## Title

Racial disparities in asthma-related health care use in the National Heart, Lung, and Blood Institute's Severe Asthma Research Program



## Journal

Journal of Allergy and Clinical Immunology, 143(6)

## ISSN

0091-6749

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## Publication Date

2019-06-01

## DOI

10.1016/j.jaci.2018.11.022

Peer reviewed

HHS Public Access

Author manuscript

*J Allergy Clin Immunol*. Author manuscript; available in PMC 2020 June 01.

Published in final edited form as:

*J Allergy Clin Immunol*. 2019 June ; 143(6): 2052–2061. doi:10.1016/j.jaci.2018.11.022.

# Racial disparities in asthma-related healthcare utilization in the National Heart, Lung and Blood Institute's Severe Asthma Research Program

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## Abstract

**Background—**Despite advances in asthma care, disparities persist. Black patients are disproportionally affected by asthma and also have poorer outcomes compared to White patients.

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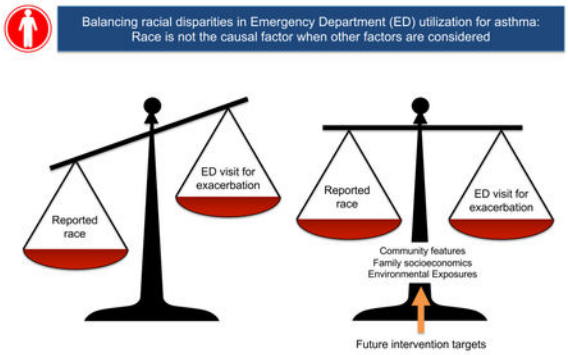
**Objective—**To determine associations between Black and White race and asthma-related healthcare utilization, accounting for complex relationships.

**Methods—**This study was completed as part of the National Heart, Lung and Blood Institute's Severe Asthma Research Program (SARP), a prospective, observational cohort. Between November 2012 and February 2015, it enrolled 579 participants 6 years and older with one year of observation time and complete data. Inverse probability of treatment weighting was utilized to balance racial groups with respect to community and family socioeconomic variables and environmental exposure variables. The primary outcome was Emergency Department (ED) utilization for asthma. Secondary outcomes included inhaled corticosteroid **(ICS)** use, outpatient physician visits for asthma, and asthma–related hospitalization.

**Results—**Black patients had greater odds of ED utilization over one year (OR, 2.19; 95% CI, 1.43–3.35) but also differed in the majority (>50%) of baseline variables measured. After statistical balancing of the racial groups, the difference between Black and White patients with respect to ED utilization no longer reached the level of significance. Instead, in secondary analyses, Black patients were less likely to see an outpatient physician for asthma management (adjusted OR: 0.57; 95% CI: 0.38 – 0.85).

**Conclusions—**The disparity in ED utilization was eliminated after consideration of multiple variables. Social and environmental policies and interventions tailored to Black populations with a high burden of asthma are critical to reduction (or elimination) of these disparities.

## Graphical apstract




## Capsule summary

Racial disparities in asthma-related healthcare utilization in Black patients are complex and largely influenced by socioeconomic and environmental variables that may be amenable to targeted policies and interventions.

### Keywords

Asthma control; Asthma exacerbation; Racial disparities; Healthcare utilization; Propensity scoring; Inverse probability of treatment weighting

## Introduction

Despite advances in asthma care, ongoing surveillance data since 2001 highlight racial disparities in asthma in the United States.[1] The most recent data estimates from 2014 continue to show a disturbing trend, with a disproportionately higher prevalence of current asthma in Black compared to White children (13.4% vs. 7.6%) and adults (8.7% vs. 7.6%).[2] Although rates of outpatient physician visits for asthma[1] and asthma exacerbation prevalence[3] were not markedly different between racial groups in those reports, Blacks have substantially greater asthma morbidity compared to Whites, with a 3.5-fold higher rate of emergency department **(ED)** visits and hospitalizations for asthma and a 2.8-fold higher rate of asthma-related death.[2]

Whether Blacks have greater intrinsic asthma severity resulting in an increased predisposition toward more severe exacerbations or other factors associated with increased healthcare utilization is not entirely clear. In a previous cross-sectional analysis of adults enrolled in the National Heart, Lung and Blood Institute's Severe Asthma Research Program **(SARP)**, biological factors including family history of asthma, aeroallergen sensitization and serum IgE concentrations were associated with asthma refractory to intensive corticosteroid treatment in Blacks but not in White patients.[4] In that same study, Black patients with severe asthma also had significantly lower lung function values and an earlier age of asthma onset, suggesting a genetic and/or biological predisposition toward more severe disease, although the analysis was limited by its cross-sectional design and lack of prospective outcome assessment.[4] Indeed, other studies have found no evidence of racial disparities in healthcare utilization for asthma after adjustment for potentially confounding effects of economic hardships and other sociodemographic and environmental variables that impact asthma disease manifestation and asthma-related healthcare utilization.[5–7] However, those studies were limited by single-center designs (potentially decreasing generalization to the larger U.S. population), minimal or no prospective phenotypic characterization of the cohort, and an exclusive focus on children.[5–7]

The third iteration of the National Heart, Lung and Blood Institute's SARP provides a unique opportunity for assessment of racial disparities in asthma healthcare utilization, given the wide range of asthma severities, the large proportion of participants with symptomatic, difficult-to-treat asthma, standardized phenotypic characterization of enrolled participants, and prospective outcome assessment. Using an adaptation of the conceptual framework proposed by Beck et al.,[5] this study assessed differences in healthcare utilization over one year of prospective study between Black and White participants with asthma enrolled in SARP after application of propensity scoring methods to balance confounders. The primary outcome was ED utilization; secondary outcomes included inhaled corticosteroid **(ICS)** use, outpatient physician visits for asthma, and asthma–related hospitalization. We hypothesized that racial disparities in asthma-related emergency department visits and hospitalizations would be apparent, but that these differences would be mitigated or eliminated after balancing of the groups for other factors associated with healthcare usage.

