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Comparisons between 2015 US asthma prevalence and two measures of asthma burden by racial/ethnic group

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ABSTRACT

Objective: Asthma affects approximately 20,383,000 Americans and costs the US \$56 billion dollars annually. Asthma burden is not uniform across different racial/ethnic groups. Although annual asthma prevalences by racial/ethnic group are provided by the CDC, these numbers do not account for the influence of other sociodemographic and clinical factors. In this study, we evaluated several measures of asthma burden that controlled for sociodemographic and clinical factors and compared them to 2015 CDC asthma prevalences by racial/ethnic group. **Methods:** We obtained unadjusted asthma predictions directly from the 2015 Behavioral Risk Factor Surveillance System (BRFSS) survey. To estimate average adjusted predictions (AAP) and adjusted predictions at the means (APM) for asthma, we controlled for sociodemographic and clinical factors through logistic models and subsequently calculated marginal probabilities for these results. **Results:** We found substantial differences at the national and state level between unadjusted prevalences and AAPs and APMs for asthma by race/ethnicity group. In addition, states that had the highest and lowest unadjusted prevalences differed from states that had the highest and lowest AAPs and APMs. For unadjusted prevalences, AAPs, and APMs, we found that states that had the highest prevalences or probabilities of asthma for Whites tended to have the widest disparities between the estimates for Whites and those of other races. **Conclusions:** The study's results highlight the need to account for sociodemographic and clinical factors when addressing asthma burden by racial/ethnic group across the US.

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Introduction

As of 2016, around 8.3% of US adults, 20,383,000 people, suffer from asthma [1]. Each year asthma costs the US approximately \$56 billion dollars in hospitalization expenses and days of missed work [2–6]. Not only is the burden of asthma high, it also contributes to around nine deaths in the US every day [3,5–7]. While advances in medicine have led to a reduction in asthma deaths, statistics from the Centers for Disease Control and Prevention (CDC) show that in the last decade the percentage of people in the US living with asthma increased by 15% [3,5,8,9]. The rise in asthma prevalence makes it especially important to properly identify which US groups and geographic areas are most impacted by this disease.

Certain sociodemographic groups such as women, those aged 18–24, Blacks and Hispanics, those who did not complete high school, and those with a

household income less than \$75,000 are more likely to suffer from asthma than others [3,5,10–19]. Differences in asthma burden are especially pronounced between Blacks and Hispanics compared to other racial/ethnic groups [3,14–17,20,21]. In addition to being hospitalized more frequently for asthma than White adults, Black adults are 2–3 times more likely to die from asthma than adults from any other racial/ethnic group [5]. Differences in asthma outcomes between races could stem from the high cost of asthma medication and lack of access to regular medical care among these particular racial/ethnic groups [3,5]. It's estimated that 1 in 4 Black adults cannot afford their asthma medication and do not regularly see a doctor about their asthma while 1 in 5 Hispanic adults cannot afford their asthma medication and 1 in 7 Hispanic adults do not regularly see a doctor about their asthma [3,5]. However, disparities in asthma prevalence and mortality among different racial/ethnic groups is complicated by other sociodemographic

factors, such as age, income, and access to medical care as well as clinical factors like obesity and smoking which must be controlled for in order to obtain an accurate picture of the impact of asthma in the US [3, 5,22–27].

The CDC provides yearly statistics on asthma burden through prevalence data by racial/ethnic group [3]. However, these numbers for each racial/ethnic group do not take into account the influence of other sociodemographic and clinical factors [28]. The inability to control for these factors makes it difficult to determine how much of an independent role race/ethnicity has in driving asthma prevalence [29]. While several studies that have looked at asthma incidence (newly diagnosed asthma cases) have adjusted for these factors in their analyses, incidence alone does not capture already existing asthma cases and thus does not provide a complete representation of asthma burden [30–34].

In this study, we will use several marginal probability techniques on the nationally representative 2015 Behavioral Risk Factor Surveillance System (BRFSS) survey that will give us the ability to determine asthma burden by racial/ethnic groups after controlling for key sociodemographic and clinical factors of asthma in all 50 US states [35]. We will compare these adjusted measures of asthma burden in each state to 2015 prevalences from the CDC for each racial/ethnic group that have not been adjusted for sociodemographic and clinical factors. This study will provide us with a clearer understanding of patterns of racial/ethnic disparities in asthma burden across the US.

Methods

Data

We used the 2015 BRFSS as our source of data for asthma prevalence and information on sociodemographic and clinical factors. The BRFSS is a nationally representative survey conducted annually by the CDC on health behaviors [35]. Potential survey participants are residents in all 50 states and the District of Columbia who are randomly contacted via landline or through cell phones [35]. Unequal survey weights are used in the BRFSS to ensure that underrepresented groups in certain geographic areas are well represented and to reduce bias [36,37]. The surveys are publicly available and can be accessed online at <https://www.cdc.gov/brfss/index.html> [35]. The 2015 BRFSS was chosen since at the time of this analysis it is the most recent iteration of the survey that allows for quick comparison between the latest CDC

published prevalences by racial/ethnic groups which have not been adjusted for other sociodemographic and clinical factors and marginal probabilities, which are a measure of asthma burden that have been adjusted for sociodemographic and clinical factors. Unadjusted prevalences for different racial/ethnic groups from the 2015 BRFSS can be found at <https://www.cdc.gov/asthma/brfss/2015/brfssdata.htm> [38].

