Asthma Prevalence, Severity, and Nonfatal Burden by Race/Ethnicity in the United States: A Bayesian Meta-regression Analysis

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Abstract

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Context: Asthma is the most common chronic respiratory disease and is characterized by inflammation of the airways in response to stimuli. Evidence also suggests that asthma is more prevalent and more severe in Black American and Hispanic populations, influenced by factors such as chronic stress, reduced access to healthcare, and medical racism. We aimed to quantify the prevalence, severity, and nonfatal burden of asthma by race/ethnicity, utilizing a Bayesian meta-regression analytical method.

Methods: We ran models of asthma prevalence by race/ethnicity, year, sex, and age, utilizing data from the National Health and Nutrition Examination Survey (NHANES) and the National Health Interview Survey (NHIS). We separately quantified the severity of asthma using NHANES data on functional health loss due to wheeze, mapping this information to health states and disability weights sourced from the Global Burden of Disease study. This information was

used to calculate Years Lived With Disability, a metric of nonfatal disease burden. We conducted a Das Gupta decomposition analysis to assess whether differences in nonfatal burden between different race/ethnicity groups were driven by prevalence or severity.

Results: Non-Hispanic Black women had the highest age-standardized asthma prevalence rates (6.0%, 95% Uncertainty Interval [UI] 5.7 to 6.3). Black women also had the highest age-standardized mean disability weight of all race/ethnicity and sex combinations (0.049, 95% UI 0.040 to 0.060), while Non-Hispanic White men had the least severe asthma on average. An estimated 65% (34 to 81) of the difference in age-standardized YLDs between Black and White women was attributable to severity.

Conclusion: This study indicates large racial disparities in the nonfatal burden of asthma in the United States, with the largest burden in Non-Hispanic Black women. Policy actions should be taken to increase access to high-quality healthcare in this group and reduce observed disparities.

Introduction

Asthma is the most common chronic respiratory disease, affecting 262 million people globally in 2019 (1). Asthma is characterized by constriction and inflammation of the airways in response to stimuli (1). Asthma can cause persistent cough, shortness of breath, and chest tightness, with most severe cases resulting in limitations in daily activity, reduced pulmonary function, and/or death (2). Although the etiology of asthma is not well-understood, important risk factors include exposure to tobacco smoke (3), high BMI (4), air pollution (5), HIV infection (6), mold, and asbestos (7).

While there is no cure for asthma, several evidence-based interventions can reduce its severity, preventing health loss and death. This includes β2 agonists such as albuterol (8), antileukotrienes, corticosteroids, and biologics in severe cases (9). Current treatment guidelines recommend the use of inhaled corticosteroid in conjunction with the long-acting bronchodilator formoterol for most children and adults, and literature suggests that these interventions are cost-effective (9,10). Educational interventions can teach people with asthma how to manage the condition, improving treatment adherence and decreasing asthma exacerbations (11,12). Despite the existence of effective asthma interventions, critical treatments remain inaccessible to many due to cost and poor health system capacity (13–15). Moreover, there is evidence that certain race/ethnicity groups experience differential access to high-quality healthcare, increasing the likelihood of adverse asthma-related health outcomes (16).

Asthma is more prevalent in Black and Puerto Rican populations than in White American populations (17). Minority populations are also much more likely to die of Asthma than White Americans, with Black children seven times more likely to die of asthma than non-Hispanic White children (18). Research suggests that chronic stress due to racism may mediate this relationship (19,20), with an association between racial stress and adverse asthma health outcomes. Access to healthcare may also contribute to this disparity, as Black and non-White Hispanic children report lower access to asthma treatments and utilize the ER for asthma management at disproportionately higher rates compared to White Americans (21,22). Furthermore, when Black and non-White Hispanic patients successfully access healthcare, many experience persistent medical racism, with physicians more likely to underestimate asthma severity in Black populations (23). Policymakers have called for various strategies to mitigate racial disparities in asthma burden, including increasing access to guidelines-based healthcare, increasing participation of people of color in

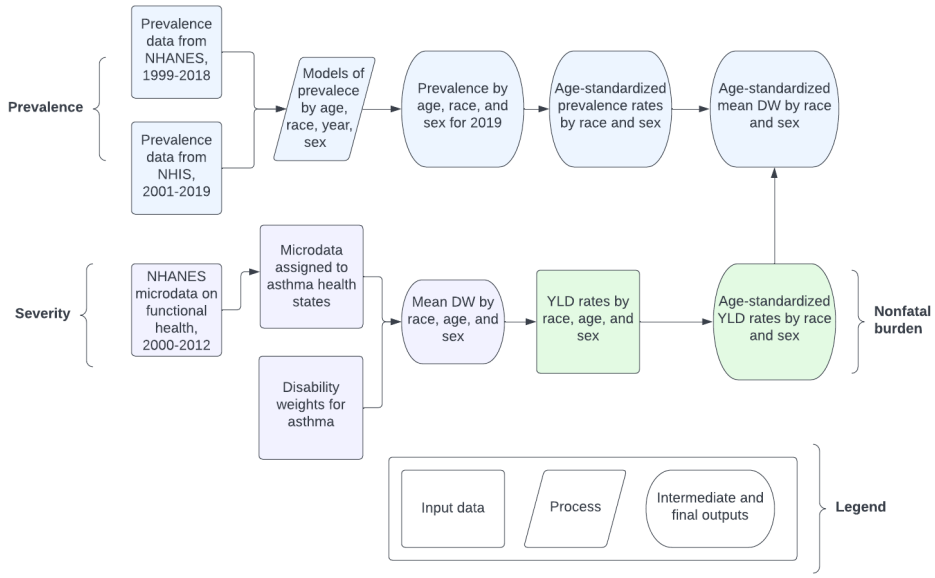
clinical trials, and mitigating structural factors that concentrate Black and Hispanic populations in areas that contain asthma-triggering pollutants (24). Estimates of asthma prevalence and burden are essential to inform service planning and resource allocation, contributing to efforts to reduce racial disparities in asthma health outcomes.

Asthma burden can be quantified using the disability-adjusted life-year (DALY), which was originally developed for the Global Burden of Disease study (GBD) (1). The DALY is the sum of Years Lived with Disability (YLDs) and Years of Life Lost (YLLs), time-based measures of health loss from disease and death. Literature suggests that Black and non-White Hispanic children have lower access to essential treatment (25), exhibit reduced pulmonary function, and bear greater burden of asthma compared to their White counterparts (26). However, there is relatively little information that links asthma prevalence to quantitative measures of asthma severity. The objective of this project is to assess asthma prevalence, severity, and nonfatal burden in the United States by race/ethnicity, utilizing a Bayesian meta-regression analytical method.

Methods

A summary of the methods of estimating prevalence, severity, and years lived with disability (YLDs) for asthma in the U.S. by race/ethnicity is shown below (**Figure 1**).

Figure 1. *Modelling flowchart*



Estimation of asthma prevalence

Data on race-specific prevalence of asthma in the USA by age, sex, and year were sourced from relevant available population-representative surveys, including the National Health Interview Surveys (NHIS) and the National Health and Nutrition Examination Surveys (NHANES) **(Table S1)**. Each data source recorded information on the current asthma status of survey respondents, defined as a self-reported diagnosis of asthma at any point in life by a healthcare provider and wheezing in the past 12 months.

We produced prevalence estimates for the following groups, using the race/ethnicity groups available in the National Health and Nutrition Examination Survey (NHANES) survey: Non-Hispanic White, Non-Hispanic Black, Hispanic, and Other. The "Other" race/ethnicity category includes Non-Hispanic Asian, American Indian/Alaska Native (AIAN), and "Other race-including multi-racial" individuals. Initial estimates of prevalence by race, age, sex, and year were calculated for each survey in R (27) using the survey package (28).

These initial prevalence estimates were then pooled via meta-regression using Meta-Regression–Bayesian, Regularized, Trimmed (MR-BRT) (29), a Bayesian meta-regression tool, with separate models run for each sex and race/ethnicity group. MR-BRT was utilized for the ability to include covariates in a meta-analysis, as well as the ability to incorporate splines to better capture non-linear patterns in asthma prevalence over age. Separate models were run for each sex to better capture differential age patterns in US asthma prevalence by sex, given higher remission in adolescent males and higher incidence in adult females (30). Separate models were also run by race/ethnicity to account for different patterns in asthma prevalence across age for these groups. A covariate on year was included to capture variation in asthma prevalence over time (31). The association between prevalence and age was quantified via a spline covariate to reflect the non-linear, non-monotonic age pattern seen in prevalence of asthma (1). These models were used to predict asthma prevalence by race, age, and sex for the year 2019. 95% uncertainty intervals were estimated from the 975^{th} and 25^{th} ordered draws of 1000 model runs after convergence.