## Methods

This was a secondary analysis of self-reported Black and White participants 6 years of age and older with one year of observation time enrolled in the National Heart, Lung and Blood Institute's SARP between November 2012 and February 2015.[8] Eligibility criteria for SARP included a physician diagnosis of asthma (of any severity) and either ≥ 12% reversibility in the forced expiratory volume in one second **($FEV_1$)** after bronchodilator administration or airway hyperresponsiveness to methacholine, evidenced by a provocative concentration of methacholine ≤ 16 mg/mL. Thirteen participants with $FEV_1$ values below 50% of predicted who could not undergo methacholine challenge due to concerns for safety were also enrolled at the discretion of the principal investigator. Relevant exclusion criteria for SARP included current smoking, smoking history >10 pack years if ≥30 years of age or >5 pack years if <30 years of age, premature birth before 35 weeks gestation, and other chronic airway disorders such as aspiration or vocal cord dysfunction. Permission to proceed with SARP was granted by the Institutional Review Board of each institution and an independent Data Safety and Monitoring Board. The study was also registered at ClinicalTrials.gov (NCT01606836). Informed written consent and assent (if less than 18 years) were obtained from all participants.

### Design and procedures.

Recruitment procedures are described in the online supplement. Participants completed a baseline characterization visit as described previously,[8–10] a telephone call at 6 months (±60 days) to assess for asthma control, medical history changes and healthcare utilization for asthma, and a repeat characterization at 12 months (±90 days) after enrollment. Each participating clinical site maintained certified staff members who utilized uniform methods for characterization that were outlined in a manual of procedures. Visits were postponed if an asthma exacerbation treated with systemic corticosteroids or a respiratory infection treated with antibiotics was reported within the preceding four or two weeks, respectively.

Participants withheld short-acting and long-acting bronchodilator medication for a minimum of 4 or 12 hours, respectively, prior to the study visit. Spirometry (KoKo® PDS, Ferraris, Louisville, CO, donated by nSpire Health, Longmont, CO) was performed according to technical standards[11] with centralized over-reading for accuracy and was interpreted according to population reference equations.[12] Exhaled nitric oxide concentrations were measured online (NIOX MINO®, Circassia Pharmaceuticals, Chicago, IL) according to recommended standards.[13] Venipuncture was obtained for total serum immunoglobulin E **(IgE)** and allergen-specific IgE to 15 aeroallergens (St. Louis Children's Hospital, St. Louis, MO). Blood eosinophils were quantified by local site laboratories. Medical history questionnaires assessed self-reported healthcare utilization over the previous 12 months, current medications, and current demographic features and exposures such as tobacco smoke. Asthma control over the past week was assessed with the 6-item and 7-item Asthma Control Questionnaire **(ACQ)**[14, 15] and asthma control over the past 4 weeks was assessed with the Asthma Control Test **(ACT)**[16, 17] or Childhood Asthma Control Test **(CACT)**.[18] Global asthma-related quality of life over the preceding two weeks was assessed with the Asthma Quality of Life Questionnaire **(AQLQ)**[19] or Pediatric Asthma Quality of Life

Questionnaire **(PAQLQ)**.[20] Community (i.e., ZIP code) characteristics were obtained from Tables S101 (Age and Sex), S1501 (Educational Attainment), S2504 (Physical Housing Characteristics for Occupied Housing Units), DP03 (Selected Economic Characteristics), and B08201 (Household Size by Vehicle Available) of the 2010–2014 American Community Survey 5-year estimates, available at www.factfinder.census.gov.[21]

### Racial designation and outcome measures.

Race was self-reported. Participants were asked to identify their racial background on a printed questionnaire. Participants selecting more than one race were also asked to identify their primary racial identification. Participants were eligible for this analysis if they reported White or Black as their racial background independent of Hispanic ethnicity, or, if they reported more than one race, designated White or Black as their primary racial identification.

The primary outcome was ED utilization for acute asthma symptoms at any time during the one-year study period after the baseline characterization visit. Secondary outcomes included an outpatient physician visit or hospitalization. Outcome occurrence was assessed at the 6-month telephone visit and again at the one-year follow-up visit. Physician visits were self-reported; ED visits and hospitalizations were verified by a review of medical records whenever possible and considered an adverse event in the parent protocol.

### Statistical analyses.

The entire dataset provided over 800 baseline variables that required a reduction in number. Variables with >5% missing data (N=34) including bronchoscopic findings, imaging results, and induced sputum biomarkers were excluded immediately. Questionnaire data were complete; responses that included “decline to answer,” “don’t know,” or “not applicable” were considered informative. Causal effects of Black compared to White race were estimated with inverse probability of treatment weighting **(IPTW)** using the propensity score as detailed by Austin et al[22] and in the online repository. A Directed Acyclic Graph **(DAG)** was adapted from Beck et al. and provided a visual display of assumed relationships between variables, including sets of covariates and unmeasured confounders.

Three models were generated: Model 1 contained no covariates (unweighted), Model 2 contained family and community socioeconomic covariates (highest household education, yearly household income, number of persons in the home, community percentage of unemployment), and Model 3 contained family and community socioeconomic covariates plus environmental exposures (years in current home, tobacco smoke exposure, cats or dogs in the home, visible cockroaches in the home, visible rodents in the home, home water damage in the past 12 months, bedding encased, carpet or rug in the bedroom). Weighted standardized mean differences **(SMDs)** were calculated using simple and complex model solutions and were used to compare means, percentages, higher-order moments and continuous interactions between racial groups. Simple model SMDs were modeled using binary logistic regression with main effects and complex model SMDs were modeled using restricted cubic splines with 4 knots for continuous predictors. A cutoff of <0.2 for the standardized mean difference was used as an indication of balance. Graphical qualitative

methods were also used to compare the distribution of continuous baseline covariates between Black and White participants in the weighted sample. Outcomes of interest included an outpatient physician visit, ED visit, or hospitalization for asthma during the one year period of observation and were assessed with binary logistic regression using simple model stabilized IPTW, trimmed at 1% and 99%. Details of IPTW model selection and weight diagnostics are provided in the online repository. Data were analyzed with SAS® software (Version 9.4, The SAS Institute, Cary, NC, USA) and CRAN R (Version 3.3, Vienna, Austria).

## Results

714 participants 6 years and older were enrolled in SARP across seven partnering institutions (Figure 1). Demographic features of the participants differed somewhat between sites but were representative of the each site's geographical region (Table E1). 669 participants were eligible for inclusion but 38 were lost to follow-up (Figure 2). Participants who were lost to follow-up were more likely to be Black (8.2% drop-out) than White (4.2% drop-out) and were younger. Participants who dropped out also tended to have lesser educational attainment ($p = 0.058$), although this difference did not reach the threshold of significance (Table E2). Features of the included participants ($N = 631$) are shown in Table 1. Although sex and ethnicity did not differ between racial groups, Black participants differed in more than 50% of the measured baseline variables (Table 1).