Asthma prevalence was assessed in our study through responses to the question “(Ever told) you had asthma?” on the BRFSS [39]. Sociodemographic factors included in our analyses were age (18–24, 25–34, 35–44, 45–54, 55–64, 65 or older), income (<\$15,000, \$15,000–<\$25,000, \$25,000–<\$35,000, \$35,000–<\$50,000, \$50,000 or more, Refused), education (Never attended school or only kindergarten, Elementary, Some high school, High school graduate, Some college or technical school, College graduate, Refused), sex (Male, Female), marital status (married, divorced, widowed, separated, never married, member of unmarried couple, Refused), health care coverage (yes/no any kind of health care coverage), access to a personal doctor (yes, only one; yes, more than one; no), and whether the individual lived in an urban or rural area (defined through the usage of Metropolitan Status Codes, MSCODE 1–3 being “urban” and MSCODE 5 being “rural”) [39]. Clinical factors included high alcohol consumption (yes/no greater than 14 weekly drinks for men and 7 for women), BMI (underweight; normal weight; overweight; obese), smoking status (Current smoker-smokes every day, Current smoker-smokes some days, Former smoker, Never Smoker, Don’t Know/Refused/Missing), and general health status (Excellent, Very good, Good, Fair, Poor, Don’t know/Not sure) [39]. We chose these particular sociodemographic and clinical factors to include in our analyses because there is a substantial body of literature linking them with asthma [18,24,40–47].

Analyses

We accounted for the complex survey design and unequal weighting using survey weights in a logistic regression model that evaluated the relationship between asthma prevalence and race, controlling for each of the sociodemographic and clinical factors listed above. All survey participants who responded to the question “(Ever told) you have asthma?” (439,963) were included in our logistic regression model. The logistic model was run using the SURVEYLOGISTIC procedure included in SAS 9.4 [48,49]. With regards

to adult asthma prevalence by race, we report four values: prevalence in the White population, Black versus White prevalence, Hispanic versus White prevalence, and Other versus White prevalence. Prevalence in the White population is given as an absolute percentage, whereas the other three values are given as comparative percentage differences. We provide three different estimates for each of these values, described below.

Unadjusted predictions

Unadjusted predictions are the values reported in the online BRFSS prevalence tables, which we reproduced as a baseline check for the validity of our methods. For each race, they represent the raw proportions of respondents who have ever had asthma, calculated for each state and nationally. No effort is made to account for any effects/interactions of other factors.

Average adjusted predictions

Average adjusted predictions (AAPs) attempt to control for other sociodemographic and clinical factors by considering a hypothetical respondent population with no variation in race [50]. For example, the White AAP is the predicted adult asthma marginal probability where the survey population was hypothetically all-White [50]. Specifically, every observation in the dataset is first set as White and a predicted probability for each observation is calculated as if it was White but otherwise the same as it originally was. Thus, the White AAP is the average predicted probability that would be observed in the study population if everyone was White all else being left as it was in the dataset. This process was repeated for all other races. The benefit of this technique is that each race now has the exact same distribution in all other non-race factors, negating any interactions between race and these factors [50]. The Black/Hispanic/Other vs. White AAP differences, also known as average marginal effects (AMEs), is the difference in asthma marginal probability between a hypothetically all-Black/Hispanic/Other survey population and a hypothetically all-White one [50,51]. We used the *margins* command in Stata 15, over the variable coded for state, in order to calculate these values.

Adjusted predictions at the means

We used adjusted predictions at the means (APMs) as our second method to control for sociodemographic and clinical factors. APMs also consider a hypothetical respondent population with no variation in race. The calculation of APMs then goes one step further by

finding the “mean” of each of the other factors and for each respondent, setting the values of his or her factors equal to these means [50,51]. As an example, to calculate White APM, the mean values of every variable in the model except the race/ethnicity variable are calculated. Next, all variables in each observation are set equal to those means. For instance, each respondent in this analysis was set at 24.5% age 55–64, 54.0% female, etc.). Hence, the White APM can be interpreted as the predicted probabilities for White individuals if they were all average in all other respects. This process was repeated for all other races. The Black/Hispanic/Other vs. White APM differences are called marginal effects at the means (MEMs) and again represent the difference in asthma marginal probability between a hypothetically all-Black/Hispanic/Other survey population and a hypothetically all-White one. We used the command *margins*, with the *atmeans* option selected in Stata 15 to calculate APMs.

Results

Our study population consisted of 439,963 individuals who were predominantly married, age 65 or older, non-Hispanic White, at least middle class, with at least a high school education, mostly reported good to excellent general health, were in the normal weight range, had health care coverage and a personal doctor/health care provider, and either mainly resided in the center city of an MSA or not in an MSA. Most respondents were also neither current smokers nor heavy drinkers.

Table 1 displays results of the logistic regression model with respect to asthma probability. With regards to sociodemographic factors, reported asthma prevalence decreases monotonically with respect to age (all age categories significant) and income (only <\$15,000 significant). Men were significantly less likely than women to have reported probability of asthma. The same was true for respondents who reported having no healthcare coverage, relative to those that had coverage. Urban residents (those living in the center city of an MSA or in a county containing the center city of an MSA) reported significantly higher probability of asthma than rural residents. These sociodemographic associations with probability of asthma are broadly in line with past research, which reported higher probability of asthma among urban residents, those with low-income, and women in adulthood [44,52,53]. Looking at the clinical factors (alcohol, BMI, smoking, general health) in the logistic

Table 1. Results of logistic regression for asthma.