Estimation of non-fatal burden of asthma

The non-fatal burden of asthma was quantified using YLDs, which were calculated by multiplying race-age-sex-specific prevalence by a disability weight. Disability weights are a key metric employed in the GBD, a systematic analysis of the burden of over 300 diseases, injuries,

and risk factors from 1990-2019. Disability weights quantitatively measure the disability of disparate diseases and injuries and their consequences. Disability weights ranged from 0 (equivalent to perfect health) to 1 (equivalent to complete loss of health).

Disability weights for asthma **(Table 1)** were derived from disability weight surveys, which sampled respondents from 9 countries, supplemented by a global internet survey. Respondents were asked to make pairwise comparisons of the relative severity of randomly chosen pairs of health states presented as brief lay descriptions (32). Lay descriptions were written collaboratively with disease expert groups, focusing on the most typical effects on a person living with a specific health state. Population health equivalence questions were used to anchor the results from pair-wise comparisons onto the 0 to 1 scale (32).

Table 1. *GBD lay descriptions and disability weights for asthma*

Severity level	**Lay description**	**Disability Weight (95% CI)**
Asymptomatic	-	0
Controlled	This person has wheezing and cough once a month, which does not cause difficulty with daily activities.	0.015 (0.007–0.026)
Partially controlled	This person has wheezing and cough once a week, which causes some difficulty with daily activities.	0.036 (0.022–0.055)
Uncontrolled	This person has wheezing, cough, and shortness of breath more than twice a week, which causes difficulty with daily activities and sometimes wakes the person at night.	0.133 (0.086–0.192)

Race-age-sex-specific disability weights of asthma cases were estimated from the National Health and Nutrition Examination Survey (NHANES) (32). The NHANES is a series of nationally representative surveys of noninstitutionalized US civilians; while the survey is conducted on an ongoing basis in 2-year cycles, the respiratory health module was last included in 2012. Respiratory health questions sampled individuals over 1 year old (**Table S2**) (33).

We derived an algorithm to assign individuals with asthma to different severity states based on functional health questions pertaining to asthma in the NHANES respiratory health questionnaire (**Table S3, Figures S1-S3**). This algorithm was derived based on the language used in the GBD health state lay descriptions (**Table 1**) and clinical guidelines for severity classification (34). As literature indicates that clinicians rate limitation of daily activities and the disturbance of sleep as the most important indicators of poor asthma control, these factors were weighted more heavily in the creation of an algorithm for severity assignment (35).

We then assigned NHANES respondents with asthma to asymptomatic, controlled, partially controlled, and controlled asthma based on our algorithm (**Table S3).** From this individual-level data, survey-weighted disability weights were calculated by age, sex, and race/ethnicity. Then, mean disability weights were multiplied by prevalence to calculate YLD rates by age group, sex, and race/ethnicity. We first estimated prevalence and mean DWs in the following age groups: 1–20 21–40, 41–60, and 61–100. We calculated age-standardized YLDs using the GBD standard reference population. Age-standardized YLDs were divided by age-standardized prevalence to derive the mean disability weight for each race/ethnicity and sex combination.

Decomposition analysis

We first calculated the difference in age-standardized YLDs between each race/ethnicity group and the race/ethnicity group with the lowest observed age-standardized mean disability weight. We conducted a Das Gupta decomposition analysis (36) to assess if differences in age-standardized YLD rates across race/ethnicity groups were primarily driven by differences in prevalence or disease severity (expressed in terms of mean disability weights). When both prevalence and severity positively contributed to differences in nonfatal burden, we calculated the percentage of the difference in nonfatal burden attributable to prevalence and severity, respectively. This was done using the following equations:

$$\%\ nonfatal\ burden\ due\ to\ severity = \left(\frac{prev_{race} + prev_{reference}}{2}\right) * (DW_{race} - DW_{reference})$$

$$\%\ nonfatal\ burden\ due\ to\ prevalence = \left(\frac{DW_{race} + DW_{reference}}{2}\right) * (prev_{race} - prev_{reference})$$

Results

Asthma prevalence

Overall, Black females had the highest age-standardized asthma prevalence at 6.0% (95% Uncertainty Interval [UI] 5.7 to 6.3) (**Figure 2**). This prevalence was 24% (95% UI 16 to 32) higher than that of White females, who had the second-highest age-standardized prevalence at 5.0% (95% UI 4.8 to 5.2). The Hispanic group had the lowest age-standardized prevalence at 2.9% in males (95% UI 2.7 to 3.1) and 3.8% (95% UI 3.6 to 4.1) in females. Modeled results indicated a decrease in asthma prevalence over time for all race/ethnicity and sex groups (**Table S4**). Modelled results also indicated variation in asthma prevalence across age and race/ethnicity, with higher prevalence of asthma in Black children (**Figure S6**).

Table 2 Age-standardized prevalence, YLD rates, and disability weights by race/ethnicity and sex, with 95% UI.

Race/ethnicity	Sex	Age-standardized prevalence rate (%)	Mean Disability Weight	Age-standardized YLD rate (%)
Black	Female	6.0 (5.7 to 6.3)	0.049 (0.040 to 0.060)	0.30 (0.24 to 0.37)
Black	Male	5.0 (4.8 to 5.3)	0.041 (0.031 to 0.055)	0.21 (0.16 to 0.27)
Hispanic	Female	3.8 (3.6 to 4.1)	0.042 (0.034 to 0.051)	0.16 (0.13 to 0.2)
Hispanic	Male	2.9 (2.7 to 3.1)	0.043 (0.031 to 0.057)	0.12 (0.09 to 0.17)
Other	Female	4.5 (4.1 to 4.9)	0.043 (0.034 to 0.053)	0.19 (0.15 to 0.24)
Other	Male	3.5 (3.1 to 3.9)	0.035 (0.028 to 0.043)	0.12 (0.09 to 0.16)
White	Female	5.0 (4.8 to 5.2)	0.034 (0.027 to 0.042)	0.17 (0.13 to 0.21)
White	Male	3.4 (3.2 to 3.5)	0.028 (0.022 to 0.037)	0.1 (0.07 to 0.12)