### Clinical outcomes at one year.

Although 51 baseline predictor variables of interest were initially considered for modeling, significant multicollinearity was noted (Table E3). To minimize redundancy, the number of potential predictors was reduced based on correlative methods and a DAG, which provided a visual display of assumed relationships between variables, including sets of covariates and unmeasured confounders (Figure 2). Variables hypothesized to fall along the causal pathway were not included in the models in attempts to avoid underestimation of the effects of community/family socioeconomic variables and environmental factors on racial disparities.

Of the 631 participants who completed one-year of follow-up, 32 participants (5%) had missing (i.e., blank) responses for one or more of the predictor variables of interest and were excluded, resulting in a final sample of 579 participants with complete data and $12.9 \pm 2.0$ months of observation time for outcome assessment. Selected features of these participants at baseline and one year are shown in Table 2. Self-reported asthma control and asthma-related quality of life improved slightly by the one-year visit but were not accompanied by significant changes in exhaled nitric oxide concentrations or pulmonary function measures (Table 2).

Given the large number of differences observed in the baseline features of Black and White participants, IPTW was utilized to obtain unbiased estimates of racial effects. Unweighted SMDs for participants with complete data ($N = 579$) were compared to those from all participants with one year of observation ($N = 631$) and results were virtually identical (data not shown), suggesting that minimal information was lost. The absolute unweighted SMDs and weighted SMDs from simple model and complex model solutions are shown in Table

E4; higher-order and interaction diagnostics for continuous variables are shown in Table E5. Using a SMD cutoff of 0.2 as an indication of confounding effects balance, the simple model and complex models had analogous performance. For purposes of reduction in analytical complexity, the simple model was retained for outcome analysis.

The results of univariate (unweighted) and weighted outcome analyses at one year are presented in Table 3. There were no differences between White and Black participants in the occurrence of an exacerbation treated with systemic corticosteroids (unweighted OR for Black vs. White: 0.99; 95% CI: 0.70, 1.32, p = 0.932) or the exacerbation rate (Black vs. White, 0.91 ± 1.83 vs. 1.03 ± 1.80, p = 0.422). However, the primary outcome, ED utilization by one year for asthma symptoms, was significantly different (i.e., greater) in Blacks compared to Whites in unadjusted models. With application of IPTW to balance potential confounding variables, these differences were eliminated. With regard to secondary outcomes, after IPTW, Black patients also had less utilization of outpatient care for asthma symptoms (Table 3). Stratification by age (<18 years versus ≥18 years) yielded similar trends (Table E6).

## Discussion

Despite overall advancements in asthma knowledge and care, racial disparities in asthma outcomes are evident and remain a significant unmet problem in the United States.[1, 3] The objective of the National Heart, Lung and Blood Institute's SARP is to understand the temporal features of severe as well as non-severe asthma in order to develop better treatments; as such, a primary long-term goal is to achieve equitable (and improved) asthma outcomes in all affected patients irrespective of race. This requires a more comprehensive understanding of disparities and a more sophisticated analytical approach than simple two-group designs since the daily lives and lived experiences of Black and White patients with asthma are clearly different. Indeed, in the present study, Blacks and Whites differed in the majority of features measured. We therefore utilized IPTW statistical methods to estimate the effects of self-reported race on healthcare utilization for asthma in an idealized setting where both races are similar and balanced with regard to community and family socioeconomic variables and environmental exposures. Although crude analyses demonstrated nearly two-fold increased odds of ED utilization in Black patients, after balancing of the racial groups for the aforementioned features, disparities in ED utilization were no longer noted. Instead, Black patients had decreased utilization of outpatient physician offices for asthma. Our results suggest that racial disparities in asthma-related healthcare utilization in Black patients are complex, but can be eliminated with consideration of socioeconomic and environmental variables. These variables may be amenable to policies and interventions specifically tailored to Black populations with a high burden of asthma.

Our findings confirm and extend the results of other studies that have demonstrated complex associations between race and asthma-related healthcare utilization.[5–7] A major strength of the present study is the comprehensive characterization of enrolled participants and the multi-center design, since patterns of asthma-related healthcare utilization can be subject to wide geographic variability.[23, 24] Indeed, a previous study of children observed 88-fold

variation in asthma hospital admission rates across a single county; this variability was associated not only with Black race but also with other community neighborhood features such as educational attainment, car access and population density.[25] Other studies have similarly observed associations between low household income and related hardships (i.e., unemployment, lack of home ownership, no spouse) and asthma-related healthcare utilization in regional populations.[5,6,26–28] Although the present study utilized crude measures of socioeconomic status such as education and income, wealth and hardship measures were not obtained. It is therefore possible that there may be residual confounding of our results by socioeconomic status. Indeed, others have previously noted that measures of hardship, in addition to more traditional measures of socioeconomic status, explained approximately 40% more of the disparity in hospital readmission between Black and White children.[6] Other analyses of adults and children presenting to the ED for asthma-related care have also identified multiple reasons for seeking emergency care that are not necessarily associated with symptom severity, including convenience and preference based on the perceived skill and expertise of the ED team.[26, 29]

Recruitment for the present study occurred at large academic medical centers across the United States with large referral catchment areas. Although participants from over 600 ZIP codes were included in the analysis, generalizability to the larger population remains a concern since the majority of the SARP centers are located at academic medical centers. Since this was not a surveillance study and relied on participant recruitment, it is possible that our patient groups may not be completely representative of their target populations. For example, omission of current smokers and participants with a history of tobacco use may have resulted in inadvertent exclusion of lower income participants. Race and ethnicity also differed between the SARP sites and self-reported Black participants were also more likely to drop out of the study. Furthermore, given that the SARP academic medical centers were located in larger cities, generalization to rural areas is also cautioned. There are also inherent limitations to ZIP code-based analyses, since ZIP code features may not necessarily correlate with the individual. Additionally, this analysis was restricted to self-reported Black versus White participants and there are many limitations with self-reported race. Several studies have highlighted significant discrepancies between self-reported race and genetic ancestry inferred using ancestral informative markers.[30] We were also not powered to study other racial or ethnic minority populations. This is an important limitation since Hispanic/Latino populations (especially Puerto Ricans) are also disproportionately affected by asthma and have an asthma death rate nearly two times that of Whites.[1,2]

