PREVENTING CHRONIC DISEASE
PUBLIC HEALTH RESEARCH, PRACTICE, AND POLICY



Public Health Actions to Reduce the Burden of Asthma: **25 years of CDC's National Asthma Control Program.**



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GUEST EDITORIAL

CDC's National Asthma Control Program: Public Health Actions to Reduce the Burden of Asthma

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Across the US, public health and clinical institutions work to meet the health care needs of children and adults with asthma (1–3). This work ranges from basic research aimed at discovering the causes, predictors, and environmental triggers of asthma (2,3) to translational activities focused on improving access to effective medications to improve asthma control and implementation of evidence-based interventions in diverse settings to improve asthma outcomes among children and adults with asthma (4–9). Despite these efforts, asthma continues to be a common chronic health condition in the US, especially among school-aged children (10). Although there is no cure for asthma, remarkably effective treatments exist that can decrease asthma exacerbations and improve quality of life among those living with asthma (11).

CDC's National Asthma Control Program

The Centers for Disease Control and Prevention's (CDC's) National Asthma Control Program (NACP) is the primary source of funding for state, tribal, local, and territorial agencies to establish and maintain asthma public health programs. The NACP supports these agencies to reduce the numbers of deaths, hospitalizations, emergency department visits, missed school days, missed workdays, and activity limitations due to asthma (1). CDC initiated the NACP in 1999 and since then has supported the planning and development of state, tribal, local, and territorial asthma control programs to conduct asthma surveillance, develop asthma interventions, evaluate the effectiveness of those interventions, and form partnerships to implement them in the communities that need them most (1,12).

This collection, *Public Health Actions to Reduce the Burden of Asthma*, consists of 9 peer-reviewed articles that highlight the history of CDC-funded asthma control programs in the US, the burden of asthma among those most affected, and examples of the development, implementation, and evaluation of asthma-related interventions to improve asthma control. These articles provide readers with examples of the activities asthma control programs conduct to describe and reduce the negative impact of asthma on the lives of people with asthma and their families.

To introduce readers to CDC's approach to improving asthma control, Etheredge et al describe the history of the NACP and the initial use of asthma surveillance to understand and raise awareness about the burden of asthma in the US (12). At the onset of the NACP, funded asthma control programs established surveillance of asthma-related emergency department visits and used the surveillance data to better understand the burden of asthma in the communities they served (12). Over time, the programs expanded to include the use of evidence-based interventions to improve asthma control, the development of partnerships with professional and community organizations, and the evaluation of the program-led surveillance, partnerships, and interventions (12). Most recently, the NACP has focused on building sustainable partnerships to expand the implementation of evidence-based strategies to address the persistent disparities in the prevalence and severity of asthma and its related outcomes (12).

Prevalence and Burden of Asthma

Several articles in this collection combine traditional and novel analytic methods to describe the US prevalence of asthma, asthma attacks, asthma-related health care use, and risk factors for asthma exacerbations (13–17). Surveillance data reported by Pate and Zahran provide insight into not only the prevalence of current asthma, asthma-related health care use, and asthma mortality but also trends in these outcomes over the past decade (13). In these data, the observed decrease over time in the prevalence of asthma among children, coupled with a decrease in the occurrence of reported asthma attacks, asthma emergency department visits, asthma hospitalizations, and asthma mortality among children suggests that US children might be experiencing improved asthma control; however, the differences reported across race and ethnicity and other characteristics indicate that asthma health disparities persist (13). A decline over time in US pediatric asthma hospitalizations is also highlighted by Binney et al, who show that while the similarity of the rates of decline across all racial and ethnic groups indicates progress in reducing the burden of asthma overall, disparities by race and ethnicity continue (14). Wang and Nurmagambetov extend our understanding of the burden of asthma among US children by reporting on the additional annual medical expenditures for children with treated asthma compared with children without treated asthma (15). Again, differences by race and ethnicity show the complexities affecting disparities in asthma control; although medical expenditures were lower for non-Hispanic Black children than for non-Hispanic White children with treated asthma, the findings raise important questions about the differences in asthma-related health care use and the financial burden experienced across racial and ethnic groups. Together, these 3 articles can guide public health and health care professionals in identifying patient groups most in need of effective and low-cost approaches to reduce the burden of asthma.

Asthma disparities also occur across geographic areas. Skochko et al applied an emerging hot spot analysis approach to identify high-burden areas in New York before and during the COVID-19 pandemic (16). This approach identified local variations in asthma emergency department visits that indicate geographic areas in which local, evidence-based asthma interventions might be especially effective.

Authors of these 4 articles each point out that some people or populations continue to experience a disproportionately greater burden of asthma. Conversely, Jaffee et al describe differences in influenza and COVID-19 vaccination rates among US adults with asthma across demographic, geographic, and demographic characteristics (17). Despite high levels of vaccination overall, variations in vaccination rates among adults with asthma indicate opportunities for education-based interventions about the benefits of vaccinations for adults with asthma, especially younger adults and adults in rural areas. Jaffee et al provide us with important information about differences in health behaviors that can affect the risk of exacerbations among people with asthma (17).

Asthma Control Activities and Evaluation

The NACP supports the development and implementation of evidence-based interventions to address the burden of asthma in the US, including the asthma disparities identified through surveillance and other assessments. Articles in this collection provide examples of how state asthma control programs and partners implement and evaluate the interventions designed to improve asthma control (18,19). One such evaluation is described by Wing et al, who report on the use of a toolkit, *Supporting Students with Asthma at School: Standards of Care,* to prepare school nurses with information about asthma, asthma management, applicable laws, and other aspects of supporting students with asthma (18). Their evaluation of the effectiveness of the toolkit identified important barriers to its use, such as time and parent engagement, as well as notable successes in training and education, the use of asthma action plans, and advocacy for medication self-carry policies. Mahin et al report on the use of a community health worker–led asthma home visiting program and the projected cost savings of its expansion to improve asthma outcomes among pediatric Medicaid patients with uncontrolled asthma (19). Their findings projected that expansion of the community health worker–led home visiting program would result in a $566.58 per-patient reduction in the 2019 costs associated with asthma emergency department visits and hospitalizations. These 2 articles provide compelling examples of how programs that support school nursing staff and community health worker home visits for asthma can improve support and lower costs, respectively, for children with asthma.

Evidence of the impact of interventions such as those described by Wing et al (18) and Mahin et al (19) often comes from evaluation of the interventions, as well as from evaluation of the surveillance systems and partnerships that support the development and implementation of such interventions. Indeed, the NACP recognizes that evaluation is an important tool for learning how to improve programs (20). In this collection, Dunklin et al (20) describe the history of the development of evaluation methods that have led the NACP and its funding recipients and partners to identify some of their most effective interventions and partnerships. The authors describe the development and use of evaluation tools and provide an inventory of tools developed by the NACP (20). The evaluation tools described are still the primary resources used today to assess and improve specific components of asthma control programs, leading to more cost-effective and engaging programs (20).