Asthma severity

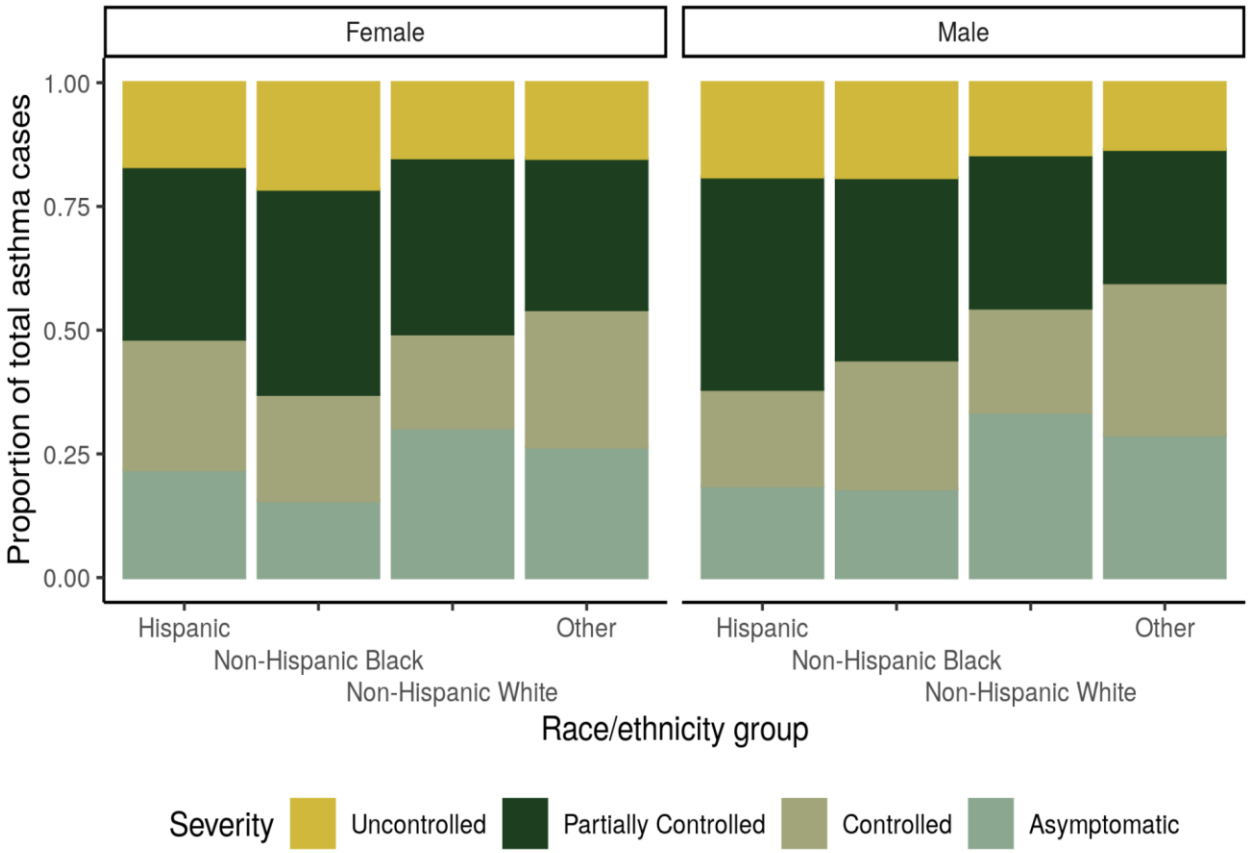
Characteristics of respondents to NHANES respiratory questionnaires, 2000-2012 are shown below (**Table 3)**. A total of 65,482 individuals responded to NHANES respiratory questionnaires distributed through 2000–2012. Of these, 774 males and 1084 females met the case definition for asthma and were included in the analysis. Respondents reported an unweighted mean of 5.5 asthma attacks and 1.99 medical visits due to wheezing in the past year. Of the 1858 asthma cases within NHANES, 651 (35%) reported sleep disturbance due to wheezing at least one night a week and 1670 (90%) reported usage of asthma medication in the past year.

Table 3. *Characteristics of NHANES respiratory module respondents with asthma, 2000-2012, unweighted*

		Total	White	Black	Hispanic	Other
Sample Size (# [%])		1858 (100%)	741 (40%)	573 (31%)	438 (24%)	106 (6%)
Sex (# [%])						
	Male	774 (42%)	273 (37%)	270 (47%)	183 (42%)	45 (42%)
	Female	1084 (58%)	465 (63%)	303 (53%)	255 (58%)	61 (57%)
Age (mean [SD])		25 (18.7)	32.1 (18.1)	25 (18.5)	25 (18.5)	26.2 (18.5)
Asthma attacks in past year (mean [SD])		5.5 (4.12)	6.2 (4.3)	4.9 (3.93)	4.9 (3.9)	5.7 (4.3)
Medical visits due to wheezing in past year (mean [SD])		1.72 (2.66)	1.6 (2.6)	1.97 (2.91)	1.8 (2.2)	1.5 (3.1)
Sleep disturbance due to wheezing (# [%])						
	Never	547 (29%)	260 (35%)	142 (25%)	115 (26%)	30 (28%)
	less than 1 night a week	660 (36%)	270 (36%)	195 (34%)	160 (37%)	35 (33%
	1 or more nights a week	651 (35%)	211 (28%)	236 (41%)	163 (37%)	41 (39%)
Missed days of work or school due to wheezing (# [%])						
	None	1107 (60%)	518 (70%)	291 (51%)	232 (53%)	66 (62%)
	1 to 7	544 (29%)	170 (23%)	193 (34%)	154 (35%)	27 (25%)
	8 to 30	158 (9%)	34 (5%)	71 (12%)	42 (10%)	11 (10%)
	31+	49 (3%)	19 (3%)	18 (3%)	10 (2%)	2 (2%)
Reported limitation of usual activities due to wheezing (# [%])						
	Not at all	766 (41%)	318 (43%)	221 (39%)	178 (41%)	49 (46%)
	A little	553 (30%)	218 (29%)	169 (29%)	135 (31%)	31 (29%)
	A fair amount	235 (13%)	84 (11%)	89 (16%)	52 (12%)	10 (9%)
	A moderate amount	132 (7%)	49 (7%)	43 (8%)	33 (8%)	7 (7%)
	A lot	172 (9%)	72 (10%)	51 (9%)	40 (9%)	9 (8%)
Medication usage (# [%])						
	Yes	1670 (90%)	645 (87%)	536 (94%)	393 (90%)	96 (90%)
	No	188 (10%)	96 (13%)	37 (6%)	45 (10%)	10 (9%)

Overall, the Non-Hispanic Black group had the highest proportion of partially controlled and uncontrolled cases, with 59% of Black respondents with asthma in these categories (**Figure 3**). The White group had the highest proportion of asymptomatic cases, with 31% of White respondents with asthma in this category (**Table S5**).

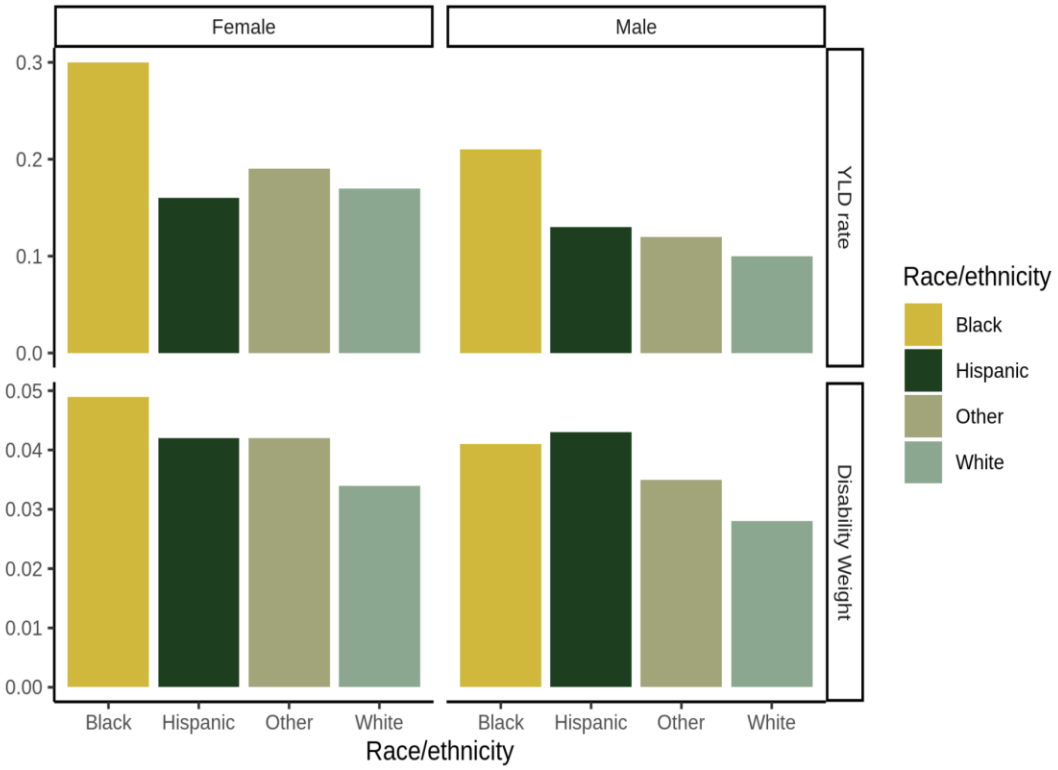
Figure 3. *Asthma cases by severity and race/ethnicity*



Nonfatal burden

After survey weighting, Black women also had the highest age-standardized mean disability weight of all race/ethnicity and sex combinations (0.049, 95% UI 0.040 to 0.060) (**Figure 4)**. White men had the lowest age-standardized mean disability weight of 0.028 (0.022 to 0.037). After accounting for severity, Black females had the highest age-standardized YLD rates, with an estimated rate of 0.30 YLDs per 100 people (95% UI 0.24 to 0.37). In comparison, White males had the lowest age-standardized rate of 0.1 YLDs per 100 people (95% UI 0.07 to 0.12) (**Table 2**).