Because the SARP protocol required repeated telephone calls and research visits at the participating academic center, access to care was less of an issue in our cohort than what has been previously reported by community-based social workers.[31] However, access to care is clearly an important contributor to poor outcomes in other asthma populations given the success of mobile asthma programs in reducing missed school/work days and acute asthma-related healthcare utilization.[32, 33] Although mobile programs reduce barriers such as transportation and lack of health insurance in addition to improving care access, results are not necessarily maintained[34] and Blacks are still less likely than Whites to achieve asthma control.[32] Access to primary care physicians and asthma specialists is also an important consideration since inability to receive a same-day appointment with an outpatient physician

is a major factor in the decision to seek emergency care.[26, 29] Blacks, compared to Whites, are also disproportionately affected by chronic conditions[35] and adults with multiple chronic conditions (including asthma) are more likely to utilize emergency healthcare services.[28, 36] However, these same patients are also more likely to delay or not obtain necessary routine healthcare services.[37] Similarly, although the supply of asthma specialists has been associated with a reduction in ED visits at the county level,[38] racial disparities in specialist access remain.[39]

Self-reported asthma controller medication usage did not change significantly in the present study over the one-year period of follow-up. However, the protocol did not permit electronic monitoring of asthma prescription adherence and this is a potential limitation since adherence to asthma controller therapy could have contributed to ED utilization during the study period. Indeed, in one study of Medicaid-enrolled children in 29 states, the ratio of long-term asthma controller medications to total asthma medications was the primary modifiable risk factor for ED utilization at the individual level.[38] At the population level, use of asthma preventive medications (i.e., inhaled corticosteroids)[40–42] and adherence to asthma prescriptions[43] is also lower in Blacks versus Whites and may be due to more negative beliefs about inhaled corticosteroids and a preference for complementary and alternative medicine approaches.[44] We also did not assess health literacy in the present study, which has been associated with adherence to asthma controller medication, asthma medication delivery (i.e., inhaler technique), and measures of asthma control.[45, 46]

In summary, the results from this analysis suggest that racial disparities in asthma-related healthcare utilization are highly complex and influenced by a number of other factors associated with self-reported race, including socioeconomic factors. Many of these factors (such as aeroallergen exposure and sensitization) are amenable to modification and offer opportunities for future intervention. In an idealized situation where Blacks and Whites are balanced with respect to selected variables, we found few differences between racial groups with regard to ED utilization. While this observation was reassuring, our finding of decreased outpatient physician visits for asthma in Black patients was concerning and not fully explained by the variables in our model. Thus, it is unclear whether this is due to differences in healthcare access, mistrust with the medical system, differences in the lived asthma experience including symptom perception, or other factors that could not be addressed with the present study design. Deeper understanding of the multiple variables associated with race is warranted and necessary for the delivery of future interventions to reduce racial disparities and eliminate unnecessary gaps in asthma outcomes.

## Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

## Acknowledgments

Supported by NHLBI to the Severe Asthma Research Program (SARP):

U10 HL109086

U10 HL109146

U10 HL109164

U10 HL109168

U10 HL109172

U10 HL109250

U10 HL109257

In addition, this program is supported through the following National Institutes of Health National Center for Advancing Translational Sciences awards:

UL1 TR001420 (Wake Forest University)

UL1 TR000427 (University of Wisconsin)

UL1 TR001102 (Harvard University)

UL1 TR002378 (Emory University)

Disclosures:

Anne M. Fitzpatrick:

Nothing to disclose.

Scott E. Gillespie:

Nothing to disclose.

David T. Mauger:

Dr. Mauger reports non-financial support from Merck, non-financial support from Boerhinger-Ingleim, non-financial support from GSK, non-financial support from TEVA, non-financial support from Vifor, outside the submitted work.

Brenda R. Phillips:

Nothing to disclose.

Eugene R. Bleecker:

Dr. Bleecker reports other from ERB has undertaken clinical trials through his employer, Wake Forest School of Medicine and University of Arizona, for AstraZeneca, MedImmune, Boehringer Ingelheim, Genentech, Johnson and Johnson (Janssen), Novartis, Regeneron, and Sanofi Genzyme, personal fees from ERB has also served as a paid consultant for AztraZeneca, MedImmune, Boehringer Ingelheim, Glaxo Smith Kline, Novartis, Regeneron, and Sanofi Genzyme, outside the submitted work.

Elliot Israel:

Dr. Israel reports personal fees from AstraZeneca, personal fees from Novartis, personal fees from Philips Respironics, personal fees from Regeneron Pharmaceuticals, personal fees and other from TEVA Specialty Pharmaceuticals, grants from Genentech, non-financial support from Boehringer Ingelheim, non-financial support from GlaxoSmithKline, non-financial support from Merck, non-financial support from Sunovion, non-financial support from TEVA, grants from Sanofi, personal fees from Bird Rock Bio, personal fees from Nuvelution Pharmaceuticals, personal fees from Vitaeris, Inc, grants from Boehringer Ingelheim, non-financial support from TEVA Specialty Pharmaceuticals, personal fees from Sanofi Genzyme, personal fees from Merck, personal fees from Entrinsic Health Solutions, personal fees from GlaxoSmithKline, other from Vorso Corp., personal fees from Pneuma Respiratory , personal fees from 4D Pharma, outside the submitted work.

Deborah A. Meyers:

Nothing to dislose.

Wendy C. Moore:

Dr. Moore reports consultancy fees from AstraZeneca, Sanofi, and GlaxoSmithKline; and is the principal investigator in multicenter clinical trials with sponsors Astrazeneca, GSK, Pearl Therapeutics, and Sanofi.

Ronald L. Sorkness:

Nothing to disclose.

Sally E. Wenzel:

Dr. Wenzel reports grants and personal fees from AstraZeneca , grants from Beohringer-Ingelheim, grants from GSK, grants from Novartis, grants and personal fees from Sanofi, personal fees from Pieris, personal fees from Up to Date, outside the submitted work; In addition, Dr. Wenzel has a patent null pending.

Leonard B. Bacharier:

Dr. Bacharier reports personal fees from GlaxoSmithKline, personal fees from Genentech/Novartis, personal fees from Merck, personal fees from DBV Technologies, personal fees from Teva, personal fees from Boehringer Ingelheim, personal fees from Sanofi/Regeneron, personal fees from Vectura, personal fees from Circassia, personal fees from AstraZeneca, outside the submitted work.

Mario Castro:

Dr. Castro reports personal fees from Astra-Zeneca, Aviragen, Boehringer-Ingelheim, Boston Scientific, Elsevier, Genentech, 4D Pharma, Mallinckrodt, Neutronic, Nuvaira, Teva, Theravance and VIDA; grants from Boehringer-Ingelheim, Chiesi, Genentech, Novartis, Sanofi-Aventis, Vectura; all outside the submitted work.