Odds Ratio Estimates			
Effect	Point Estimate	95% Confidence Limits	
Age (ref group: 65 or older)			
18–24	2.58	2.19	3.03
25–34	1.85	1.65	2.08
35–44	1.49	1.37	1.62
45–54	1.24	1.15	1.33
55–64	1.18	1.11	1.25
Income (Ref group: \$50,000 or more)			
<\$15,000	1.35	1.23	1.47
\$15,000–<\$25,000	1.12	1.04	1.21
\$25,000–<\$35,000	1.03	0.94	1.13
\$35,000–<\$50,000	1.02	0.94	1.1
Refused	1.02	0.95	1.1
Education (Ref group: College graduate)			
Never attended school or only kindergarten	1.03	0.51	2.1
Elementary	0.9	0.78	1.04
Some high school	0.98	0.89	1.09
High school graduate	0.81	0.76	0.86
Some college or technical school	0.96	0.91	1.02
Refused	0.67	0.45	1.02
Race (ref group: White)			
Black	0.94	0.87	1.02
Hispanic	0.72	0.64	0.81
Other	1.01	0.91	1.11
Refused	1.09	0.9	1.32
Sex (ref group: Female)			
Male	0.68	0.65	0.72
Heavy Drinking (ref group: No)			
Yes	0.97	0.87	1.08
Refused	0.89	0.77	1.04
Current Smoker (ref group: No)			
Yes	1.04	0.981	1.113
Refused	1.02	0.84	1.25
General Health (ref group: Excellent)			
Very Good	1.42	1.3	1.53
Good	1.79	1.65	1.94
Fair	2.95	2.691	3.233
Poor	4.47	4.04	4.94
Don't Know/Not Sure	2.01	1.25	3.21
Refused	2.86	1.51	5.42
Healthcare Coverage (ref group: Yes)			
No	0.78	0.7	0.87
Don't Know/Not Sure	0.88	0.51	1.51
Refused	0.89	0.5	1.56
Personal Doctor (ref group: Yes, only one)			
Yes, more than one	1.05	0.97	1.13
No	0.73	0.67	0.79
Don't Know/Not Sure	1.09	0.71	1.66
Refused	0.66	0.41	1.05
Marital Status (ref group: Married)			
Divorced	1.23	1.16	1.32
Widowed	0.94	0.88	1.01
Separated	1.39	1.2	1.61
Never Married	1.12	1.03	1.22
A member of an unmarried couple	1.42	1.22	1.67
Refused	1.21	0.85	1.72
BMI (ref group: Normal weight)			
Underweight	1.01	0.85	1.2
Overweight	1.07	1.01	1.14
Obese	1.48	1.4	1.57
MSCODE (ref: MSCODE = 5)			
MSCODE 1	1.07	1.01	1.13
MSCODE 2	1.08	1.01	1.15
MSCODE 3	0.98	0.9	1.06

model, we found that overweight and obese respondents had a higher probability of asthma compared to those reporting normal weight. Neither heavy smokers nor heavy drinkers reported a significantly higher probability of asthma than those that did not report those habits. With respect to probability of asthma, the most notable clinical factor was general health status. As reported general health decreased in quality, the probability of asthma increased dramatically.

Table 2 displays the unadjusted predictions, AAPs, and APMs at the national and state levels for different racial/ethnic groups with respect to asthma prevalences. The national results indicate a distinctly lower estimated probability of asthma for Blacks than in past studies. However, it is more insightful to examine state level results and compare unadjusted state prevalences and adjusted state probabilities of asthma [2,54].

In our three figures, we present White probability estimates (Figures 1a, 2a, 3a), the Black vs. White probability difference (Figures 1b, 2b, 3b), the Hispanic vs. White probability difference (Figures 1c, 2c, 3c), and the Other vs. White probability difference (Figures 1d, 2d, 3d). In our unadjusted figure (Figure 1), which shows calculations of asthma estimates without controlling for sociodemographic and clinical factors, Blacks and Other had higher prevalences than Whites whereas Hispanics had a lower prevalence than Whites. On the other hand, when we calculated AAPs (Figure 2) or APMs (Figure 3), Black respondents now had a lower estimated probability of asthma than White respondents. Hispanics continued to have a lower probability of asthma than Whites, and Other also continued to have a higher probability than Whites. Looking at the unadjusted state-level estimates for White respondents, the highest asthma prevalences, about 1.5–3.5% higher than the national average, were concentrated in Western states and those along the Mexican border (Washington, Oregon, Nevada, Arizona, New Mexico). Several Midwestern states (the Dakotas, Nebraska, Minnesota, Iowa, Wisconsin) and Hawaii had the lowest prevalences, about 1.5–3% less than the national average. After accounting for sociodemographic and clinical factors in the calculation of AAPs, the states with the highest probabilities of asthma for Whites changed. California and much of the Southeastern states now have the highest estimates of probabilities of asthma for Whites, with Mississippi, Kentucky, and Alabama having estimated prevalences 1.5–2% higher than average (Figure 2a). States in the West had the lowest estimated probabilities of asthma and included Montana, Idaho, and

Utah, whose estimated probabilities were about 1% less than the national average (Figure 2a). This pattern is almost identical to the one seen if we instead compute APMs, except that North Carolina replaces California as one of the states with the highest probability of asthma (Figure 3a).