Figure 4. *Age-standardized mean disability weight and YLD rate by race/ethnicity and sex, 2019*



In comparison to White women, the age-standardized YLD rate of Black women was higher by 0.13 YLDs per 100 people (95% UI 0.06 to 0.21). Moreover, 65% (95% UI 34 to 81) of this difference was attributable to higher severity and the remainder to higher prevalence. Although Non-Hispanic females exhibited a greater mean disability weight than White females, lower prevalence resulted in a minimal difference in age-standardized YLDs between both groups (-0.007, 95% UI -0.06 to 0.042). Differences in nonfatal burden between White Americans and other race/ethnicity groups were not statistically significant (**Table 4**).

Table 4. *Difference in age-standardized YLDs between White group and other race/ethnicity groups, with 95% UI. Bolded results are statistically significant.*

Sex	Measure	Black	Hispanic	Other
Female	Difference in YLDs compared to White group	**0.13 (0.06 to 0.21)**	-0.007 (-0.06 to 0.042)	0.022 (-0.038 to 0.08)
Female	Difference in YLDs due to prevalence	**0.041 (0.026 to 0.06)**	**-0.044 (-0.057 to -0.032)**	**-0.019 (-0.035 to -0.002)**

Female	Difference in YLDs due to severity	**0.086 (0.024 to 0.16)**	0.037 (-0.013 to 0.088)	0.041 (-0.014 to 0.096)
Female	% of difference due to prevalence	**35 (19 to 66)**	*-364 (-1981 to 3269)**	*-308 (-1479 to 543)**
Female	% of difference due to severity	**65 (34 to 81)**	*-264 (-3169 to 2081)**	*408 (-443 to 1579)**
Male	Difference in YLDs compared to White group	**0.11 (0.051 to 0.18)**	0.03 (-0.014 to 0.079)	0.027 (-0.015 to 0.066)
Male	Difference in YLDs due to prevalence	**0.058 (0.042 to 0.074)**	**-0.017 (-0.028 to -0.008)**	0.004 (-0.009 to 0.018)
Male	Difference in YLDs due to severity	**0.053 (0.0 to 0.114)**	**0.047 (0.002 to 0.098)**	0.023 (-0.016 to 0.06)
Male	% of difference due to prevalence	**57 (36 to 101)**	*-78.5 (-487.5 to 447.9)**	*18 (-133 to 181)**
Male	% of difference due to severity	44 (-0.8 to 64)	*178.5 (-347.9 to 587.5)**	*82 (-81 to 233)**

***** *when prevalence and severity contribute to YLD rates in different directions, proportion values can be negative and/or have an absolute value greater than 1.*

Discussion

Results indicate that age-standardized prevalence of asthma was highest in Non-Hispanic Black women, followed by White women. Among men only, age-standardized prevalence rates were highest among Black men. Moreover, Non-Hispanic Black people generally had the most severe asthma while Non-Hispanic White people had the least severe asthma on average. The difference in nonfatal burden of asthma between Black and White Americans was primarily driven by differences in the severity of disease. This was also true for Hispanic populations, which exhibited greater severity compared to White Americans, but much lower prevalence, resulting in slightly lower nonfatal burden.

Our results demonstrate large variation in the prevalence and severity of asthma by race/ethnicity group in the United States. This study also indicates that Non-Hispanic Black Americans have particularly severe asthma compared to groups. Results presented here align with literature that indicates that across race/ethnicity and sex categories, Black women experience the most prevalent, severe, and fatal asthma (22,37). Moreover, our findings indicate that differences in nonfatal burden are primarily driven by severity, rather than prevalence. This suggests that policy actions should concentrate on interventions that improve access to high-quality clinical care to reduce persistent disparities by race/ethnicity. Although most of the difference in nonfatal burden between Black and White Americans is largely attributable to severity, the large magnitude

of age-standardized YLDs attributable to prevalence indicate that concerted action should also be taken to mitigate exposure to pollutants that can trigger asthma in Black and brown communities.

To our knowledge, this study is the first of its kind to map data sources on asthma severity and prevalence to disability weights, a useful metric for quantifying the severity of disease. Previous works have had to rely on other methods to estimate the disability weights of asthma cases in the population. For example, in the GBD, the Short-Form 12 (SF-12; a validated health status questionnaire) is mapped to disability weights to quantify YLDs for many nonfatal conditions (32). However, the SF-12 captures the cumulative disability weight of all conditions a respondent is living with, and the disability weights specific to each nonfatal condition are estimated via a mixed-effects regression to control for comorbid conditions. Additionally, SF-12 data on people with nonfatal conditions are sourced from the Medical Expenditure Panel Surveys (MEPS), a survey of non-institutionalized Americans seeking healthcare (38). Because asthma cases generally represent treatment seekers (either for asthma or another condition), data from this source may not be representative of the general population of asthma cases. We considered the National Health and Nutrition Examination Surveys (NHANES) a better source for asthma severity as respondents answered detailed questions regarding their asthma severity that align with the symptoms described in the lay descriptions of GBD asthma severity states.

Additionally, while this analysis focuses on the US, data sources that report functional indicators of disease severity, such as those included in this analysis, may improve our understanding of disease severity in other countries, including those where data are sparse. This approach is particularly promising for asthma, as several international surveys include functional health indicators such as frequency of wheeze, wheeze-related activity limitations, and sleep disturbance (39,40). Moreover, by leveraging survey data that often contain detailed sociodemographic variables, this approach presents the opportunity to reveal disparities in disease severity by subpopulation, which can aid policymakers in developing targeted interventions.

Results presented in this manuscript are subject to several limitations. Due to our reliance on NHANES surveys completed prior to 2011, our estimates by race/ethnicity include a broad "Other" category, which includes American Indian/Alaska Native (AIAN), Non-Hispanic Asian, and multi-racial individuals. This limits our capacity to generalize findings for this residual group, as the Non-Hispanic Asian group generally exhibits a disease profile distinct from AIAN and multiracial groups (41).

We relied upon prevalence data from NHANES and NHIS to model the burden of asthma by age, sex, and race/ethnicity, defining cases of asthma as individuals with a diagnosis and wheezing in the past year. However, NHIS surveys ask respondents if they have had an asthma attack in the past year, whereas NHANES surveys ask respondents if they have had an episode of wheezing in the past year. Although we did not observe large variation in the prevalence of asthma by data source (**Figure S4),** variation in wording of this question may introduce variation in prevalence data by survey source and should be noted when interpreting modelled estimates.

Moreover, we relied on NHANES surveys from 2000-2012 to calculate the proportion of individuals with asymptomatic, controlled, partially controlled, and uncontrolled asthma. This was necessary, as the NHANES respiratory health module containing questions on wheezing and functional health was not administered after 2012. We pooled information across these years and assumed that the severity distribution of cases from this time period was the same in 2019. Findings from our analysis indicate a relatively stable severity distribution over time (**Figure S8)**. However, this assumption limits our ability to assess changes in the severity distribution of asthma cases by race/ethnicity over time. Future iterations of the NHANES respiratory health module would serve as a useful tool to monitor trends in nonfatal burden by race/ethnicity, allowing researchers to assess if progress has been made in reducing racial disparities.

We assigned individuals to asymptomatic, controlled, partially controlled, and severe asthma based on reported activity limitations, sleep disturbance, and emergency medical visits due to wheezing. Several tools have been developed to categorize asthma patients in a similar fashion, with applications in varied clinical settings (42–44). However, the limitations of self-reported measures of functional health are well-documented, as these questions may be subject to differential item functioning by race/ethnicity and/or sex (45,46). Additionally, the 12-month recall period associated with functional health questions may introduce recall bias, masking true differences in health status between groups (47,48). Our severity assignment algorithms rely, partially, on data on medical visits due to wheezing, which may inadvertently skew severity estimates in race/ethnicity groups with lower access to healthcare (16).