Loren C. Denlinger:

Dr. Denlinger reports personal fees from AstraZeneca, personal fees from Sanofi, personal fees from GSK, outside the submitted work.

Serpil C. Erzurum:

Dr. Erzurum reports serving as the Chair of the American Board of Internal Medicine Pulmonary Disease Board, outside the submitted work.

John V. Fahy:

Dr. Fahy reports consultancy fees from Boehringer Ingelheim, Pieris, Entrinsic Health Solutions, Sanofi Genzyme; and is a named inventor on three patents, outside the submitted work.

Benjamin M. Gaston:

Nothing to disclose.

Nizar N. Jarjour:

Nothing to disclose.

Allyson Larkin:

Nothing to disclose.

Bruce D. Levy:

Nothing to disclose.

Ngoc P. Ly:

Dr. Ly reports grants from Vertex 2017, personal fees from Gilead 2017, outside the submitted work.

Victor E. Ortega:

Nothing to disclose.

Stephen P. Peters:

Nothing to disclose.

Wanda Phipatanakul:

Nothing to disclose.

Sima Ramratnam:

Nothing to disclose.

W. Gerald Teague:

Dr. Teague reports salary support from the University of Virginia Ivy Foundation (Endowed Chair); Grant support from Panera Bread, TEVA Respiratory, Astra Zeneca and Sanofi/Regeneron; Advisory Boards for Sanofi/Regeneron, TEVA Respiratory, GSK, Genentech, Aviragen; Speaker Bureaus with personal fees from Genentech/Novartis, TEVA Respiratory (QVAR); and Writing committees for the American College of Allergy and Immunology, outside the submitted work.

ClinicalTrials.Gov registration number: NCT01606836

## Abbreviations

| | |
|---|---|
| **ACQ** | Asthma Control Questionnaire |
| **ACT** | Asthma Control Test |
| **AQLQ** | Asthma Quality of Life Questionnaire |
| **CACT** | Childhood Asthma Control Test |
| **DAG** | Directed Acyclic Graph |
| **ED** | Emergency department |
| **$FEV_1$** | Forced expiratory volume in one second |
| **ICS** | Inhaled corticosteroid |
| **IgE** | Immunoglobulin E |
| **IPTW** | Inverse probability of treatment weighting |
| **PAQLQ** | Pediatric Asthma Quality of Life Questionnaire |
| **SARP** | Severe Asthma Research Program |
| **SMD** | Standardized mean difference |

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### Clinical implications

Racial disparities in asthma-related Emergency Department utilization are evident between Black and White patients with asthma, but can be eliminated when socioeconomic and environmental variables are equally balanced between groups.