States that had the highest prevalences or probabilities of asthma for Whites also tended to have the widest disparities between the estimates for Whites and those of other races. This was the case whether we looked at unadjusted prevalence differences or either of the two adjusted probabilities (AAPs or APMs) and held for each of the Black vs. White, Hispanic vs. White, and Other vs. White differences. Looking at the unadjusted differences (Figure 1b–d), we see that Western, Mexican border, and Northeast states have the largest disparities between non-White and White respondents, regardless of race. The Black and Other vs. White differences are most positive in these states, whereas Hispanic vs. White differences are most negative in these states. The same pattern holds for the AAPs and APMs (Figures 2–3b–d). States with the highest prediction of White adult asthma prevalence differ when we use unadjusted vs adjusted predictions (AAPs/APMs). As a result, depending on whether we look at unadjusted or adjusted predictions, the states with the largest disparities in asthma prevalence between Whites and other races vary. Now, the Other vs. White difference is most positive and the Black and Hispanic differences are most negative in the Southeastern states. Overall, the higher the estimated probability of asthma for Whites, the more spread out the estimates for the four races are; low probability of asthma for Whites is associated with clustered probabilities for all races.

Discussion

In a nationwide study, we compared unadjusted asthma prevalences from the CDC with two different methods to estimate asthma burden by racial/ethnic group that accounted for sociodemographic and clinical factors of asthma. There were considerable differences at the national and state level between unadjusted prevalences and AAPs and APMs for asthma by racial/ethnic group. In addition, the states that had the highest and lowest unadjusted prevalences differed from the states that had the highest and lowest AAPs and APMs. For unadjusted prevalences, AAPs, and APMs, we found that states that had the highest prevalences or probabilities of asthma for

Table 2. Unadjusted predictions (%), average adjusted predictions (AAPs) (%), and adjusted predictions at the means (APMs) at the national and state levels for different racial/ethnic groups with respect to asthma prevalences via answers to BRFSS' question: "ever told) you had asthma?"*