Classification such as the approach utilized in this manuscript may obscure the fact that even cases of asthma that present as mild may result in fatal exacerbations if poorly controlled. Symptom-based classification systems may be a convenient and achievable way to assess asthma severity at the population level. However, Global Initiative for Asthma (GINA) guidelines

recommend classifying people with asthma based on control status rather than severity, meaning that asthma severity can only be assessed upon good asthma control where the patient has been "stepped down" to their lowest possible dosage (49). This approach is not feasible in the US, given differential access to quality healthcare by race/ethnicity and socioeconomic status among other factors (16,23,50). Larger population-based studies on asthma control and severity, such as the recent Global Asthma Network survey series (39), are needed to comprehensively assess asthma management and associated health loss. Given that asthma severity is an important driver of mortality risk (51), future studies that quantify the relationship between nonfatal and fatal burden may strengthen our understanding of disparities in asthma-related mortality (18).

In conclusion, this study illustrates persistent racial disparities in asthma prevalence and severity of disease in the United States. Given the particularly large nonfatal burden of asthma in Black women, targeted interventions are needed to improve asthma control in this population and reduce preventable health loss.

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Appendix: “Asthma Prevalence, Severity, and Nonfatal Burden by Race/Ethnicity: A Bayesian Meta-regression Analysis”.

Supplemental Tables and Figures

Section 1. Methods

Section 2. Prevalence results

Section 3. Severity results

Section 1. Methods

Table S1. Data sources for asthma prevalence modelling.

Data Source	Survey Years	Diagnosis question	Wheezing question
National Health Interview Surveys (NHIS)	2001-2019	"Has a doctor or other health professional ever told you that you had asthma?"	"During the past 12 months, have you had an episode of asthma or an asthma attack?"
National Health and Nutrition Examination Surveys (NHANES)	1999-2018	Has a doctor or other health professional ever told {you/SP} that {you have/s/he/SP has} asthma (az-ma)?	In the past 12 months, {have you/ has SP} had wheezing or whistling in {your/his/her} chest?

Table S2. NHANES functional health questions pertaining to asthma.

Survey Question	Question	Groups
Activity limitations	During the past 12 months, how much did {you/SP} limit {your/his/her} usual activities due to wheezing or whistling? Would you say…	Not at all; a little; a fair amount; a moderate amount; a lot
Sleep disturbance	[In the past 12 months], how often, on average, has {your/SP's} sleep been disturbed because of wheezing? Would you say this happens . . .	Never; 1 or more nights per week; Less than 1 night per week
Wheeze after exercise	[In the past 12 months], has {your/SP's} chest sounded wheezy during or after exercise or physical activity?	Yes; No
# wheezing/ whistling attacks	In the past 12 months {have you/has SP} had wheezing or whistling in {your/his/her} chest?	1 to 12, Range of Values
# Medical visits for wheezing attacks	[In the past 12 months], how many times {have you/has SP} gone to the doctor's office or the hospital emergency room for one or more of these attacks of wheezing or whistling?	0 to 15, Range of Values; 20, 20 or more
Missed work or school	During the past 12 months, how many days of work or school did {you/SP} miss due to wheezing or whistling?	None; 1 to 7; 8 to 30; 31 plus

Table S3. Classification of asthma cases by GBD health state.

Health state	**Classification**
Asymptomatic	**Rule 1:** Activity limitation = "not at all" or "a little" **and** Sleep disturbance < 1 /wk **and** < 2 medical visits due to wheezing **and** No missed days of work or school due to asthma
Controlled	**Rule 1:** Activity limitation = "not at all" or "a little" **and** Sleep disturbance < 1 /wk **and** < 2 medical visits due to wheezing **and** Missed days due to work or school > 1 and < 30 **Rule 2:** Activity limitation= " a moderate amount" or "a fair amount" **and** sleep disturbance < 1 night a week **and** medical visits < 2 **and** < 8 missed days of work and school **Rule 3:** Activity limitation= "a lot" **and** sleep disturbance < 1 night a week **and** medical visits < 2 **and** 0 missed days of work and school **Rule 4:** Not classified under Rules 1-3 **and** medical visits < 2 **and** not falling under "asymptomatic" classification
Partially Controlled	**Rule 1:** Activity limitation= "A lot" **and** 1-30 missed days of work and school and none of the following: - Sleep disturbance at least one night a week - 2+ medical visits due to wheezing in the past year **Rule 2:** Activity limitation= "a moderate amount" or "a fair amount" **and** 1 of the following: - Sleep disturbance > 1 night a week - 8+ missed days of work and school - 2+ medical visits due to wheezing in the past year **Rule 3:** Activity limitation= "not at all" or "a little" **and** 1 of the following: - Sleep disturbance > 1 night a week - 8+ missed days of work and school - 2+ medical visits due to wheezing in the past year **Rule 4:** Not classified under Rules 1-3 **and** Medical visits > 2 **and** not falling under "uncontrolled" classification
Uncontrolled	**Rule 1:** Activity limitation= "A lot" **and** 1 or more of the following: - Sleep disturbance at least one night a week - 8+ missed days of work and school - 2+ medical visits due to wheezing in the past year

	Rule 2: Activity limitation= “a moderate amount” or “a fair amount” **and** 2 or more of the following: - Sleep disturbance > 1 night a week - 8+ missed days of work and school - 2+ medical visits due to wheezing in the past year **Rule 3:** 31+ missed days of work or school due to wheezing or 5+ medical visits due the wheezing in the past year **Rule 4:** Activity limitation= “not at all” or “a little” **and** all of the following: - Sleep disturbance > 1 night a week - 8+ missed days of work and school - 2+ medical visits due to wheezing in the past year

Figure S1. Flowchart of health state assignment for NHANES respondents who report no or little limitation of daily activities due to wheeze.

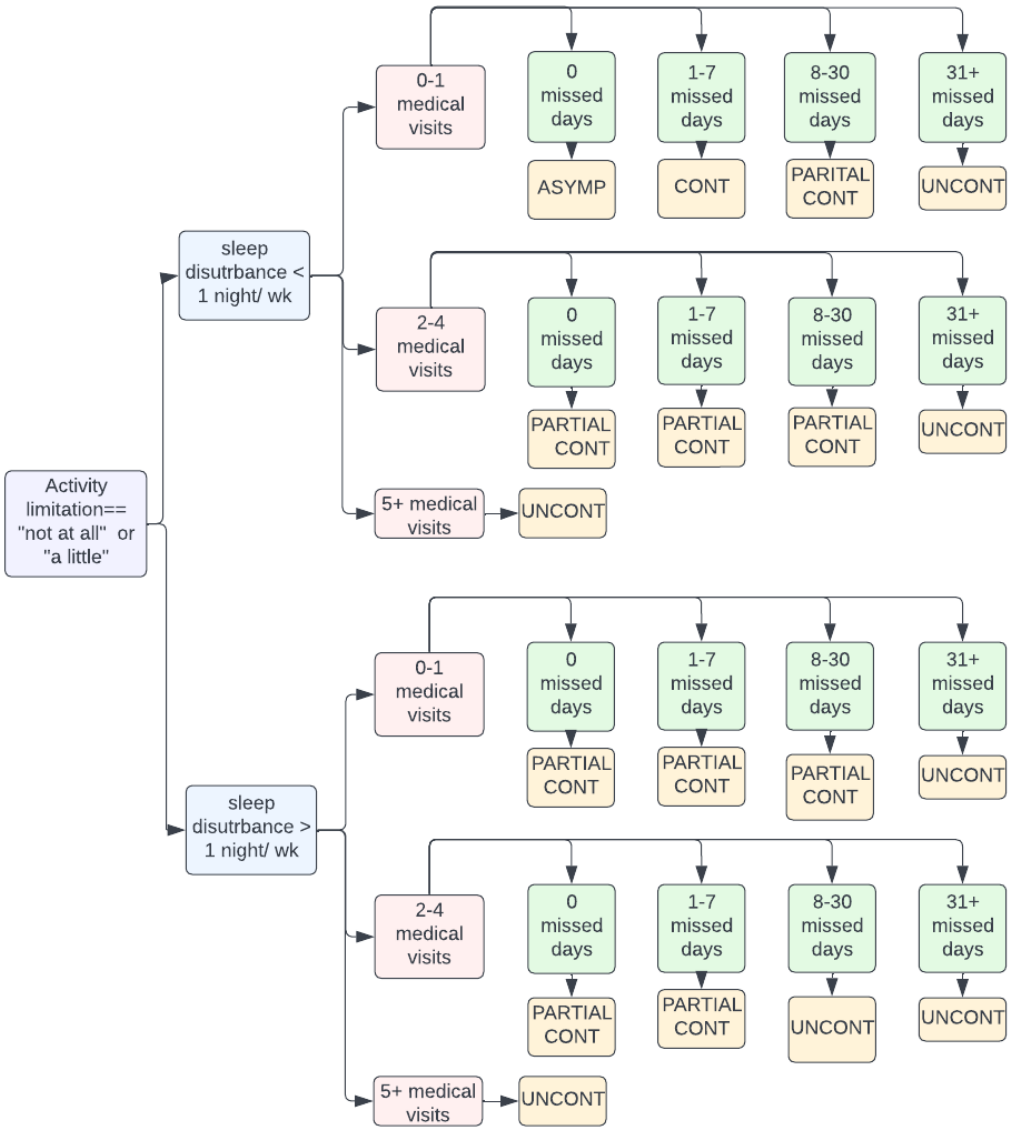


Figure S2. Flowchart of health state assignment for NHANES respondents who report a fair amount or a moderate amount of limitation of daily activities due to wheeze.

