27	4.3 (2.4, 6.2)	

Abbreviations: CI, confidence interval;

^a Numbers are unweighted; percentages and means are weighted for sampling probability and non-response; variance estimation accounts for complex survey design.

^b Current diabetes medication use was based on self-report of currently taking insulin or diabetic pills for blood sugar.

^c Current hypertension classification was based on an average systolic blood pressure ≥ 140 mmHg or diastolic blood pressure ≥ 90 mmHg from up to three measurements at mobile examination center, or self-report of currently taking medication to lower blood pressure.

^e Comparisons exclude those with missing values.

Supplementary Table 4. Sensitivity analysis of age-adjusted prevalence of asthma and asthma attack of women aged 18-44 years by serum cotinine (ng/dL), NHANES 2001-2014 (N=10,024).^a

	Asthma (N = 944)				Asthma attack (N = 515)		
	Total	n	% Yes (% 95 CI)	p-value ^c	n	% Yes (95% CI)	p-value ^c
Smoking (Serum cotinine) ^b				<0.01			0.01
≥10 ng/mL	2,130	288	12.3 (10.8, 13.9)		157	6.6 (5.4, 7.8)	
<10 ng/mL	7,223	607	8.8 (7.9, 9.8)		331	4.9 (4.2, 5.5)	
Missing	671	49	9.0 (5.7, 12.2)		27	5.3 (2.6, 8.0)	

Abbreviations: CI, confidence interval.

^a Numbers are unweighted; percentages and means are weighted for sampling probability and non-response; variance estimation accounts for complex survey design.

^b Smoking was determined by serum cotinine levels measured at mobile examination center.

^c Comparisons exclude those with missing values