Future Direction

CDC’s NACP will continue to focus on improving the lives of people and communities most affected by asthma. To increase the number of people with asthma whose health is improved because of the asthma control programs where they live and to maximize the impact of these programs, the NACP is prepared to pursue 3 approaches in the coming years:

1. **Strategic investment of resources** on cost-efficient, scalable, and sustainable public health interventions, with a focus on implementing interventions in communities most affected by asthma
2. **Strong partnerships** across multiple sectors to more effectively develop and implement evidence-based asthma interventions
3. **Environmental health guidance** that can be used across the US to reduce indoor, outdoor, and occupational asthma triggers

To support these approaches, the next iteration of CDC's NACP, Advancing Health Equity in Asthma Control Through EXHALE Strategies, will focus on funding programs to address the environmental, social, and systematic drivers of existing disparities in asthma (21). The intention is that asthma control programs will accomplish this by strengthening the relationships with their partners to implement EXHALE strategies (22). EXHALE strategies are described in CDC's EXHALE Technical Package (22) and include 6 approaches proven to reduce asthma-related emergency department visits, hospitalizations, and health care costs. The strategies are: E = Education on asthma self-management; X = X-tinguish smoking and exposure to secondhand smoke among people with asthma; H = Home visits for trigger reduction and asthma self-management education; A = Achievement of guidelines-based medical management; L = Linkages and coordination of care across settings; E = Environmental policies or best practices to reduce asthma triggers from indoor, outdoor, and occupational sources (22). By supporting programs to implement these strategies during its next funding cycle, the NACP will strengthen sustainable and effective leadership, program management, partnerships, surveillance, health communication, and program evaluation. Successful implementation of these strategies will contribute to the reduction in asthma-related emergency department visits, hospitalizations, and health care costs in the populations that need them most.

Conclusions

This collection shares articles highlighting successes of CDC's NACP over the past 25 years. The insights and findings identified by CDC, funded asthma control programs, and other partners offer examples of evidence-based asthma interventions that can be built on moving forward. Reducing asthma health disparities by improving asthma control among people most affected by asthma should improve the lives and health of everyone affected by asthma. Fewer emergency department visits, hospital stays, school and workdays missed, medical expenses, and deaths due to asthma improve the lives of people with asthma and those who care for them.

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ESSAY

CDC's National Asthma Control Program: Looking Back with an Eye Toward the Future

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Introduction

Asthma is one of the most prevalent chronic respiratory diseases among adults and the most common chronic disease among children in the US, costing the nation more than $80 billion each year (1). More than 25 years ago, the increasing prevalence of asthma prompted the Centers for Disease Control and Prevention (CDC) to establish a nationwide program to address asthma's rising public health burden. When the National Asthma Control Program (NACP) began in 1999, early efforts focused on capacity building of states, territories, and local levels; tracking the burden of asthma by collecting and analyzing surveillance data; identifying and implementing science-based interventions to help individuals manage and control their asthma; and establishing and maintaining national, state, and community partnerships to reduce asthma burden with a focus on states with high burdens. To date, the NACP has played a critical role in efforts to help millions of people in the US with asthma. Data from the past 10 years indicate asthma prevalence has decreased among some populations; however, racial and ethnic disparities persist (2). We provide a brief history of the NACP, from its origins to the rich successes and challenges of building an environmental public health program. This essay is intended to raise awareness and support for state and local public health asthma control efforts, and lessons learned through the NACP's history and current state can assist others in planning environmental public health programs in asthma and other chronic and environmental health topics to achieve population-level impact.

Where We Started

The NACP originated in CDC's then-named Air Pollution and Respiratory Health Branch (APRHB), which was created shortly after the adoption of the Clean Air Act amendments in 1990. The National Institutes of Health's National Heart, Lung, and Blood Institute introduced the first national evidence-based guidelines for diagnosing and managing asthma in 1991 (3). The guidelines aimed to help health care professionals bridge the gap between current knowledge and practice. The President's Task Force on Environmental Health Risks and Safety Risks to Children in the late 1990s prioritized children's environmental health, with specific emphasis on childhood asthma.

In 1997, CDC, the American Association of Health Plans and Prevention, and Emory University collaborated with diverse organizations to form a coalition addressing asthma in 400 children from low-income households in Atlanta's economic empowerment zone. The economic empowerment zone is an area of economically disadvantaged urban communities receiving supports such as financial incentives, tax benefits, grants, technical assistance, and access to resources. The coalition implemented the ZAP Asthma Program (https://stacks.cdc.gov/view/cdc/41511) as a community-based initiative by using trained community health workers (CHWs). CHWs conducted asthma home visits, educated parents and caregivers about environmental triggers, and implemented interventions, including in-home environmental assessments and asthma self-management education. This program demonstrated the value of engaging communities to develop and implement asthma control interventions that fit their local context.

Tracking the Burden of Asthma

In 1998, CDC published the first national review of asthma surveillance data, revealing an increase in asthma prevalence and death rates in the US from 1960 through 1995 (4). However, the available surveillance data were insufficient to assess state and local trends. In 1999, Congress appropriated funding to CDC to conduct local asthma surveillance activities and compile and annually publish data on the prevalence of children having asthma in each state as well as the childhood asthma death rate nationally and in each state. Recognizing the need for a more comprehensive approach, CDC began developing the NACP, initiating a surveillance cooperative agreement program in 1999. The program aimed to establish and evaluate a sentinel surveillance system in hospital emergency departments, focusing on monitoring trends and identifying reasons for receiving asthma care. This proactive step was driven by the understanding that enhanced state and local asthma surveillance could lead to more effective prevention and management strategies. The 1998 national asthma surveillance report significantly raised awareness of asthma's burden in the US and is cited over 945 times in peer-reviewed literature (4).

Over the years, the NACP played a pivotal role in tracking asthma burden through surveillance and epidemiology. Key initiatives include integration of asthma modules within the Behavioral Risk Factor Surveillance System (BRFSS), the first effort to systematically collect state-based asthma prevalence data. In 2003, NACP developed and tested a National Asthma Survey (NAS) through the State and Local Area Integrated Telephone Survey (SLAITS), later renamed the Asthma Call-back Survey (ACBS), which, by 2010, expanded to include 40 states, the District of Columbia, and Puerto Rico. The survey collected household and health data monthly from selected respondents, allowing NACP to investigate the health, socioeconomic, behavioral, and environmental predictors related to better asthma control. ACBS was a cornerstone for understanding asthma prevalence, symptoms, health care use, and environmental risk factors. These comprehensive data collection efforts, due in part to NACP investment in resources and design of survey questions, significantly enhanced public health decision-making, enabling focused interventions and evaluations to reduce the burden of asthma at both the state and local levels.

Program Interventions

NACP has dedicated substantial funding and technical assistance to partners to develop interventions, scientifically evaluate their effectiveness, and translate them for widespread implementation across diverse communities. In 2004, NACP funded 7 cities through the Controlling Asthma in American Cities Project (CAACP), aiming to translate scientific advances in the treatment of asthma into innovative, comprehensive approaches for improving asthma control among children who are up to 18 years old living in economically disadvantaged urban communities with a high asthma burden (5). Some of the interventions tailored to suit the specific circumstances of the local communities included educating day care providers and parents on asthma management for young children, integrating asthma self-management training into faith-based organizations, establishing links between high-risk children and specialty asthma services through schools, training community pharmacists to educate individuals with asthma on proper medication usage, and collaborating with managed care plans to ensure reimbursement for asthma self-management training.

In 2009, leveraging insights from these past projects, CDC allocated funding for health departments to establish asthma programs through the Addressing Asthma from a Public Health Perspective cooperative agreement. This effort supported 34 states, the District of Columbia, and Puerto Rico, fostering collaborative efforts to implement evidence-based interventions, enhance asthma surveillance, and develop and implement state asthma plans with their state and local partners over a 5-year period. Valuable lessons include promoting cross-jurisdictional collaboration among funded health departments to enhance asthma surveillance and program activities, establishing mentoring programs for newly funded health departments to facilitate knowledge exchange and capacity building, and fostering creativity within partnerships to facilitate innovative strategies and sustainability. Subsequent NACP-supported cooperative agreements were launched in 2014, 2016, and 2019, with each iteration leveraging successes and incorporating lessons learned from the previous project periods. As of August 2024, NACP funds 23 state, 1 territorial, and 1 local public health departments.