States	Abs	Federal Information Processing Standards (FIPS) Code	Unadjusted Predictions					Average adjusted predictions (AAPs)					Adjusted predictions at the means (APMs)				
			White	Black	Hispanic	Others	White	Black	Hispanic	Others	White	Black	Hispanic	Others	White	Black	Hispanic
National	USA	-	13.53	15.82	12.21	14.46	13.29	12.77	10.17	13.42	12.01	11.52	9.06	12.14	12.01	11.52	9.06
Alabama	AL	1	14.70	16.09	7.09	18.86	14.99	14.42	11.54	15.13	13.55	13.00	10.27	13.68	13.55	13.00	10.27
Alaska	AK	2	12.96	19.91	19.37	13.41	12.74	12.24	9.73	12.86	11.52	11.05	8.68	11.64	11.52	11.05	8.68
Arizona	AZ	4	15.52	13.19	13.54	16.59	13.00	12.50	9.95	13.13	11.74	11.25	8.85	11.86	11.74	11.25	8.85
Arkansas	AR	5	13.51	18.28	19.97	19.94	14.26	13.72	10.97	14.40	12.78	12.26	9.66	12.91	12.78	12.26	9.66
California	CA	6	14.36	20.33	10.07	13.95	13.80	13.27	10.60	13.93	12.39	11.89	9.36	12.52	12.39	11.89	9.36
Colorado	CO	8	14.38	18.67	8.80	18.45	12.01	11.54	9.15	12.13	10.96	10.50	8.24	11.07	10.96	10.50	8.24
Connecticut	CT	9	14.92	19.28	20.88	12.99	12.47	11.98	9.51	12.60	11.39	10.92	8.58	11.51	11.39	10.92	8.58
Delaware	DE	10	13.59	15.23	14.89	14.07	13.43	12.91	10.29	13.56	12.15	11.65	9.17	12.27	12.15	11.65	9.17
District of Columbia	DC	11	11.13	19.63	21.91	11.68	13.23	12.72	10.12	13.36	12.02	11.53	9.07	12.14	12.02	11.53	9.07
Florida	FL	12	12.81	12.83	12.81	13.35	12.92	12.41	9.88	13.04	11.65	11.17	8.78	11.77	11.65	11.17	8.78
Georgia	GA	13	13.29	15.30	7.51	15.29	13.81	13.28	10.60	13.94	12.43	11.92	9.39	12.56	12.43	11.92	9.39
Hawaii	HI	15	10.36	4.61	22.34	18.42	12.35	11.86	9.41	12.47	11.35	10.88	8.55	11.46	11.35	10.88	8.55
Idaho	ID	16	13.22	13.78	8.98	19.69	12.34	11.85	9.42	12.46	11.03	10.57	8.30	11.14	11.03	10.57	8.30
Illinois	IL	17	13.49	19.19	12.46	15.13	13.32	12.81	10.20	13.46	12.03	11.53	9.08	12.15	12.03	11.53	9.08
Indiana	IN	18	13.57	18.57	9.74	18.84	13.51	12.99	10.36	13.64	12.18	11.68	9.20	12.31	12.18	11.68	9.20
Iowa	IA	19	11.63	17.32	6.77	21.09	12.23	11.75	9.33	12.36	11.07	10.61	8.33	11.19	11.07	10.61	8.33
Kansas	KS	20	12.91	17.77	10.48	18.16	12.34	11.85	9.40	12.46	11.29	10.83	8.50	11.41	11.29	10.83	8.50
Kentucky	KY	21	15.78	16.51	20.16	26.33	14.79	14.23	11.39	14.93	13.29	12.76	10.07	13.43	13.29	12.76	10.07
Louisiana	LA	22	13.09	14.66	29.85	16.57	14.64	14.08	11.26	14.78	13.27	12.74	10.05	13.41	13.27	12.74	10.05
Maine	ME	23	15.49	19.55	20.73	18.18	12.95	12.45	9.91	13.08	11.71	11.23	8.83	11.83	11.71	11.23	8.83
Maryland	MD	24	13.88	14.32	12.69	15.23	13.01	12.50	9.95	13.13	11.80	11.32	8.90	11.93	11.80	11.32	8.90
Massachusetts	MA	25	15.10	19.17	15.35	12.54	12.68	12.18	9.68	12.80	11.58	11.11	8.73	11.71	11.58	11.11	8.73
Michigan	MI	26	14.39	18.17	16.04	17.23	13.31	12.79	10.19	13.44	12.08	11.58	9.12	12.20	12.08	11.58	9.12
Minnesota	MN	27	10.53	18.10	11.87	12.87	12.11	11.63	9.22	12.23	11.04	10.58	8.31	11.16	11.04	10.58	8.31
Mississippi	MS	28	10.78	12.88	13.23	17.08	14.78	14.22	11.38	14.92	13.36	12.82	10.12	13.50	13.36	12.82	10.12
Missouri	MO	29	13.37	15.10	19.14	15.51	13.73	13.20	10.53	13.87	12.40	11.90	9.37	12.53	12.40	11.90	9.37
Montana	MT	30	12.04	0.00	15.18	16.78	12.10	11.63	9.23	12.23	10.89	10.44	8.19	11.00	10.89	10.44	8.19
Nebraska	NE	31	11.69	18.18	7.44	17.73	12.49	12.00	9.53	12.61	11.38	10.91	8.57	11.49	11.38	10.91	8.57
Nevada	NV	32	15.03	24.18	10.93	19.81	12.84	12.34	9.82	12.96	11.55	11.08	8.71	11.68	11.55	11.08	8.71
New Hampshire	NH	33	14.43	23.70	16.54	14.90	12.00	11.53	9.14	12.12	10.93	10.48	8.22	11.04	10.93	10.48	8.22
New Jersey	NJ	34	10.78	18.54	11.27	9.43	13.17	12.66	10.08	13.30	11.98	11.49	9.04	12.11	11.98	11.49	9.04
New Mexico	NM	35	16.59	24.26	12.97	13.69	13.26	12.75	10.16	13.39	11.90	11.41	8.98	12.03	11.90	11.41	8.98
New York	NY	36	14.07	15.89	17.78	10.82	13.65	13.13	10.47	13.79	12.37	11.86	9.34	12.49	12.37	11.86	9.34
North Carolina	NC	37	12.76	14.40	7.66	13.09	13.79	13.26	10.58	13.93	12.43	11.92	9.39	12.56	12.43	11.92	9.39
North Dakota	ND	38	11.76	21.06	21.58	17.82	12.15	11.67	9.25	12.27	11.17	10.71	8.41	11.28	11.17	10.71	8.41
Ohio	OH	39	13.04	16.14	18.53	14.58	13.50	12.98	10.35	13.63	12.20	11.70	9.21	12.33	12.20	11.70	9.21
Oklahoma	OK	40	12.68	12.40	10.98	18.03	13.97	13.43	10.73	14.10	12.62	12.11	9.54	12.75	12.62	12.11	9.54
Oregon	OR	41	17.17	19.11	17.84	18.40	12.69	12.19	9.69	12.81	11.48	11.01	8.65	11.60	11.48	11.01	8.65
Pennsylvania	PA	42	13.87	15.16	22.80	13.26	13.22	12.70	10.11	13.35	12.06	11.57	9.10	12.19	12.06	11.57	9.10
Rhode Island	RI	44	15.59	12.23	16.07	16.50	13.04	12.54	9.97	13.17	11.90	11.41	8.98	12.03	11.90	11.41	8.98
South Carolina	SC	45	12.65	11.81	10.56	17.15	13.64	13.11	10.45	13.77	12.31	11.81	9.30	12.44	12.31	11.81	9.30
South Dakota	SD	46	10.44	3.77	21.45	18.67	12.20	11.72	9.31	12.33	11.12	10.66	8.37	11.23	11.12	10.66	8.37
Tennessee	TN	47	13.54	17.74	10.02	13.78	14.55	14.00	11.19	14.69	13.11	12.58	9.93	13.25	13.11	12.58	9.93
Texas	TX	48	14.79	14.14	8.70	9.20	13.43	12.91	10.29	13.56	12.15	11.65	9.17	12.27	12.15	11.65	9.17
Utah	UT	49	14.12	20.41	10.77	15.66	12.26	11.77	9.34	12.38	11.15	10.68	8.39	11.26	11.15	10.68	8.39

(Continued)

Table 2. Continued.