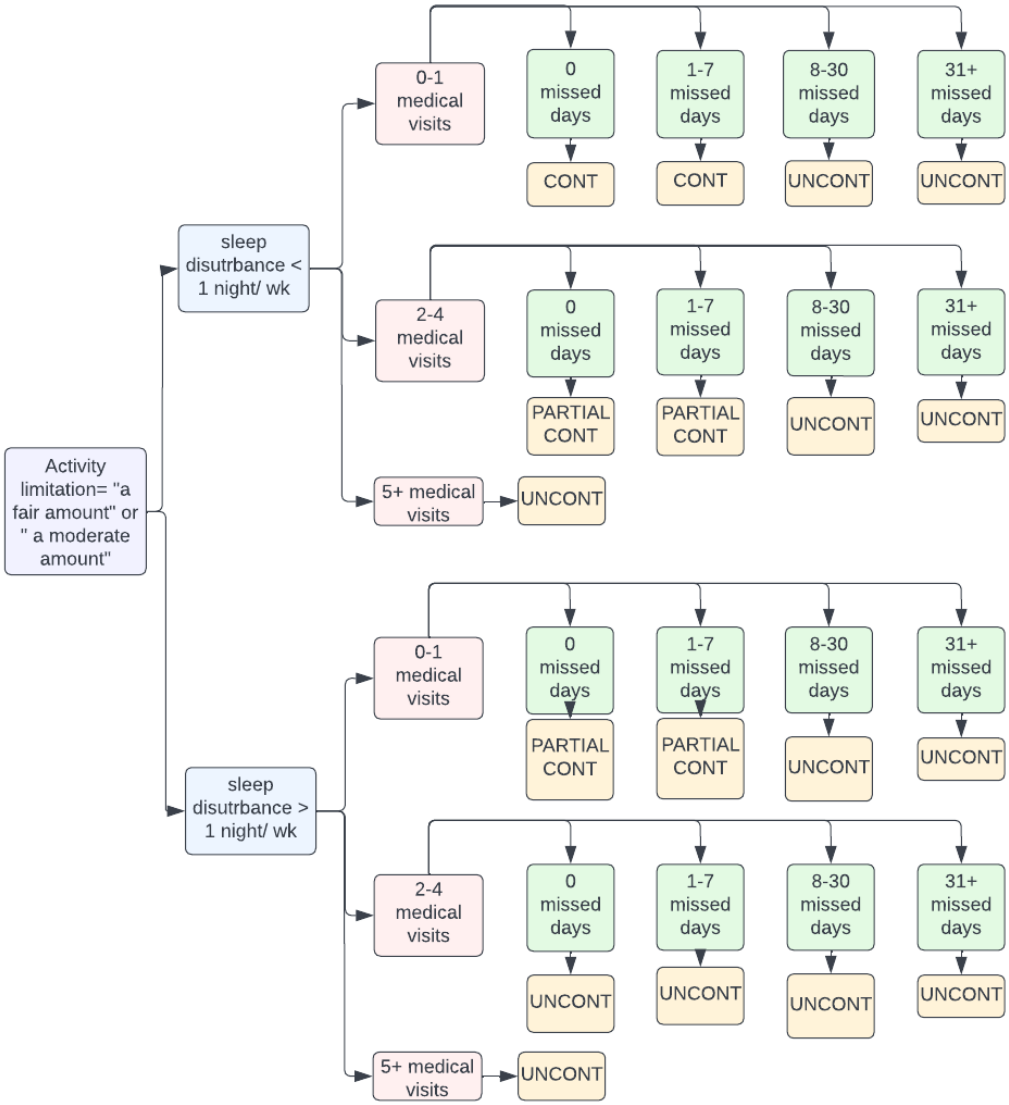
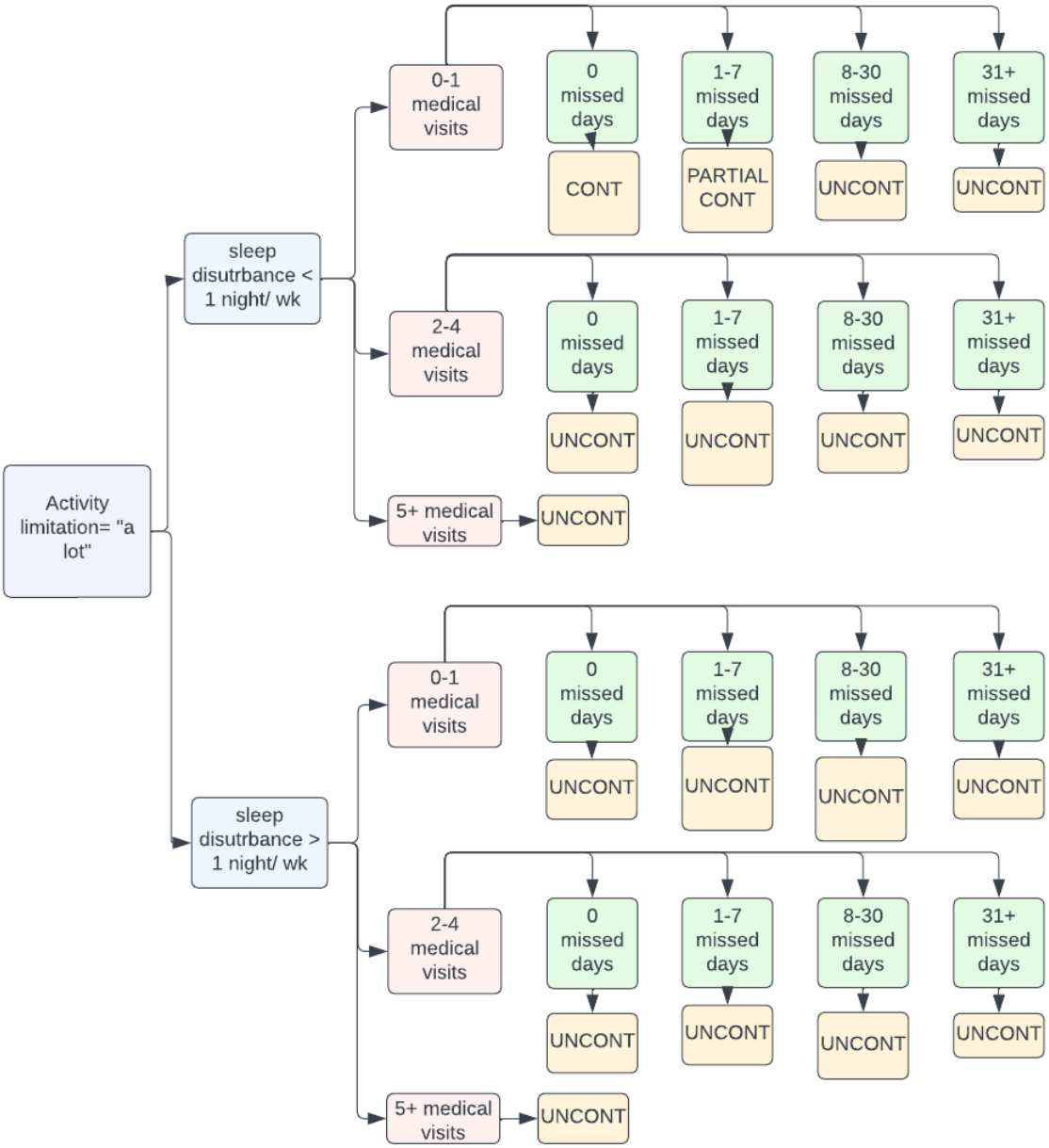


Figure S3. Flowchart of health state assignment for NHANES respondents who report a lot of limitation of daily activities due to wheeze.