Evaluation Approach

In the 2009 funding cycle, the program expanded evaluation by mandating that funded state asthma programs allocate a half-time staff person to support evaluation activities. Programs worked with partners in the first 6 months of the cooperative agreement to develop an evaluation agenda, referred to as a strategic evaluation plan. These plans ensured that evaluations were responsive to broad information needs and conducted in a coherent sequence; program planning was strengthened through strategic evaluative thinking. Programs developed individual evaluation plans to guide evaluations of major program components: partnerships, surveillance, and interventions. To support these activities, NACP established a team of evaluation technical advisors and created "Learning and Growing through Evaluation," a series of evaluation guides based on the CDC Framework for Program Evaluation in Public Health (6). These resources and a suite of other evaluation tools facilitated hundreds of evaluations. For example, since 2014, the Utah Asthma Program and the Utah Pediatric Partnership to Improve Healthcare Quality have collaborated with 37 clinics to improve primary care diagnosis and team-based management of asthma patients through a 6-month learning collaborative. A follow-up evaluation conducted in 2022 demonstrated significant improvements in various areas among participating clinics: for example, an increase in the use of a standardized asthma assessment tool from 38% to 90% and an increase in patients with an active asthma action plan or self-management plan on file from 55% to 100%. Although later funding cycles dropped the staffing requirement, evaluation remains integral, with programs using findings to expand partnerships, create new surveillance products, and make programming decisions that increased efficiency and effectiveness. NACP's efforts have been acknowledged in the evaluation field, culminating in the creation of an evaluation textbook, *Planting the Seeds for High-Quality Program Evaluation in Public Health*, in collaboration with partners in 2021 (7).

Developing a Framework for Asthma Programs

In 2007, NACP initiated a comprehensive review of asthma interventions through the Community Preventive Services Task Force (8). Findings from the Task Force solidified NACP's support of community-level implementation of multicomponent interventions to address asthma, including guidelines-based medical management, asthma self-management education (AS-ME), indoor and outdoor trigger reduction interventions, and linkages to services to help reduce exposure to asthma triggers (8). Interventions that use policy, systems, and environmental approaches at the population level can help expand the reach of public health efforts to control and manage asthma. In 2018, NACP formally characterized this multistrategy approach in a technical package known as EXHALE, designed to inform decision-making for communities, organizations, and states as well as facilitate multisector collaborations that would build on asthma-related public health and health care collaboration in CDC's 6|18 initiative (9,10). EXHALE is a set of 6 strategies used to facilitate asthma control in children and adults. Each strategy is designed to reduce emergency department visits and hospitalizations, which are key indicators of poor asthma control for individuals. The strategies also improve health equity by encouraging public health interventions that directly affect health inequities, such as connecting people with asthma to local support services to improve conditions where people live, work, play, and learn. Since the development of the 2019 asthma cooperative agreement, NACP has applied the EXHALE technical package as a framework for public health asthma program development. Given evidence that a multicomponent approach to controlling asthma is more effective than individual strategies applied in isolation (9), multiple federal agencies have used EXHALE in their asthma-related activities, including the Centers for Medicare and Medicaid Services and the Indian Health Service.

Establishing and Maintaining Partnerships

Over the past 22 years, NACP has partnered with nongovernmental organizations to promote intervention programs and expand outreach across groups from diverse racial, ethnic, and socioeconomic backgrounds to implement activities such as asthma health education enhancement programs. These organizations — American Lung Association, Allergy & Asthma Network, and Asthma and Allergy Foundation of America (the National Environmental Education Foundation was added in 2010) — have worked to promote evidence-based asthma strategies through patient-oriented and clinician-oriented education and multisector partnerships.

The Future Direction of NACP

The NACP has made advancements over the past 25 years in developing and implementing a public health approach to address asthma. Substandard housing, particularly in urban and rural neighborhoods, and racial and ethnic disparities are associated with poor asthma outcomes (11–13). These factors contribute to increased exposure to environmental triggers, such as pollutants and allergens, and inadequate access to health care services (11,12,14). Addressing social determinants of health (SDOH) is key to reducing asthma disparities and requires a multifaceted approach (9,14). Two strategies highlighted within NACP's EXHALE technical package can address SDOH: 1) linkages and coordination of care across settings, which can be advanced by implementing Medicaid health homes and patient-centered medical homes, integrating community health workers and case managers to facilitate resource linkage and community referrals and provide asthma self-management and education training, and creating school-based programs that provide coordinated care through school nurses or other staff; and 2) environmental policies or best practices to reduce asthma triggers from indoor, outdoor, and occupational sources, which can be advanced by facilitating smoke-free policies and clean diesel school buses, eliminating exposure to asthma triggers in schools, and facilitating home energy efficiency (including home weatherization assistance programs).

Expanding implementation of the evidence-based strategies presented in the EXHALE technical package provides potential to address SDOH, but these strategies cannot be carried out by public health alone. Partnerships are integral vehicles for driving EXHALE implementation, and collaborating across multiple sectors such as schools, health care systems, housing organizations, transportation organizations, community and faith-based organizations, and tribal communities can lead to comprehensive solutions that address the multifaceted causes of asthma disparities. Strategies to build and sustain these partnerships include identifying common goals and vision, leveraging existing networks such as coalitions, identifying partnership champions, having strong leadership, and having clear structures and processes. By working together across sectors, resources can be pooled effectively to achieve better outcomes.

NACP aims to expand its reach to more states with incremental approaches to strengthen their asthma programs. This could be a challenge given the current level of funding for NACP; however, all states would benefit from receiving the support and resources needed to increase implementation of EXHALE strategies for asthma, particularly in communities that have been marginalized. If funding remains the same, NACP will strategically maximize available resources through focused investments on selected cost-efficient, evidence-based, EXHALE-related public health activities, especially in communities at higher risk of asthma-related emergencies (eg, activities to improve sustainability of results-based health equity partnerships to reduce asthma-related illness, death, and disparities). NACP will also work to further identify, strengthen, and leverage existing asthma surveillance systems to inform public health policy and planning while also exploring use of innovative strategies that address environmental risk factors affecting millions of people in the US with asthma, including poor air quality and wildfires.

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ORIGINAL RESEARCH

The Status of Asthma in the United States

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PEER REVIEWED

Summary

What is already known on this topic?

Asthma is associated with substantial illness and death and disproportionately affects some populations more than others in the US.

What is added by this report?

Our article demonstrates ongoing disparities and trends in the current status of asthma, asthma-related health care use, and deaths.

What are the implications for public health practice?

Our findings provide information that may improve the delivery of care to reduce preventable asthma-related emergency department visits, hospitalizations, and deaths.

Abstract

Introduction

Asthma imposes a substantial health and economic burden on patients and their families and on the health care system. An assessment of the status of asthma in the US may lead to effective strategies to improve health and quality of life among people with asthma. The objective of our study was to assess the historical trends and current state of asthma illness and death among children and adults in the US.

Methods

We assessed asthma-related emergency department visits and hospitalizations among children and adults by using data from the 2010–2021 National Health Interview Survey (NHIS), the 2010–2020 Nationwide Emergency Department Sample (NEDS), the National (Nationwide) Inpatient Sample (NIS), the Healthcare Cost and Utilization Project (HCUP), and the Agency for Healthcare Research and Quality (AHRQ). Asthma death rates were calculated by using 2010–2021 National Vital Statistics System data.

Results

Asthma prevalence increased significantly among adults from 2013 through 2021 (P = .04 for the annual percentage change [APC] slope) and decreased among children from 2010 through 2021 (P values for slopes: 2010–2017, P = .03; 2017–2021, P = .03). Prevalence of current asthma was higher among non-Hispanic Black people (children, 12.5%; adjusted prevalence ratio [APR] = 2.19; 95% CI, 1.68–2.84 and adults, 10.6%; APR = 1.25; 95% CI, 1.09–1.43) compared with non-Hispanic White people (children, 5.7%; adults, 8.2%). Prevalence of asthma attacks and use of asthma-related health care declined among adults and children. Asthma prevalence and asthma-related emergency department visits, hospitalization, and death rates differed by select characteristics.