States	Abs	Federal Information Processing Standards (FIPS) Code	Unadjusted Predictions				Average adjusted predictions (AAPs)				Adjusted predictions at the means (APMs)			
			White	Black	Hispanic	Others	White	Black	Hispanic	Others	White	Black	Hispanic	Others
Vermont	VT	50	14.37	10.71	18.33	22.09	11.87	11.40	9.03	11.99	10.83	10.38	8.14	10.94
Virginia	VA	51	11.47	16.06	8.47	9.51	12.71	12.21	9.70	12.83	11.55	11.08	8.71	11.67
Washington	WA	53	15.21	14.63	11.33	15.57	12.72	12.22	9.72	12.84	11.53	11.05	8.69	11.65
West Virginia	WV	54	14.67	15.02	15.77	17.63	14.56	14.01	11.21	14.70	13.01	12.49	9.85	13.15
Wisconsin	WI	55	11.81	18.60	17.22	21.80	12.50	12.01	9.54	12.62	11.37	10.90	8.56	11.49
Wyoming	WY	56	12.66	25.07	13.18	17.20	12.11	11.63	9.23	12.23	10.90	10.45	8.20	11.02

*Statistical significance with respect to differences between Black, Hispanic, and Other versus those of White: in bold & italic: sig. at 0.001 level; bold only: sig. at 0.01 level; italic only: sig. at 0.05 level; normal: not sig.

Whites usually also the widest disparities between the estimates for Whites and those of other races.

Given that the BRFSS question used to generate our data asked whether an adult had ever had asthma, we will primarily compare our findings to past research on race and adult asthma. It is of note that previous research examining race as a possible factor for asthma prevalence has tended to focus on its relationship with childhood asthma [2,10,54,55]. Research from the past two decades by Akinbami et al. [2], Akinbami et al. [54], Litonjua et al. [10] and Winer et al. [55] that has looked at race as a factor associated with adult asthma prevalence has arrived at different conclusion. Work by Akinbami et al. [2], Akinbami et al. [54], and Litonjua et al. [10] has generally concluded that Blacks and Hispanics were at greater risk for asthma than Whites. Conversely, recent research by Winer et al. [55] using the 2006 and 2008 editions of the BRFSS was unable to identify any significant differences among races. Our results are inconsistent with the findings of these four studies [2,10,54,55]. Discrepancies with past studies could be due to non-recent data, small sample sizes and scope, analyses that only offer the equivalent of the unadjusted estimates in our study, and the non-nationwide adoption of the asthma module in earlier BRFSS surveys.

Our study has several limitations that need to be considered. First, the BRFSS is a self-reported survey. Although there is no way to know the true accuracy of the entire self-reported BRFSS dataset, past studies have shown that the correlations between in person measurements of the clinical factors we used (obesity, smoking) and BRFSS responses ranged from 74 to 82% [56]. A study comparing Massachusetts electronic health records (EHR) to Massachusetts BRFSS responses found that prevalence of smoking (EHR: 13.5%, BRFSS: 14.7%) and obesity (EHR: 22.8%, BRFSS: 23.8%), along with other health issues like hypertension and diabetes were very similar between the two data sources [57]. Another BRFSS validation study that examined the correlation between self-reported BMI with in-clinic BMI measurements found a male correlation of $R^2=0.89$ and female correlation of $R^2=0.92$ [58]. We thus feel any issues concerning accuracy of self-report to be minor if not negligible. Any minor loss of accuracy due to self-report will likely result in minimal non-differential misclassification bias [59]. Second, some residual and unmeasured confounding may remain even after our extensive adjustment for multiple sociodemographic and clinical factors. However, we included all of the covariates