Section 2: Prevalence results

Figure S4. Input data by study source and sex. Each point represents an estimate from one survey round for an age-sex-race/ethnicity.

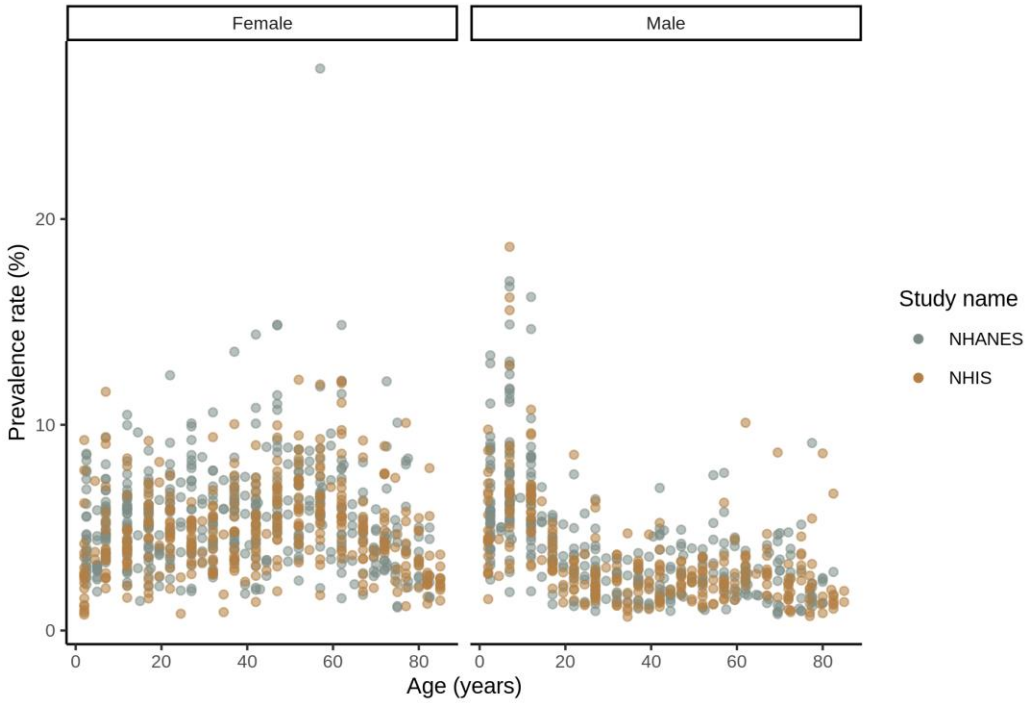


Figure S5. Estimated asthma prevalence rate by race/ethnicity, sex, and age, 2019, with 95% UI. Points are input data from all years, line is predicted prevalence for 2019, shaded area is 95% UI.

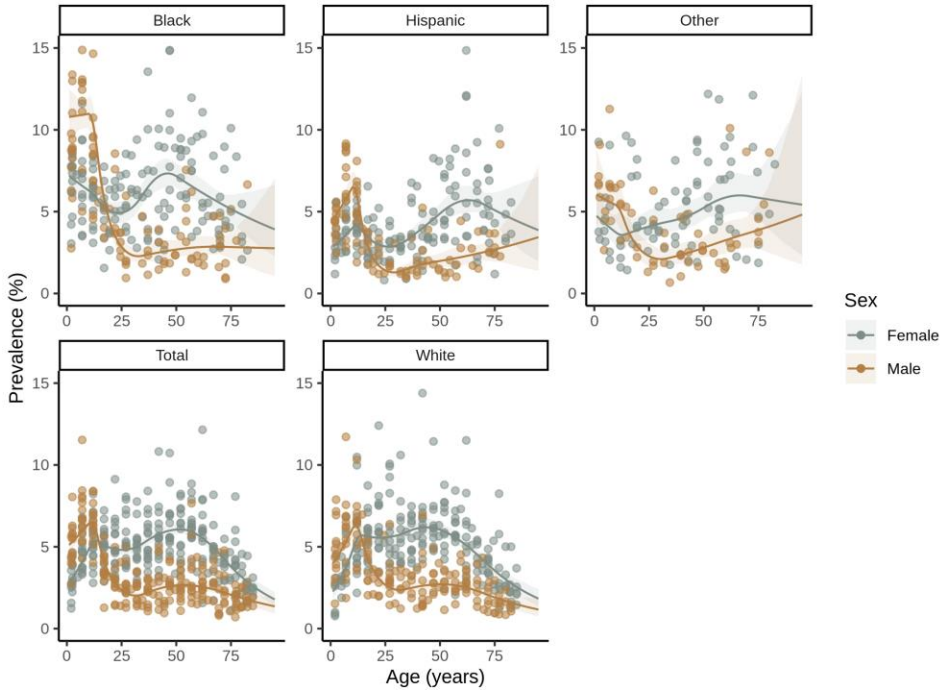


Figure S6. Estimated prevalence rate by race/ethnicity, sex, and age, 2019 (with 95% UI).

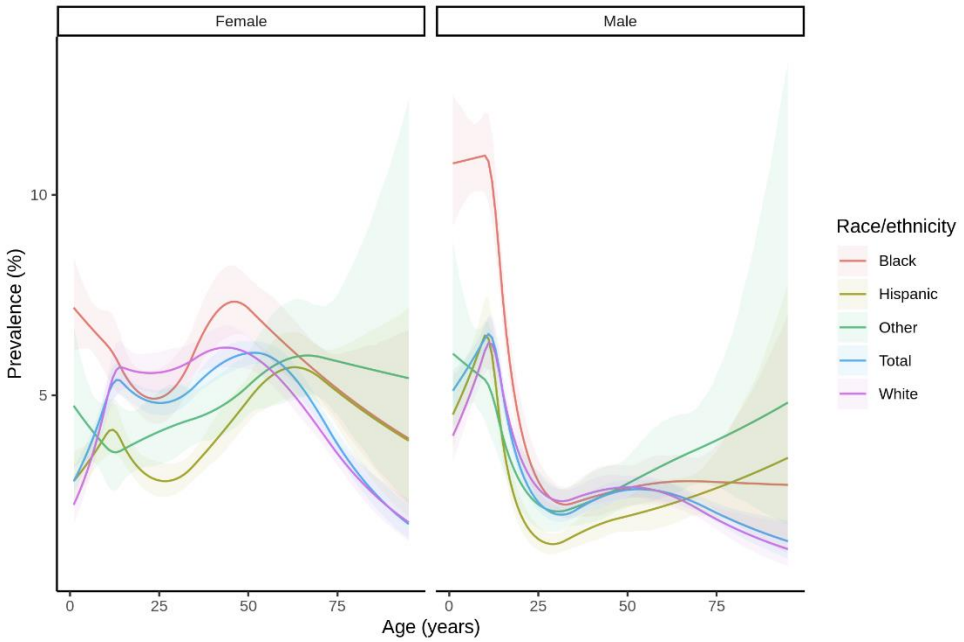
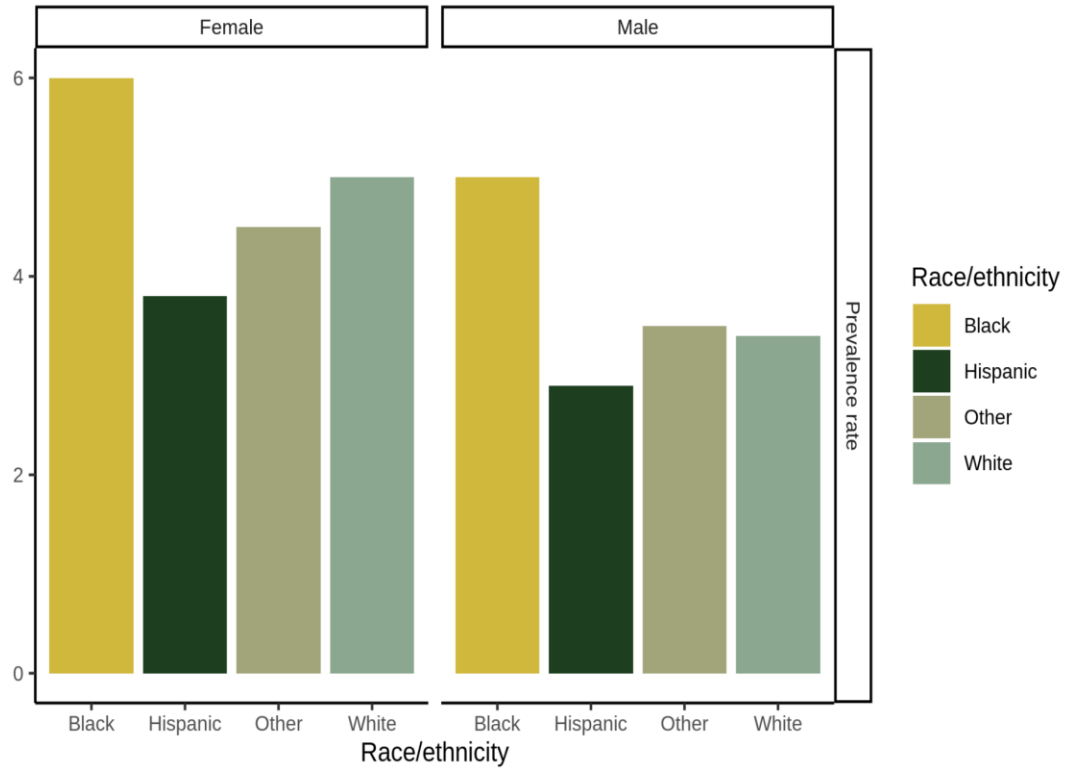