Conclusions

Although asthma attacks, ED visits, hospitalizations, and deaths have declined since 2010 among all ages, current asthma prevalence declined only among children, and significant disparities in health and health care use still exist.

Introduction

Asthma, a chronic respiratory disease, is associated with substantial illness and death (1–3), requiring ongoing medical management. The disorder is associated with a large economic cost (4) and a substantial number of missed school and workdays (5). The disorder is the focus of the Healthy People 2030 initiative to reduce asthma attacks, emergency department (ED) visits, hospitalizations, and deaths (6). Asthma disproportionately affects people from some racial and ethnic minority groups (3,7), people with low incomes (3,7), and people facing certain environmental factors (7,8).

Asthma is uncontrolled in approximately 50% of children (9) and 62% of adults (10) and results in frequent and intense episodes of symptoms (1), most commonly among children aged 0 to 4 years (59.1%) and Black people (62.9%) (9). Furthermore, ED visits, hospitalizations, and number of missed school days are higher among children with uncontrolled asthma (11). Children's ED visits for asthma declined substantially from 2006 through 2018, but disparities in these children's sociodemographic characteristics persist (3). Although asthma deaths have declined, these, too, are related to socioeconomic and demographic health disparities (3,7,12). Progress in asthma treatment has been slow, and asthma hospital admissions and deaths have declined only slightly in the past decade (13).

The Centers for Disease Control and Prevention's (CDC's) National Asthma Control Program was established in 1999 to fund asthma control in state, territorial, and municipal health departments. The program's goals are to reduce the number of deaths, hospitalizations, ED visits, school days or workdays missed, and limitations on activity due to asthma. This includes monitoring the health of people with asthma and determining health and health care disparities by analyzing data from multiple national and state-based surveys, hospital discharge records, and death vital statistics. Our objective was to describe asthma in the US by assessing prevalence of current asthma (defined as people who have ever been diagnosed with asthma by a health care professional and report still having asthma) and asthma attacks, asthma-related health care use, and asthma deaths among children and adults by sociodemographic characteristics and by trends across time.

Methods

Data sources

We used 3 data sources to calculate prevalence of current asthma and asthma attacks, asthma hospitalization rates, and asthma ED visit rates per 10,000 of the 2020 US census resident population, and to calculate the asthma death rate per million of the 2021 US census resident population: 1) the National Health Interview Survey (NHIS), 2010–2021 (14); 2) the Healthcare Cost and Utilization Project's (HCUP's) National Emergency Department Samples (NEDS) (15) and National Inpatient Sample (NIS), 2010–2020 (16); and 3) CDC Wonder (CDC Wide-Ranging Online Data for Epidemiologic Research), 2010–2021 (17). NHIS is an annual cross-sectional, in-person, household survey of noninstitutionalized US civilians that uses a geographically clustered sampling design (14). NEDS, a stratified probability sample of a set of hospital-owned EDs, is a large US all-payer database that gives national estimates of ED visits. Its data come from US hospital-owned EDs with data in the HCUP State Emergency Department Databases and the State Inpatient Databases (15). NIS data are acquired from 48 partners (47 states and the District of Columbia) and represent more than 97% of the US population. Its data include a sample of all discharges from US community hospitals, excluding rehabilitation and long-term acute care hospitals (16).

Study population

We analyzed NHIS data to calculate prevalence per 10,000 of the US census resident population for current asthma and asthma attacks among people with current asthma. We also analyzed CDC mortality data offered online from the National Vital Statistics System for asthma death rates per million US census population for 2010 through 2021 and trends across all years for 3 groups: all ages, children (aged <18 y) (hereinafter, children), and adults (aged ≥18 y) (hereinafter, adults) (17). We applied the following select characteristics to all calculations: sex (male or female, as shown in the medical record), age (0–4 y, 5–17 y, 18–34 y, 35–64 y, or ≥65 y), race (White, Black, other), ethnicity (Hispanic, non-Hispanic), and US census region (Northeast, Midwest, South, or West). The "other race" group includes Asian or Pacific Islanders, American Indians or Alaska Natives, and people of any other race (17), another single race, or multiple races. Data from the other-race group were combined to obtain sufficient sample size for reliable estimates.

Current asthma and asthma attacks

People were classified as having current asthma if they responded yes to 2 questions: "Has a doctor or other health professional ever told you that you had asthma?" and "Do you still have asthma?" People with asthma were classified as having asthma attacks if they responded yes to 1 question: "During the past 12 months, have you had an episode of asthma or an asthma attack?" (14). Prevalence was calculated by our select characteristics.

Asthma-related emergency department visits, inpatient hospital stays, and deaths

We used NEDS to calculate ED visits per 10,000 and defined a visit as one in a which asthma is the primary diagnosis according to an ICD (International Classification of Diseases)-10-CM diagnosis code of J45 (15,18). We used NIS to calculate asthma hospitalization rates per 10,000, defined as hospital in-patient short stays (<30 days) with asthma as the primary diagnosis according to ICD 10-CM code J45 (16,18). Data from the National Vital Statistics System, accessed through CDC WONDER, were used to generate asthma death rates per million where asthma was the underlying cause of death (ICD-10 codes J45 and J46) (17). Data from 2010 through 2021 were used to calculate trends in asthma mortality rates, and estimates in 2021 were calculated by our select characteristics. Because our study was a secondary analysis of publicly available, de-identified data, it did not require CDC institutional review board approval.

Statistical analysis

We used SAS version 9.4 and SAS-callable SUDAAN 11 (Research Triangle Institute) to account for the complex sampling design of the survey data. Descriptive statistics such as stratification by our select characteristics were used to show asthma-related outcomes as they were observed in the population. We evaluated trends from 2010 to 2021 in prevalence of current asthma and having 1 or more asthma attacks during the past year among all ages, children, and adults with current asthma. In 2019, the NHIS questionnaire was redesigned (https://www.cdc.gov/nchs/nhis/2019_quest_redesign.htm), but changes did not affect our estimates. We also determined asthma indicators by our select characteristics and US census region for 2021. Sample weights were provided in the data sets for each year and were used to adjust for survey nonresponse, poststratification, and probability of selection (14) to get a more accurate representation of the study population. Participant response categories of don't know, refused, not ascertained, and missing values were treated as missing. Wald χ^2 tests were conducted to determine associations among demographic characteristics, US census regions, and study outcomes (ie, prevalence of current asthma and prevalence of asthma attacks among people with current asthma).

We estimated trends for 2010 through 2020 in use factor rates for asthma-related health care, including asthma ED visits and hospitalizations, per 10,000 of the US 2020 census resident population. Rates in 2020 were estimated by our select demographic characteristics. Discharge-level weights were applied from the database to produce unbiased national annual estimates from sample data (19,20). Cell sizes less than or equal to 10 using HCUP data sets were suppressed.

Trends in rates per million of asthma deaths were calculated for 2010 through 2021, and for 2021 alone, among all ages, children, and adults. Prevalence of current asthma and asthma attacks, rates of asthma health care use, and asthma death rates were also calculated. The difference between 2 population groups was assessed by using nondirectional 2-tailed *z* tests (at the $\alpha < 0.05$ level). We used Joinpoint Regression software, version 5.0.2.0 (National Cancer Institute) to analyze trends by using log-linear regression models to determine significance trends. Joinpoint software calculates the fewest number of linear segments necessary to characterize a trend and the year(s) where 2 segments with different slopes meet. Associations between current asthma or asthma and select covariates were examined by using multivariable logistic regression models. The association between each health outcome (eg, current asthma or asthma attack) was assessed in separate models in which health outcome regressed over independent variables along with sex, age, and race and ethnicity. Adjusted prevalence ratios (APRs) were estimated by adjusting for sex, age, and race and ethnicity for all ages, children, and adults. Each of these 3 variables was only adjusted by the 2 other variables in the model (eg, age is adjusted by sex and race and ethnicity). Statistical tests used a significance level of $P < .05$, and 95% CIs were calculated for all estimates.