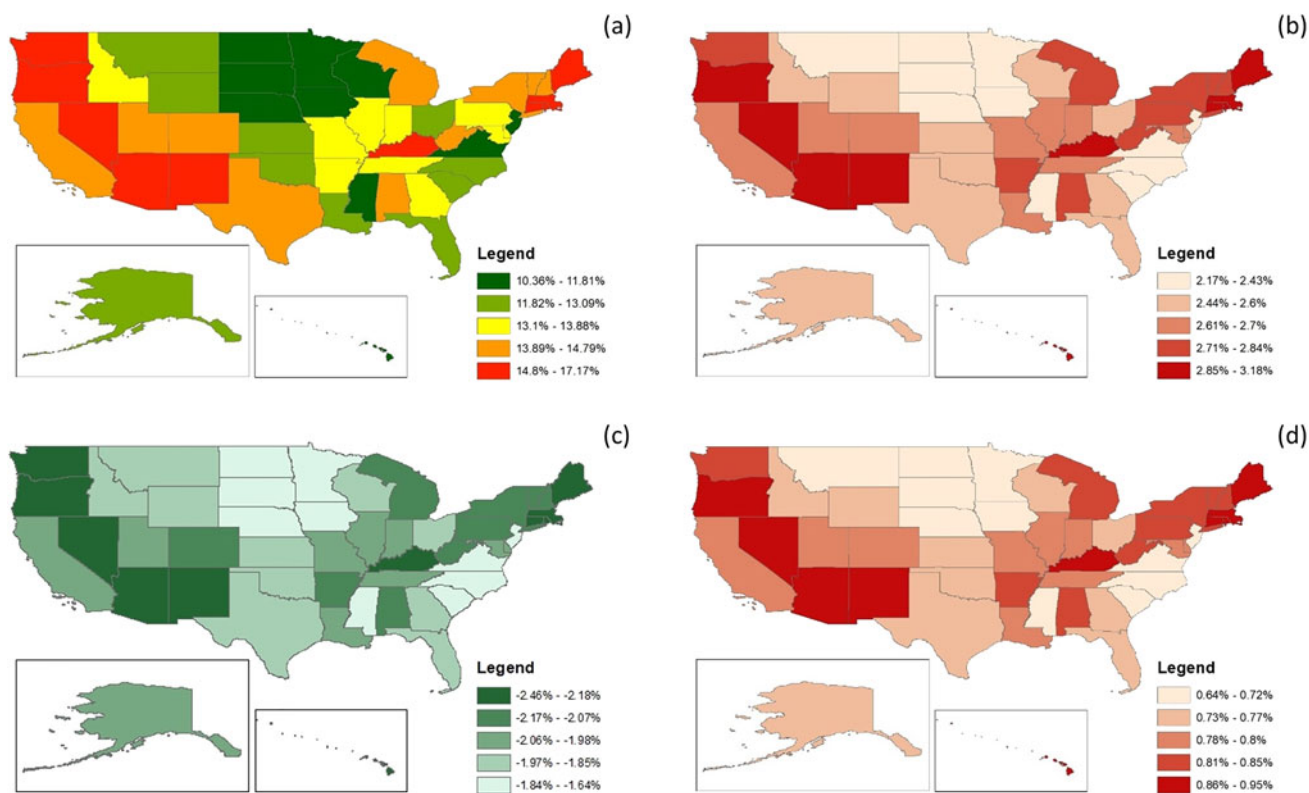


Figure 1. Unadjusted predictions of adult asthma prevalence of White, and unadjusted marginal effects of (b) Black versus White, (c) Hispanic versus White, and (d) Other versus White.

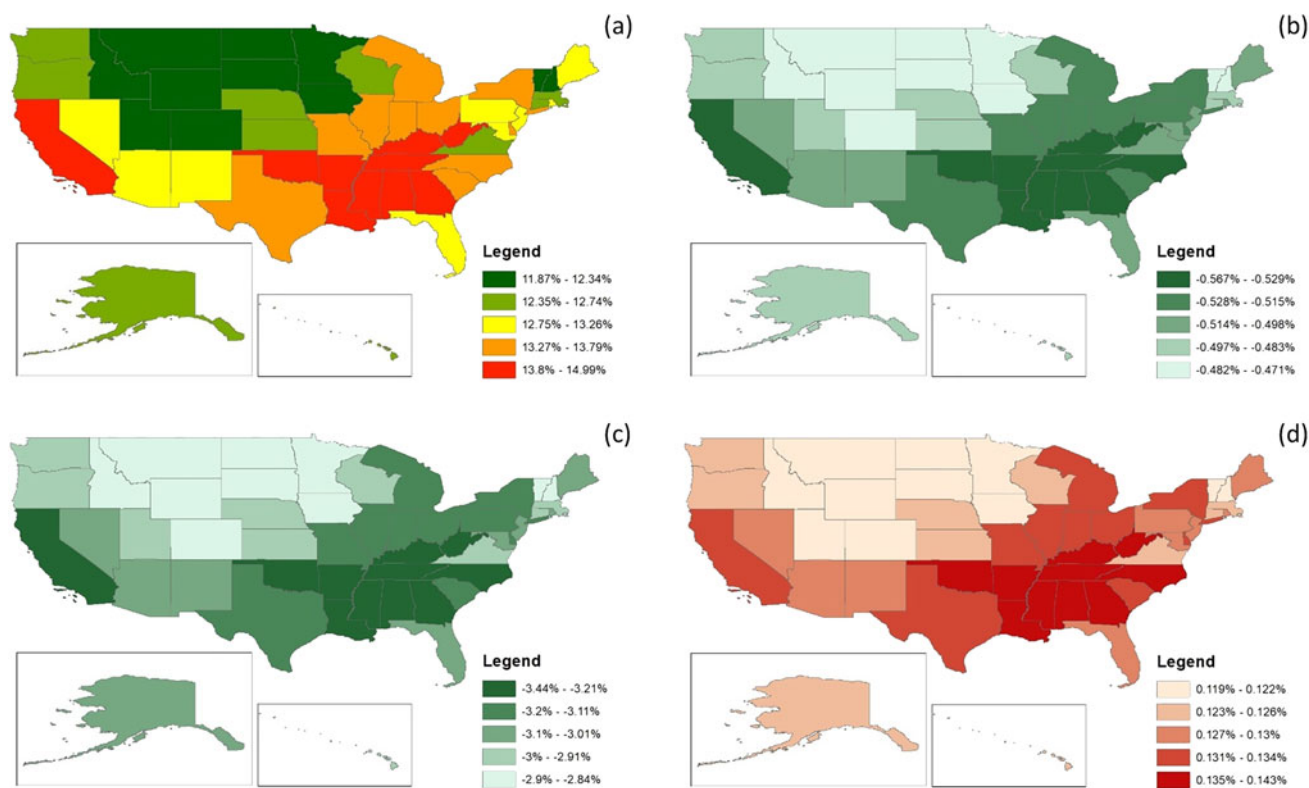


Figure 2. Average Adjusted Predictions (AAPs) of adult asthma prevalence of White, and average marginal effects (AMEs) of (b) Black versus White, (c) Hispanic versus White, and (d) Other versus White.