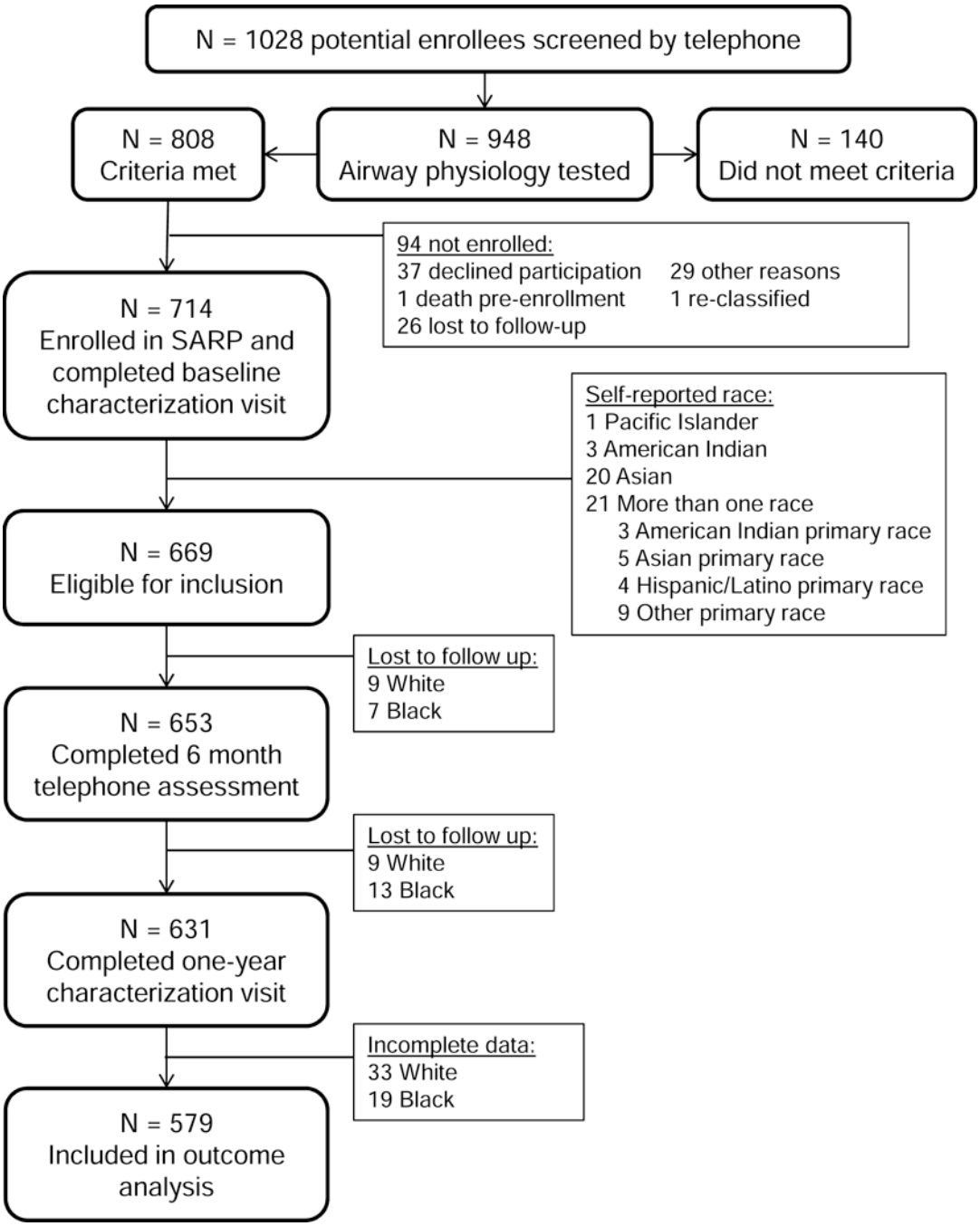


**Figure 1.**
Flowchart depicting participant inclusion in the study.

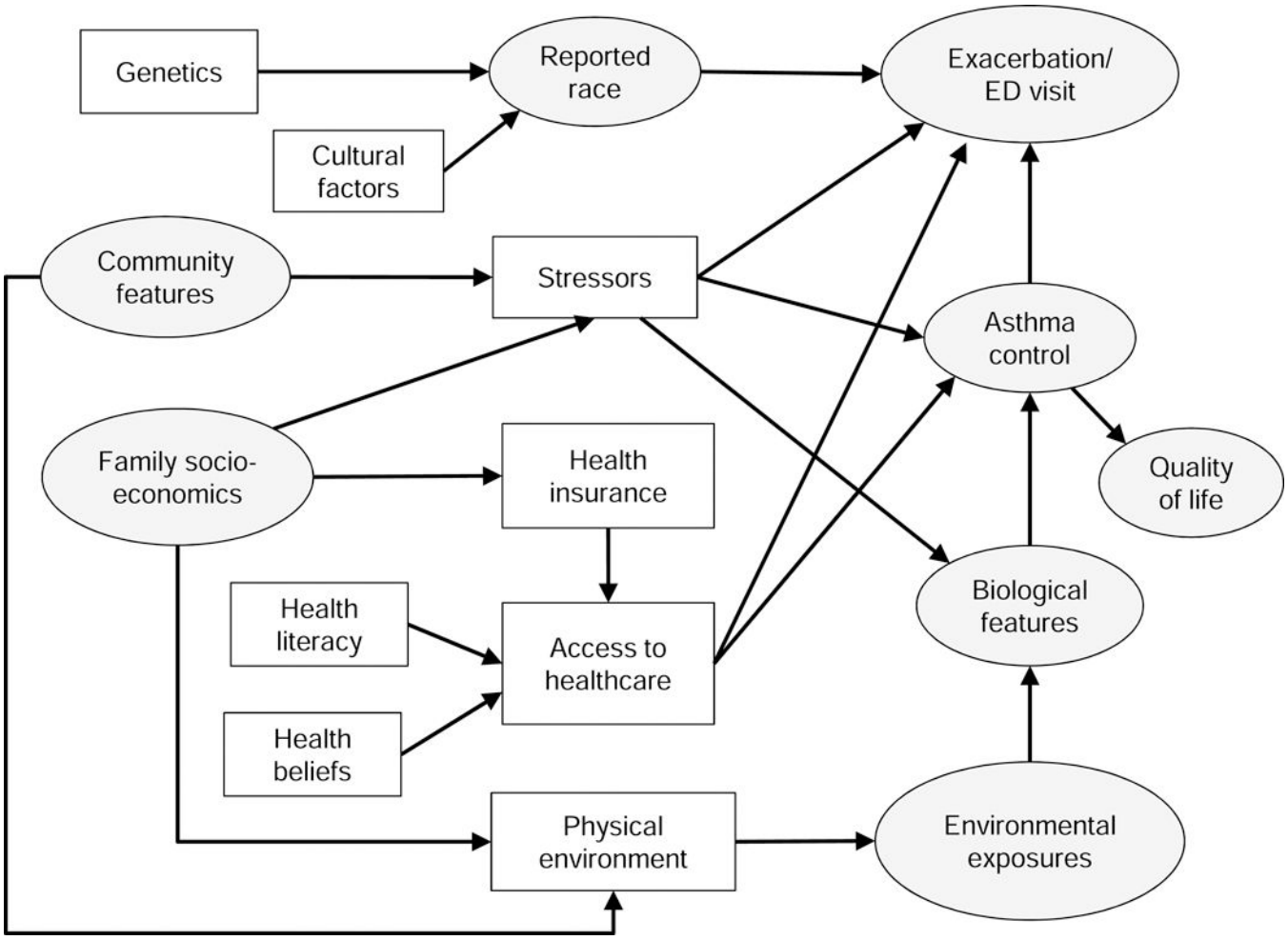


**Figure 2.**

Hypothesized variable relationships and potential confounding of the association between race and asthma-related Emergency Department (ED) visits. Variables in white boxes were unmeasured. Variables hypothesized to fall along the causal pathway were not included in the models in attempts to avoid underestimation of the effects of community/family socioeconomic variables and environmental exposures on racial disparities.

**Table 1.**

Features of included participants at the baseline visit. Data represent the mean ± SD, median (IQR), or the number of participants (%).