Results

Current asthma

In 2021, 24.9 million people in the US (4.7 million children and 20.3 million adults, 7.7% of the population) had asthma (Table 1). Asthma prevalence varied over time. Current asthma among all ages and among adults showed a nonsignificant decrease in 2010–2013 (Figure 1), then increased through 2021 significantly for adults ($P = .04$ for the slope). Among children, asthma prevalence significantly decreased from 2010 through 2021 ($P = .03$ for 2010–2017 trend slope, $P = .03$ for 2017–2021 trend slope).

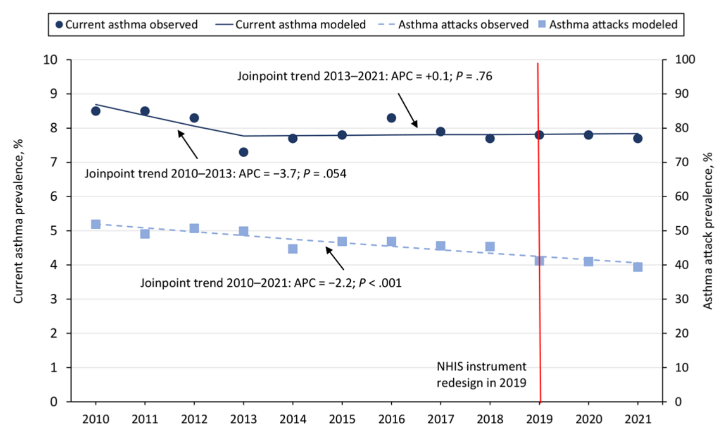

Figure 1. Prevalence of current asthma and asthma attacks among all ages by year. The *P* value of the trend line slope is significant at $P < .05$. The trend line is based on estimates from the statistical model and observed prevalence estimates (estimates as is from the survey data) (dots). The trend slope is numbered (slope 1, slope 2) when there is more than one significant trend line, as in the current asthma trend lines. Data source: National Center for Health Statistics, National Health Interview Survey, 2010–2021 (14).

Current asthma prevalence varied by our selected demographic characteristics. Prevalence was significantly associated with sex (adults, $P < .001$; children, $P = .007$); age ($P < .001$ all ages), and race and ethnicity (adults, $P < .001$; children, $P < .001$). Among adults, current asthma prevalence was higher among females than males (9.8% females vs 6.2% males; APR = 1.57 [95% CI, 1.43–1.73]) and among non-Hispanic Black adults than non-Hispanic White adults (10.6% vs 8.2%; APR = 1.25 [95% CI, 1.09–1.43]) (Table 1). Current asthma prevalence was lower among Hispanic adults compared with non-Hispanic White adults (5.8% vs 8.2%; APR = 0.68 [95% CI, 0.59–0.80]) and adults who lived in the South compared with adults who lived in the West (7.4% vs 8.3%; APR = 0.80 [95% CI, 0.71–0.92]). Prevalence was significantly lower among children aged 0 to 4 years (1.9%) and among adults aged 65 years or older (7.2%) than among adults aged 18 to 34 years (8.4%) (Table 1).

Among children, current asthma prevalence was higher among non-Hispanic Black children (12.5%; APR = 2.19 [95% CI, 1.68–2.84]) compared with non-Hispanic White children (5.7%) (Table 1). Current asthma prevalence was lower among female children (5.6%; APR = 0.77 [95% CI, 0.64–0.93]) compared with male children (7.3%).

Asthma attacks

In 2021, about 39.4% of people with current asthma reported having 1 or more asthma attacks in the past 12 months (39.6% among adults and 38.7% among children) (Table 1). Prevalence of asthma attacks significantly decreased over time. Among people of all ages with asthma, the prevalence of attacks decreased significantly, from 51.9% in 2010 to 39.4% in 2021 (P < .001 for the trend slope) (Figure 1). Among adults with asthma, attack prevalence decreased from 58.3% in 2010 to 38.7% in 2021 (P < .001 for the trend slope); among children, attack prevalence decreased from 49.1% in 2010 to 39.6% in 2021 (P = .003 for the trend slope).

Prevalence of asthma attacks among adults with current asthma was significantly associated with sex (P < .001) and age (P < .001). Asthma attack prevalence was significantly higher among female adults (43.6%; APR = 1.35 [95% CI, 1.18–1.53]) compared with male adults (32.8%) and was significantly lower among non-Hispanic Black adults (33.3%; APR = 0.80 [95% CI, 0.66–0.97]) than non-Hispanic White adults (40.6%). Asthma attack prevalence was significantly higher among children aged 0 to 4 years (63.1%; APR = 1.73 [95% CI, 1.34–2.24]) and among adults aged 35 to 64 years (44.9%; APR = 1.17 [95% CI, 1.01–1.37]), and significantly lower among adults aged 65 years or older (30.3%; APR = 0.77 [95% CI, 0.62–0.94]) compared with adults aged 18 to 34 years (36.9%) (Table 1). We found no significant differences in prevalence of asthma attacks by census region among all ages, children, or adults.

Asthma-related emergency department visits

Approximately 1 million people in the US had an ED visit for asthma in 2020 (29.8 per 10,000 US census 2020 resident population) (Table 2). The asthma ED visit rate per 10,000 for all ages decreased significantly in 2018, from 62.7 in 2010 to 50.2 in 2018 (P = .02 for the slope), but no significant changes occurred between 2018 and 2020 (P = .06 for the slope) (Figure 2). Among adults, the asthma ED visit rate per 10,000 decreased significantly, from 52.3 in 2010 to 27.8 in 2020 (P <.001 for the slope). The asthma ED visit rate per 10,000 among children declined from 2010 through 2020 but was only significant between 2018 and 2020 (P = .03 for the slope).