Table S4. Model coefficients on year by race/ethnicity and sex, logit-space.

Race	Sex	Year
Black	Female	-0.0013383
Black	Male	-0.0010366
Hispanic	Female	-0.0015725
Hispanic	Male	-0.001328
Other	Female	-0.0016127
Other	Male	-0.0014175
Total	Female	-0.0014662
Total	Male	-0.0013231
White	Female	-0.0014702
White	Male	-0.0013521

Figure S7. Age-standardized prevalence rate of asthma (%) by race/ethnicity and sex, 2019.



Section 2: Severity results

Figure S8. Asthma cases by severity and year, unweighted.

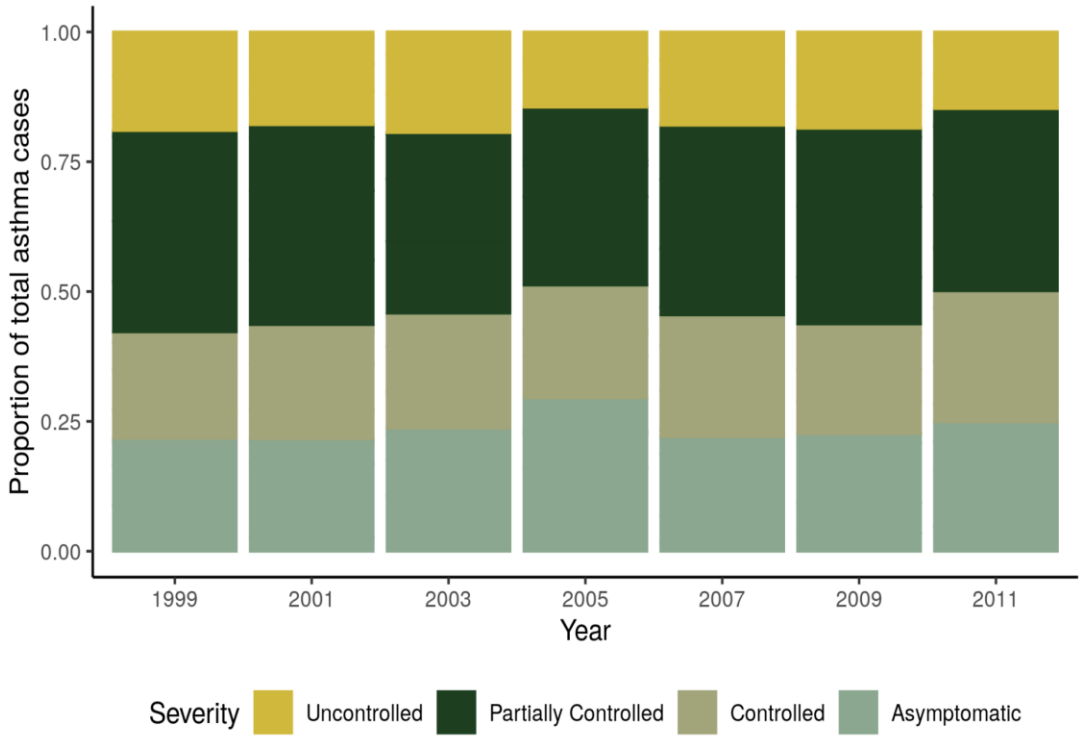


Figure S9. Asthma cases by severity, race and age group, with average disability weights above.

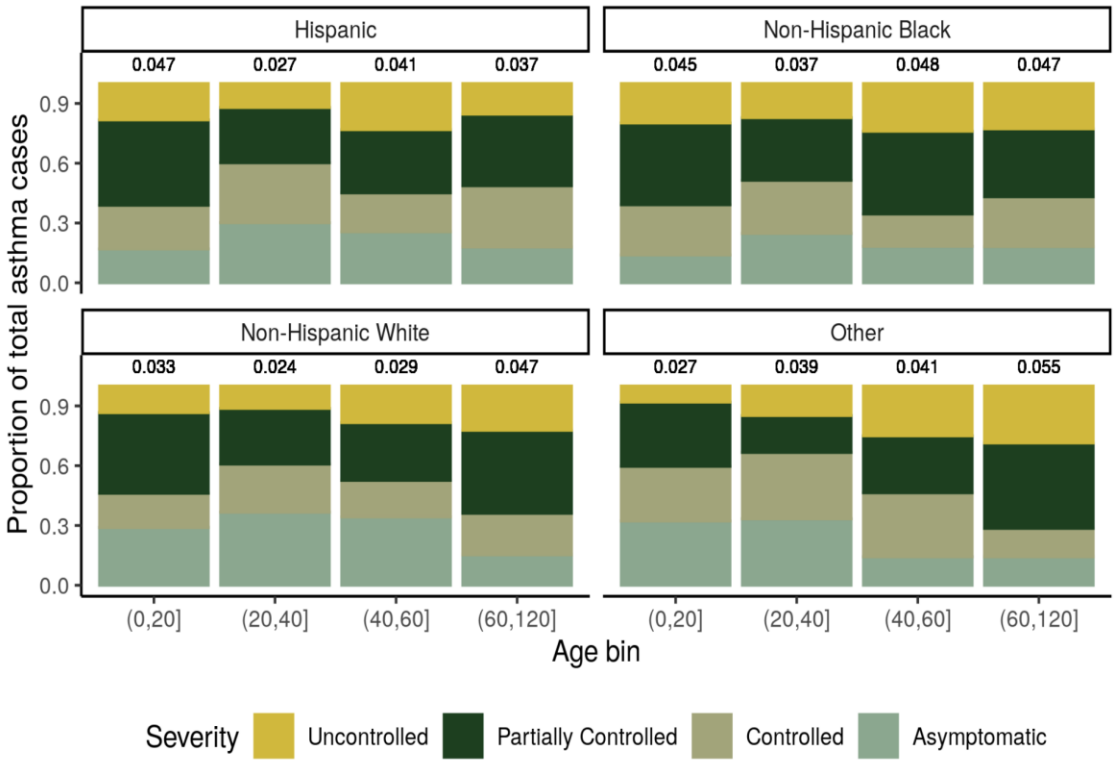


Table S5. Counts of respondents by severity, proportional distribution by race/ethnicity, unweighted.

Race/ethnicity	Asymptomatic cases	Controlled cases	Partially controlled cases	Uncontrolled cases	Total cases
Counts					
Non-Hispanic White	274	172	295	130	871
Hispanic	109	125	204	95	533
Other	34	36	36	18	124
Non-Hispanic Black	120	172	295	130	871
Proportions					
Non-Hispanic White	0.31	0.20	0.34	0.15	1
Hispanic	0.42	0.19	0.23	0.17	1
Other	0.27	0.29	0.29	0.15	1
Non-Hispanic Black	0.17	0.24	0.39	0.20	1