| Feature | Characteristic | Overall N = 631 | White N = 408 | Black N = 223 | p-value |
|---|---|---|---|---|---|
| Demographics | Age (years) | 38.15 ± 19.93 | 42.21 ± 19.19 | 30.72 ± 19.14 | < 0.001 |
| | Age of symptom onset (years) | 13.26 ± 14.67 | 15.36 ± 15.54 | 9.42 ± 12.06 | < 0.001 |
| | Male | 257 (40.7%) | 165 (40.4%) | 92 (41.3%) | 0.842 |
| | Hispanic ethnicity | 36 (5.7%) | 27 (6.6%) | 9 (4%) | 0.181 |
| | Immediate family history of asthma | 368 (58.3%) | 225 (55.1%) | 143 (64.1%) | 0.029 |
| | BMI Category<br>Underweight/Normal<br>Overweight<br>Obese | 157 (24.9%)<br>165 (26.1%)<br>309 (49%) | 104 (25.5%)<br>125 (30.6%)<br>179 (43.9%) | 53 (23.8%)<br>40 (17.9%)<br>130 (58.3%) | < 0.001 |
| Community socioeconomic features | Total population (in thousands) (N=620) | 27.36 ± 15.34 | 25.66 ± 15.69 | 30.49 ± 14.19 | < 0.001 |
| | Percentage of unemployment (N=620) | 9.53 ± 5.48 | 7.63 ± 3.32 | 13.04 ± 6.8 | < 0.001 |
| | Median household income (thousand $) (N=620) | 57.18 ± 24.46 | 63.01 ± 24.07 | 46.44 ± 21.38 | < 0.001 |
| | Families in poverty (%) (N=619) | 12.21 ± 9.46 | 9.01 ± 6.81 | 18.11 ± 10.74 | < 0.001 |
| | Private insurance (%) (N=620) | 69.74 ± 15.38 | 74.61 ± 12.56 | 60.75 ± 16.05 | < 0.001 |
| | Bachelor's degree (%) (N=620) | 35.12 ± 19.01 | 38.22 ± 19.43 | 29.40 ± 16.81 | < 0.001 |
| | Rental homes (%) (N=620) | 39.59 ± 18.85 | 35.47 ± 18.76 | 47.19 ± 16.54 | < 0.001 |
| | Homes with no vehicle access (%) (N=620) | 13.37 ± 12.33 | 10.75 ± 11.43 | 18.21 ± 12.51 | < 0.001 |
| Family socioeconomic features | Highest household education<br>High school or Less<br>Some college or technical training<br>Associate degree<br>Bachelor's degree<br>Graduate or professional degree<br>Decline to answer/Don't know | 82 (13%)<br>143 (22.7%)<br>100 (15.8%)<br>155 (24.6%)<br>143 (22.7%)<br>8 (1.3%) | 29 (7.1%)<br>78 (19.1%)<br>60 (14.7%)<br>121 (29.7%)<br>115 (28.2%)<br>5 (1.2%) | 53 (23.8%)<br>65 (29.1%)<br>40 (17.9%)<br>34 (15.3%)<br>28 (12.6%)<br>3 (1.4%) | < 0.001 |
| | Yearly household income<br>Less than $25,000<br>$25,000 to <$50,000<br>$50,000 to <$100,000<br>$100,000 or more<br>Decline to answer<br>Don't know | 137 (21.7%)<br>129 (20.4%)<br>172 (27.3%)<br>109 (17.3%)<br>52 (8.2%)<br>32 (5.1%) | 54 (13.2%)<br>78 (19.1%)<br>135 (33.1%)<br>100 (24.5%)<br>27 (6.6%)<br>14 (3.4%) | 83 (37.2%)<br>51 (22.9%)<br>37 (16.6%)<br>9 (4%)<br>25 (11.2%)<br>18 (8.1%) | < 0.001 |
| | Individuals in household<br>≤ 3<br>> 3 | 411 (66.3%)<br>209 (33.7%) | 274 (68.2%)<br>128 (31.8%) | 137 (62.8%)<br>81 (37.2%) | 0.181 |
| Environmental exposures | Years in current home (N=628) | 9.52 ± 10.46 | 11.27 ± 10.96 | 6.33 ± 8.64 | < 0.001 |

| Feature | Characteristic | Overall N = 631 | White N = 408 | Black N = 223 | p-value |
|---|---|---|---|---|---|
| | Tobacco smoke exposure | 78 (12.4%) | 36 (8.8%) | 42 (18.8%) | < 0.001 |
| | Cats or dogs in the home (N=630) | 353 (56%) | 274 (67.3%) | 79 (35.4%) | < 0.001 |
| | Visible cockroaches in the home (N=630) | 36 (5.7%) | 14 (3.4%) | 22 (9.9%) | < 0.001 |
| | Visible rodents in the home (N=630) | 99 (15.7%) | 77 (18.9%) | 22 (9.9%) | 0.003 |
| | Water damage in past 12 months (N=630) | 88 (14%) | 59 (14.5%) | 29 (13%) | 0.550 |
| | Bedding encased (N=630) | 241 (38.3%) | 159 (39.1%) | 82 (36.8%) | 0.778 |
| | Carpet or rug in bedroom (N=630) | 257 (40.8%) | 169 (41.5%) | 88 (39.5%) | 0.615 |
| Biological features | Serum IgE (log-transformed kU/L) (N=619) | 181.5 (53.2, 509.8) | 135 (34.1, 373.9) | 315.4 (121.5, 853.8) | < 0.001 |
| | Blood eosinophil count (per microliter) (N=630) | 321.65 ± 296.72 | 308.43 ± 277.19 | 345.77 ± 328.68 | 0.151 |
| | Blood eosinophil percentage (N=630) | 4.54 ± 3.78 | 4.16 ± 3.49 | 5.23 ± 4.17 | 0.001 |
| | Percentage of positive aeroallergens | 33.66 ± 29.42 | 27.04 ± 26.17 | 45.97 ± 31.17 | < 0.001 |
| | (N=626) | | | | |
| | Exhaled nitric oxide (ppb) (N=624) | 32.32 ± 31.17 | 30.66 ± 28.21 | 35.34 ± 35.83 | 0.094 |
| Asthma control | ACT or CACT score[2] | 17.32 ± 4.68 | 17.46 ± 4.85 | 17.07 ± 4.34 | 0.319 |
| | ACQ score[1]<br>6-item questionnaire (N=626)<br>7-item questionnaire (N=626) | <br>1.44 ± 1.07<br>1.62 ± 1.04 | <br>1.44 ± 1.08<br>1.63 ± 1.04 | <br>1.44 ± 1.06<br>1.59 ± 1.03 | <br>0.975<br>0.660 |
| | Asthma prevents work or school | 274 (43.4%) | 158 (38.7%) | 116 (52%) | 0.002 |
| | FVC (% of predicted value) | 89.28 ± 18.67 | 87.82 ± 18.64 | 91.94 ± 18.47 | 0.008 |
| | $FEV_1$ (% of predicted value) | 76.99 ± 20.88 | 75.98 ± 21.09 | 78.85 ± 20.4 | 0.098 |
| | Outpatient physician visit for asthma in past 12 months | 475 (75.3%) | 303 (74.3%) | 172 (77.1%) | 0.425 |
| | Asthma specialist visit in past 12 months | 366 (58%) | 246 (60.3%) | 120 (53.8%) | 0.115 |
| | ED visit in past 12 months | 196 (31.1%) | 98 (24%) | 98 (43.9%) | < 0.001 |
| | Hospitalization in past 12 months | 94 (14.9%) | 52 (12.7%) | 42 (18.8%) | 0.040 |
| | Current ICS use | 572 (90.7%) | 368 (90.2%) | 204 (91.5%) | 0.597 |
| | Number of controller medications<br>≤ 2<br>> 2 | 350 (55.5%)<br>281 (44.5%) | 219 (53.7%)<br>189 (46.3%) | 131 (58.7%)<br>92 (41.3%) | 0.221 |

| Feature | Characteristic | Overall N = 631 | White N = 408 | Black N = 223 | p-value |
|---|---|---|---|---|---|
| Asthma quality of life | AQLQ or PAQLQ total score[3] (N=630) | 5.09 ± 1.31 | 5.15 ± 1.31 | 4.98 ± 1.3 | 0.124 |

ACT = Asthma Control Test

ACQ = Asthma Control Questionnaire

AQLQ = Asthma Quality of Life Questionnaire

BMI = Body mass index

CACT = Childhood Asthma Control Test

ED = Emergency department

$FEV_1$ = Forced expiratory volume in one second FVC = Forced vital capacity

ICS = Inhaled corticosteroid

IgE = Immunoglobulin E

LABA = long-acting beta-agonist

PAQLQ = Pediatric Asthma Quality of Life Questionnaire

[1]Scores on the Asthma Control Questionnaire (ACQ) are summed and averaged by the number of items on the questionnaire. Higher scores reflect poorer asthma control, with scores of 1.5 or higher reflective of asthma that is not well controlled.