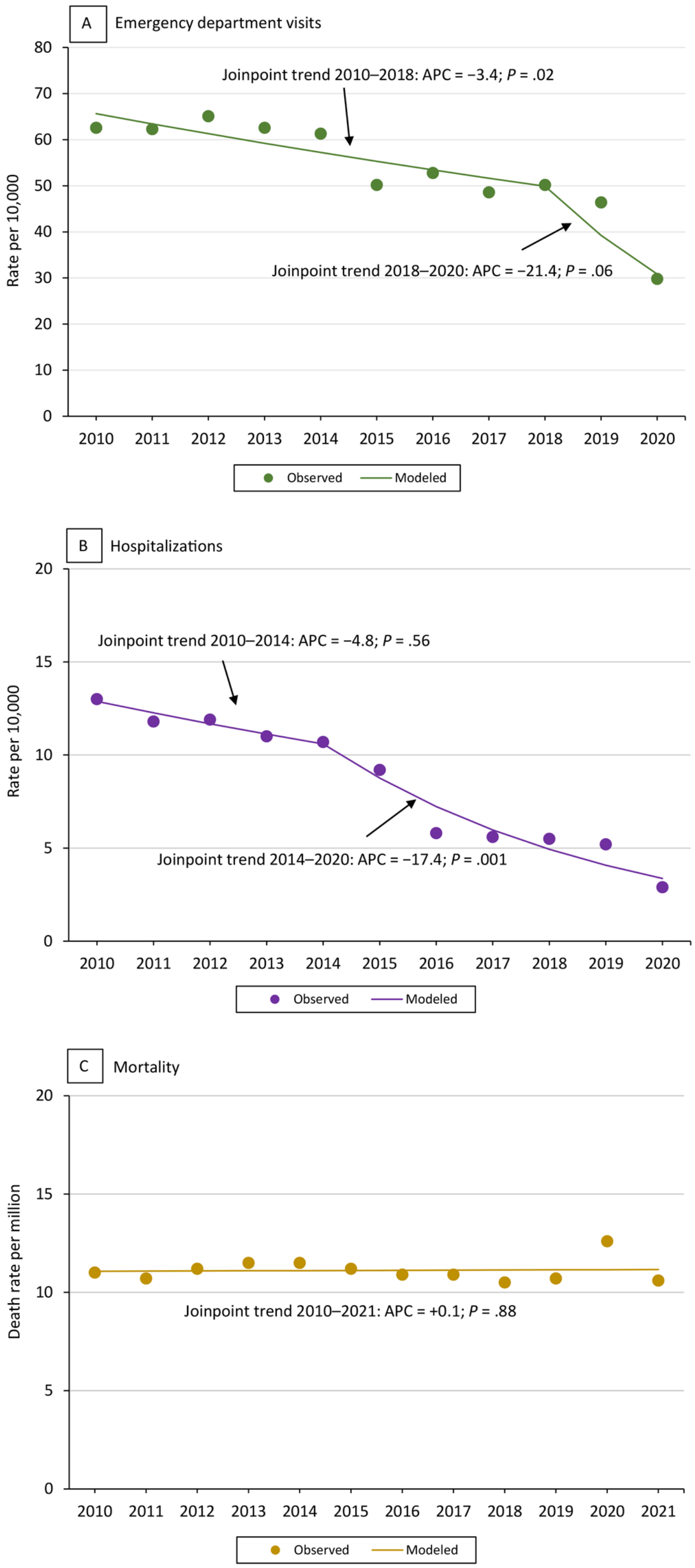

Figure 2. Asthma-related health care use and death rate among all ages by year. The *P* value of trend line slope is significant at .05. The trend line is based on estimates from the statistical model and observed prevalence estimates (estimates as is from the survey data) (dots). The trend slopes are numbered (slope 1, slope 2) when there is more than 1 significant trend line, as in the current asthma trend lines. The health care use rate is shown as the number of hospitalizations and emergency department visits per the US Census resident population for the given year. Data sources: asthma emergency department visits and hospitalizations: Healthcare Cost and Utilization Project, National (Nationwide) Inpatient Sample (16) and National (Nationwide) Emergency Department Sample (15), Agency for Healthcare Research and Quality. Asthma deaths: CDC Wonder (Wide-Ranging Online Data for Epidemiologic Research) (17).

The asthma ED visit rate per 10,000 varied by demographic characteristics (Table 2). It was significantly lower among adults aged 35 or older (35–64 y, 27.4; ≥65 y, 12.5) compared with adults aged 18 to 34 years (39.5). Among adults aged 18 or older, the asthma rate was higher for females (33.1) than males (22.3). The rate was also higher among Black (80.6), other races (64.3), and Hispanic (26.3) adults compared with White adults (13.7) (Table 2).

Among children, the asthma ED visit rate per 10,000 was significantly higher for males (43.0) than for females (29.5) and for Black (89.5), other race (86.0), and Hispanic (35.2) children than for White children (14.4).

Asthma hospital inpatient stays

Nearly 100,000 people in the US were hospitalized for asthma in 2020 (2.9 per 10,000 US census 2020 resident population) (Table 2). The rate was 13.0 per 10,000 for all ages in 2010 and 10.7 per 10,000 in 2014, but no significant changes occurred between 2010 and 2014 ($P = .56$ for the slope). The rate then decreased significantly, to 2.9 per 10,000 in 2020 ($P = .001$ for the slope) (Figure 2).

The trend in asthma hospitalizations for children and adults also declined across time. Among adults, the asthma hospitalization rate per 10,000 decreased significantly, from 12.0 in 2010 to 2.6 in 2020 ($P < .001$ for the slope). The rate among children decreased significantly from 2010 through 2018 and further decreased through 2020 ($P = .006$, 2010–2018; $P = .005$, 2018–2020 for the slopes).

The asthma hospitalization rate varied by demographic characteristics (Table 2). Asthma hospitalization rates per 10,000 among all other age groups (0–4 years: 5.7; 5–17: 2.9; 35–64: 3.0; ≥65 years: 2.8) were significantly higher than among people aged 18 to 34 years (1.9) (Table 2). Among adults, the asthma hospitalization rate was significantly higher among females (3.6) than males (1.6). The rate was also higher among Black (6.5), other race (6.0), and Hispanic (2.4) adults compared with White adults (1.5) (Table 2).

Among children, the asthma hospitalization rate per 10,000 was significantly higher for males (4.2) than for females (3.0). The rate was also significantly higher for Black (8.6), other race (8.0), and Hispanic (2.9) children than for White (1.5) children.

Asthma as the underlying cause of death

In 2021, asthma was the underlying cause of death for 3,517 (10.6 per million) people in the US (Table 3). The trend in asthma death rates among all ages (P =.88 for the slope), among adults (P = .99 for the slope), and among children (P = .35 for the slope) were stable from 2010 through 2021 (Figure 2).

The asthma death rate per million varied by demographic characteristics (Table 3). The rate was significantly lower among children (0–4 y, 1.4; 5–17 y, 2.2), and significantly higher among adults aged 35 years or older (35–64 y, 11.5; ≥65 y, 27.1) compared with people aged 18 to 34 years (5.4). Rates for adults aged 18 years or older were higher for females (15.4) than males (10.6). The rate was also higher among non-Hispanic Black adults (29.7), and lower for adults of non-Hispanic other race (8.5) and Hispanic adults (7.8) compared with non-Hispanic White adults (11.8) (Table 3).

Among children, the asthma death rate per million was significantly higher for males (2.4) than for females (1.6) and also was significantly higher for non-Hispanic Black children (7.7) than for non-Hispanic White children (1.0).

Discussion

We found that current asthma prevalence among adults increased significantly from 2013 through 2021 and decreased significantly among children from 2010 through 2021. Akinbami et al (21) found an increased trend in asthma prevalence among children from 2001 through 2008, plateauing thereafter with a possible decline starting in 2013. Improvements in asthma diagnostic testing (1,2) or changes in exposure to environmental factors linked to developing asthma might explain the trends reported in that study (22).

Another study found that prevalence of asthma attacks did not show a significant trend in either direction among adults or children in the first decade of this century (23). However, another study found a decrease in prevalence of asthma attacks among children with current asthma from 2001 through 2016 (24). We found that prevalence of asthma attacks continued to decline, showing a significant decrease in prevalence from 2010 through 2021 among both children and adults. Asthma-related ED visits and hospitalizations among children and adults decreased significantly, but the decrease in ED visits among children was only significant in later years, 2018 through 2020. Although the COVID-19 pandemic could account for asthma-related ED visits and hospitalizations in 2020, other possible reasons for the declines over the years may include improved, ongoing public health programs and use of emerging evidence-based strategies in asthma diagnosis, management, and treatment (2). Studies have also found that ED visits for asthma were lower during the COVID-19 pandemic compared with pre-pandemic years (before 2020), especially among children. This was explained by changes in the health care–seeking behaviors possibly due to the pandemic, such as exposure avoidance and fears of visiting an ED. Also, ED visits for asthma attacks triggered by COVID-19 may have been classified as COVID-19 (25). A separate trend analysis of asthma-related ED visits and hospitalization data showed significant declines among children and adults from 2010 through 2019.