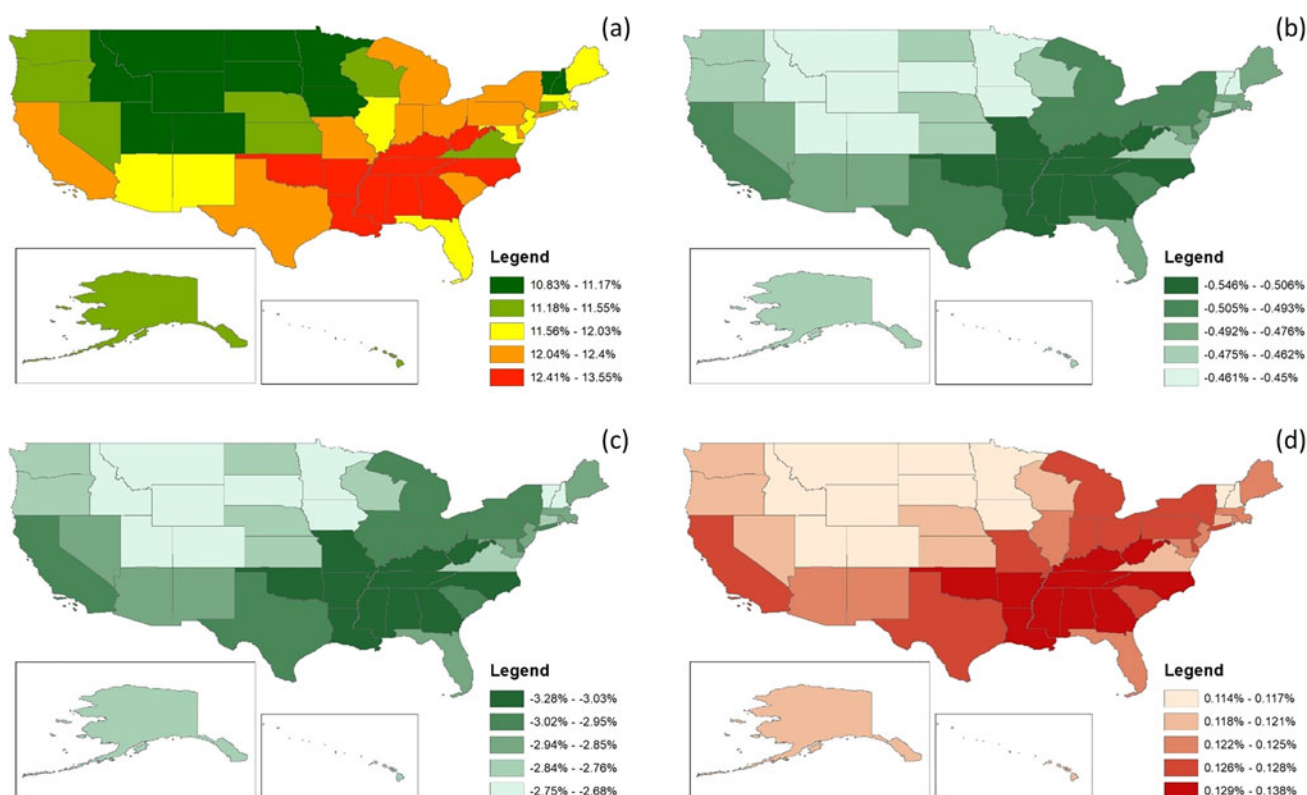


Figure 3. (a) Adjusted Predictions at the Means (APMs) of adult asthma prevalence of White, and marginal effects at the means (MEMs) of (b) Black versus White, (c) Hispanic versus White, and (d) Other versus White.

included in other studies on race/ethnicity and asthma in our analyses [2,10,54,55].

The few limitations this study has are countered by its strengths. Although using the BRFSS causes reliance on self-reported data, it also allowed our study to have a large, national sample size greater than 400,000 respondents that accurately represents the racial/ethnic distribution of the US population. Furthermore, this study's data was pulled from the 2015 BRFSS, the most recent survey in which unadjusted prevalences for different racial/ethnic groups were readily available for comparison with our AAPs and APMs. Relative to past studies examining factors associated with asthma burden, this study was based off of more contemporary data [2,45,54]. Given that this study's data was as contemporary as possible; our findings accurately portray the current asthma landscape.

This study's findings lead to several suggestions on dealing with confounding to race-specific asthma prevalence. Caution should be exercised when presenting race-specific asthma prevalence that has not been adjusted for sociodemographic and clinical factors of asthma. Unadjusted race-specific asthma prevalence alone does not provide a complete picture of racial differences in asthma as our study results show

that unadjusted race-specific asthma prevalence varies markedly from adjusted race-specific asthma prevalence. When crafting public health policies and interventions to reduce asthma prevalence, the use of unadjusted race-specific asthma prevalence should be complemented with adjusted race-specific asthma prevalence.

Conclusions/key findings

Our study results demonstrate that controlling for sociodemographic and clinical factors while assessing asthma burden by race/ethnicity is crucial. Not only does the racial/ethnic group with the highest asthma burden change between unadjusted and adjusted measures, but the states with the highest and lowest level of burden shift as well. By properly accounting for sociodemographic factors that influence asthma burden, we can obtain accurate measures that can be used to guide decision making for new asthma treatment initiatives and asthma education programs.

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