[2]Scores on the Asthma Control Test (ACT) range from 5 to 25 and scores on the Childhood Asthma Control Test (CACT) range from 0 to 27. For both tools, scores of 19 or less indicate that asthma is not controlled.

[3]Total scores on the Asthma Quality of Life Questionnaire (AQLQ) and Pediatric Asthma Quality of Life Questionnaire (PAQLQ) are averaged from a series of items and range from 1 to 7, with higher scores indicating improved asthma-related quality of life.

**Table 2.**

Unweighted features of the included participants with complete data (N = 579) at baseline and at the one-year follow-up visit. Data represent the mean ± SD.

| Characteristic | White, N=375 | | | Black, N=204 | | |
|---|---|---|---|---|---|---|
| | Baseline Visit | One-Year Visit | P-Value | Baseline Visit | One-Year Visit | P-Value |
| ACT or CACT score[1] | 17.51 ± 4.82 | 18.25 ± 4.77 | <0.001 | 17.05 ± 4.34 | 18.46 ± 4.44 | <0.001 |
| AQLQ or PAQLQ total score[2] | 5.14 ± 1.32 | 5.33 ± 1.32 | <0.001 | 4.98 ± 1.29 | 5.3 ± 1.34 | <0.001 |
| Exhaled nitric oxide | 30.01 ± 27.1 | 32.87 ± 31.32 | 0.043 | 34.76 ± 33.16 | 36.23 ± 28.61 | 0.390 |
| FVC (% predicted) | 87.7 ± 18.36 | 87.77 ± 18.77 | 0.876 | 92.22 ± 18.49 | 92.36 ± 17.9 | 0.833 |
| $FEV_1$ (% predicted) | 75.77 ± 21.02 | 75.82 ± 21.8 | 0.928 | 79.28 ± 20.73 | 79.74 ± 19.51 | 0.570 |

[1]Scores on the Asthma Control Test (ACT) range from 5 to 25 and scores on the Childhood Asthma Control Test (CACT) range from 0 to 27. For both tools, scores of 19 or less indicate that asthma is not controlled.

[2]Total scores on the Asthma Quality of Life Questionnaire (AQLQ) and Pediatric Asthma Quality of Life Questionnaire (PAQLQ) are averaged from a series of items and range from 1 to 7, with higher scores indicating improved asthma-related quality of life.

**Table 3.**

Univariate (unweighted) outcome analysis at one year and weighed outcomes analysis using simple model stabilized inverse probability of treatment weighting (IPTW).

| Model | Estimate (SD) | OR (95% CI) for Black vs. White | p-value | Change in OR relative to Model 1 |
|---|---|---|---|---|
| ***Primary outcomes*** | | | | |
| **ED visit for asthma** | | | | |
| Model 1 (unweighted)[1] | 0.78 (0.22) | 2.19 (1.43 – 3.35) | **<0.001** | -- |
| Simple Model 2[2] | −0.10 (0.23) | 0.91 (0.58 – 1.42) | 0.663 | −58.4% |
| Simple Model 3[3] | −0.20 (0.23) | 0.82 (0.52 – 1.29) | 0.387 | −62.6% |
| **ED visit for asthma and received systemic corticosteroids** | | | | |
| Model 1 (unweighted) | 0.55 (0.24) | 1.73 (1.09 – 2.77) | **0.021** | -- |
| Simple Model 2 | −0.30 (0.25) | 0.74 (0.45 – 1.21) | 0.233 | −57.2% |
| Simple Model 3 | −0.34 (0.26) | 0.71 (0.43 – 1.18) | 0.187 | −59% |
| ***Secondary outcomes*** | | | | |
| **Currently taking ICS** | | | | |
| Model 1 (unweighted) | 0.25 (0.28) | 1.28 (0.74 – 2.20) | 0.375 | -- |
| Simple Model 2 | 0.39 (0.29) | 1.48 (0.83 – 2.63) | 0.182 | 15.6% |
| Simple Model 3 | 0.43 (0.30) | 1.54 (0.86 – 2.75) | 0.143 | 20.3% |
| **Outpatient physician visit for asthma** | | | | |
| Model 1 (unweighted) | −0.14 (0.19) | 0.87 (0.59 – 1.26) | 0.457 | -- |
| Simple Model 2 | −0.45 (0.20) | 0.64 (0.44 – 0.94) | **0.022** | −26.4% |
| Simple Model 3 | −0.57 (0.21) | 0.57 (0.38 – 0.85) | **0.006** | −34.5% |
| **Outpatient physician visit for asthma and received systemic corticosteroids** | | | | |
| Model 1 (unweighted) | −0.10 (0.21) | 0.91 (0.61 – 1.37) | 0.648 | -- |
| Simple Model 2 | −0.12 (0.21) | 0.89 (0.59 – 1.34) | 0.580 | −2.2% |
| Simple Model 3 | −0.24 (0.22) | 0.79 (0.51 – 1.21) | 0.271 | −13.2% |
| **Hospitalization for asthma** | | | | |
| Model 1 (unweighted) | 0.11 (0.34) | 1.11 (0.57 – 2.16) | 0.756 | -- |
| Simple Model 2 | −0.38 (0.38) | 0.69 (0.33 – 1.44) | 0.317 | −37.8% |
| Simple Model 3 | −0.31 (0.39) | 0.74 (0.35 – 1.57) | 0.426 | −33.3% |

ED = Emergency department

[1] Model 1 contains no covariates (unweighted)

[2] Model 2 contains community and family socioeconomic covariates (community percentage of unemployment, highest household education, household income, and individuals in household).

[3] Model 3 community and family socioeconomic covariates plus environmental exposure variables (above variables plus years in current home, tobacco smoke exposure, cats or dogs in the home, visible cockroaches in the home, visible rodents in the home, water damage to the home in the past 12 months, bedding encased, and carpet or rug in the bedroom).