Our study also found that in 2021, current asthma prevalence was lower but asthma attack prevalence was higher among children aged 0 to 4 years compared with adults aged 18 to 34 years. Past studies also found similar patterns in such children (3). Lower asthma prevalence among children aged 0 to 4 years could be because asthma in children in this age group is often underdiagnosed; its symptoms, such as wheezing and coughing, can be caused by other respiratory tract infections (eg, rhinitis, croup, pneumonia, bronchiolitis) and because of difficulties in using diagnostic lung tests (eg, spirometry) accurately in children in this age group (1). Current asthma prevalence was lower among adults aged 65 years or older than those aged 18 to 34 years. Asthma in older adults may be underdiagnosed because of underuse of diagnostic tests, challenges in application and interpretation of tests, and difficulty distinguishing asthma symptoms from similar symptoms because of other conditions (eg, congestive heart failure, emphysema, chronic bronchitis, chronic aspiration, gastroesophageal reflux disease, tracheobronchial tumors) (26,27).

Among adults, prevalence of current asthma and asthma attacks was higher for females compared with males after adjusting for age and race and ethnicity but lower for children. Asthma attacks also were not associated with sex. The reason for this sex pattern in asthma could be the effect of sex-specific hormones and pathophysiology (28).

Current asthma prevalence was higher among non-Hispanic Black children and adults and lower among Hispanic adults, after adjusting for sex and age, compared with non-Hispanic White adults. Although asthma attack prevalence did not differ by race and ethnicity, after adjusting for age and sex, prevalence was lower among non-Hispanic Black adults compared with non-Hispanic White adults. Disparities persist since our last asthma surveillance summary, which also demonstrated that prevalence remains higher among non-Hispanic Black children and adults and lower among Hispanic adults than non-Hispanic White adults (3). People with low incomes and from some racial and ethnic minority groups disproportionately experience adverse health outcomes, which may be associated with factors such as poor housing quality (7,29,30), adverse environmental exposures (7,8,12,29,30), reduced access to health care (7,31), and health care quality (7,30,31). We did not examine factors contributing to lower asthma attacks among non-Hispanic Black people. Further research is needed to identify those factors.

Further disparities were found in health care use. Children had higher rates of asthma ED visits and hospitalizations than adults, which was consistent with the findings of McDermott et al (32) and Qin et al (33). McDermott et al (32) determined that asthma was the most common reason for potentially preventable pediatric hospitalization in 2017. Despite recent advancements in medical care, an estimated 94,560 people were hospitalized and 986,453 people had ED visits for asthma in 2020, which represents a substantial burden on patients and the health care system. We also found that people of races and ethnicities other than non-Hispanic White had significantly higher rates of asthma ED visits and hospitalizations than White people. Qin et al (33) found that non-Hispanic Black and Hispanic people were more likely to have asthma-related ED visits (33). Asthma disorders and health care use are affected by socioeconomic and demographic factors that contribute to health disparities (7,31). Among children with asthma, more non-Hispanic White children used the doctor's office as their usual place for medical care than non-Hispanic Black and Hispanic children (34). Also, more Black children with insurance had cost barriers to seeing a doctor compared with White children (35).

As other studies show, the contributing factors to health disparities in asthma may include smoking (29,30), economic instability (7), poor housing and environmental conditions (7,8,29,30), health care access (7,12,31), quality of care (7,12,30), and medication adherence (30). Guidelines-based care, including evidence-based interventions and tailored asthma management, may alleviate the burden of asthma and reduce disparities (2).

We found that the asthma death rate was higher for female than male adults but higher among male than female children. We also found this sex pattern for current asthma and health care use. The asthma death rate was also higher among older adults, which was observed in other studies that showed asthma mortality increased with age (26). Baptist and Busse noted that management and medical care for asthma among older adults might be difficult and complicated because of comorbidities and age-related pathophysiologic changes, which can increase risk of death from asthma (26). Although some declines in asthma outcomes have been observed, that article showed continued opportunities to address health disparities.

Our study's strengths are that asthma prevalence and attack data come from NHIS, which is the major and longest-running household health survey in the US (14), and from its decades worth of data to determine trends. These data include multiple major indicators (current asthma, asthma attacks, asthma-related health care use, and asthma mortality), hospital administrative data, and vital statistics data.

Our study had limitations. NHIS responses are self-reported; therefore, some misclassification and associated biases may result. Because NHIS is a cross-sectional study, a cause-and-effect relationship between outcome and independent variables cannot be inferred. In addition, asthma estimates for children are based on proxy (adult) responses and may be misclassified, although the proxy adult selected was the one most knowledgeable about the child's health. Trend results need to be interpreted considering the transition in diagnostic coding from ICD-9-CM to ICD-10-CM in October 2015 and redesign of NHIS in 2019. Additionally, the analysis time period of our study includes the COVID-19 pandemic, which began in 2020 and likely affected survey processes and asthma ED visits.

Conclusion

Although asthma attacks, asthma ED visits, asthma hospitalizations, and asthma deaths declined since 2010 among all ages, current asthma prevalence declined only among children. Significant disparities in health and health care use still exist. Our study's results can help decision makers and public health practitioners provide tailored interventions and health care initiatives to improve the health of people with asthma and reduce preventable health care use.

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Tables

Table 1. Prevalence of Current Asthma[a] and Asthma Attacks[b] Among All Ages, Children Aged 0–17 Years, and Adults Aged ≥18 Years, by Select Characteristics, National Health Interview Survey, 2021[c]

Characteristic	Current asthma				Asthma attacks			
	Estimated number[d]	% (SE)	APR (95% CI)[e]	*P* value	Estimated number[d]	% (SE)	APR (95% CI)[e]	*P* value
All ages								
Total	24,946,797	7.7 (0.18)	NA	NA	9,810,021	39.4 (1.05)	NA	NA
Sex								
Male	10,268,285	6.5 (0.22)	Reference	<.001[f]	3,507,730	34.2 (1.66)	Reference	<.001[f]
Female	14,678,512	8.9 (0.26)	1.36 (1.25–1.48)		6,302,291	43.0 (1.31)	1.27 (1.14–1.42)	
Age, y								
0–4	369,646	1.9 (0.34)	0.24 (0.17–0.34)	<.001[f]	233,364	63.1 (8.09)	1.73 (1.34–2.24)	<.001[f]
5–17	4,305,830	8.1 (0.42)	0.99 (0.85–1.14)		1,577,699	36.6 (2.55)	1.03 (0.86–1.24)	
18–34	6,157,181	8.4 (0.44)	Reference		2,269,833	36.9 (2.50)	Reference	
35–64	10,079,876	8.2 (0.27)	0.97 (0.86–1.10)		4,515,241	44.9 (1.62)	1.17 (1.01–1.37)	
≥65	4,034,264	7.2 (0.33)	0.83 (0.73–0.96)		1,213,884	30.3 (2.21)	0.77 (0.62–0.94)	
Race or ethnicity								
Hispanic	3,496,174	5.7 (0.35)	0.74 (0.65–0.84)	<.001[f]	1,370,503	39.2 (2.80)	0.96 (0.82–1.12)	.13
Non-Hispanic Black	4,234,040	11.1 (0.64)	1.41 (1.24–1.60)		1,438,527	34.0 (2.63)	0.82 (0.70–0.97)	
Non-Hispanic Other[g]	2,087,484	7.1 (0.53)	0.91 (0.78–1.07)		901,769	43.3 (3.66)	1.07 (0.89–1.27)	
Non-Hispanic White	15,129,098	7.8 (0.22)	Reference		6,099,221	40.4 (1.34)	Reference	
US census region								
Northeast	4,096,784	7.4 (0.47)	0.87 (0.75–1.02)	.08	1,490,033	36.3 (2.52)	0.90 (0.77–1.07)	.43
Midwest	5,744,256	8.5 (0.38)	0.99 (0.88–1.12)		2,188,525	38.2 (2.19)	0.94 (0.81–1.09)	
South	9,047,848	7.3 (0.30)	0.83 (0.74–0.93)		3,686,723	40.8 (1.84)	1.04 (0.91–1.20)	
West	6,057,909	7.8 (0.30)	Reference		2,453,177	40.6 (1.84)	Reference	
Adults ≥18 years								
Total	20,271,321	8.0 (0.34)	NA	NA	7,998,958	39.6 (2.02)	NA	NA
Sex								
Male	7,573,139	6.2 (0.25)	Reference	<.001[f]	2,473,035	32.8 (1.94)	Reference	<.001[f]
Female	12,698,183	9.8 (0.30)	1.57 (1.43–1.73)		5,525,924	43.6 (1.40)	1.35 (1.18–1.53)	
Race and ethnicity								

Abbreviation: APR: adjusted prevalence ratio; NA: not applicable; SE: standard error.
[a] People who responded yes to the following questions: "Has a doctor or other health professional ever told you that you had asthma?" and "Do you still have asthma?"
[b] Among those with current asthma, respondents were classified as having asthma attacks if they responded yes to "During the past 12 months, have you had an episode of asthma or an asthma attack?"
[c] National Center for Health Statistics (14).
[d] May not sum to total because of rounding and missing values.
[e] Adjusted for age, sex, and race or ethnicity when regressing the dependent variables (ie, current asthma and asthma attacks) over each independent variable by using multivariable logistic regression models. For age, sex, and race or ethnicity variables, only adjusted for the other 2.
[f] Significant at $P<.05$. Calculated by using the Wald χ^2 test of the association between outcomes and characteristics.
[g] Non-Hispanic Asian, Non-Hispanic American Indian or Alaska Native, any other race or ethnicity, other single race, or multiple races.

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Table 1. Prevalence of Current Asthma[a] and Asthma Attacks[b] Among All Ages, Children Aged 0–17 Years, and Adults Aged ≥18 Years, by Select Characteristics, National Health Interview Survey, 2021[c]

Characteristic	Current asthma				Asthma attacks			
	Estimated number[d]	% (SE)	APR (95% CI)[e]	*P* value	Estimated number[d]	% (SE)	APR (95% CI)[e]	*P* value
Hispanic	2,486,966	5.8 (0.43)	0.68 (0.59–0.80)	<.001[f]	987,746	39.7 (3.38)	0.95 (0.79–1.14)	.17
Non-Hispanic Black	3,130,895	10.6 (0.69)	1.25 (1.09–1.43)		1,039,101	33.3 (3.06)	0.80 (0.66–0.97)	
Non-Hispanic Other[g]	1,638,065	7.6 (0.67)	0.90 (0.75–1.08)		705,552	43.2 (4.21)	1.07 (0.87–1.30)	
Non-Hispanic White	13,015,396	8.2 (0.24)	Reference		5,266,559	40.6 (1.45)	Reference	
US census region								
Northeast	3,534,987	8.0 (0.52)	0.89 (0.76–1.05)	.08	1,288,580	36.5 (2.86)	0.89 (0.75–1.08)	.32
Midwest	4,633,048	8.8 (0.43)	0.97 (0.85–1.11)		1,719,494	37.2 (2.39)	0.90 (0.76–1.06)	
South	7,123,176	7.4 (0.34)	0.80 (0.71–0.92)		2,915,835	41.0 (2.11)	1.02 (0.88–1.19)	
West	4,980,112	8.3 (0.39)	Reference		2,075,049	41.8 (2.27)	Reference	
Children <18 y								
Total	4,675,475	6.5 (0.32)	NA	NA	1,811,063	38.7 (2.51)	NA	NA
Sex								
Male	2,695,146	7.3 (0.49)	Reference	.007[f]	1,034,696	38.4 (3.40)	Reference	.87
Female	1,980,329	5.6 (0.41)	0.77 (0.64–0.93)		776,367	39.2 (3.70)	1.02 (0.79–1.32)	
Race or ethnicity								
Hispanic	1,009,208	5.4 (0.55)	0.95 (0.75–1.21)	.001	382,757	37.9 (5.61)	0.95 (0.68–1.34)	.88
Non-Hispanic Black	1,103,145	12.5 (1.36)	2.19 (1.68–2.84)		399,426	36.2 (5.85)	0.90 (0.62–1.30)	
Non-Hispanic Other[g]	449,419	5.7 (0.81)	1.01 (0.75–1.37)		196,217	43.7 (7.56)	1.05 (0.70–1.56)	
Non-Hispanic White	2,113,703	5.7 (0.42)	Reference		832,662	39.4 (3.64)	Reference	
US census region								
Northeast	561,797	5.0 (0.75)	0.76 (0.54–1.07)	.11	195,906	34.9 (6.57)	0.95 (0.61–1.48)	.69
Midwest	1,111,208	7.4 (0.69)	1.11 (0.85–1.44)		469,031	42.2 (5.31)	1.14 (0.80–1.62)	
South	1,924,672	6.8 (0.56)	0.91 (0.71–1.16)		767,998	39.9 (4.16)	1.14 (0.81–1.60)	
West	1,077,798	6.2 (0.59)	Reference		378,128	35.1 (4.42)	Reference	

Abbreviation: APR: adjusted prevalence ratio; NA: not applicable; SE: standard error.
[a] People who responded yes to the following questions: "Has a doctor or other health professional ever told you that you had asthma?" and "Do you still have asthma?"
[b] Among those with current asthma, respondents were classified as having asthma attacks if they responded yes to "During the past 12 months, have you had an episode of asthma or an asthma attack?"
[c] National Center for Health Statistics (14).
[d] May not sum to total because of rounding and missing values.
[e] Adjusted for age, sex, and race or ethnicity when regressing the dependent variables (ie, current asthma and asthma attacks) over each independent variable by using multivariable logistic regression models. For age, sex, and race or ethnicity variables, only adjusted for the other 2.
[f] Significant at $P < .05$. Calculated by using the Wald χ^2 test of the association between outcomes and characteristics.
[g] Non-Hispanic Asian, Non-Hispanic American Indian or Alaska Native, any other race or ethnicity, other single race, or multiple races.

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Table 2. Asthma Emergency Department Visits and Hospitalization Rates[a] by Patient Characteristics Among All Ages, Children Aged 0–17 Years, and Adults Aged ≥18 Years, US, 2020

Characteristic	Emergency department visits			Hospitalizations		
	Estimated number[b]	Rate per 10,000 (SE)[c]	*P* value for *z* score	Estimated number[b]	Rate per 10,000 (SE)[c]	*P* value for *z* score
All ages						
Total	986,453	29.8 (0.98)	NA	94,560	2.9 (0.06)	NA
Sex[d]						
Male[e]	445,261	27.1 (1.01)	Reference	36,110	2.2 (0.06)	Reference
Female	541,130	32.3 (1.00)	<.001[f]	58,450	3.5 (0.07)	<.001[f]
Age, y						
0–4	80,898	42.0 (3.66)	<.001[f]	11,020	5.7 (0.34)	<.001[f]
5–17	189,432	34.5 (2.39)	<.001[f]	16,035	2.9 (0.18)	<.001[f]
18–34[e]	299,453	39.5 (1.27)	Reference	14,445	1.9 (0.05)	Reference
35–64	348,767	27.4 (0.94)	<.001[f]	37,630	3.0 (0.06)	<.001[f]
≥65	67,896	12.5 (0.44)	<.001[f]	15,430	2.8 (0.07)	<.001[f]
Race, excluding ethnicity						
Black	371,608	82.8 (4.89)	<.001[f]	31,725	7.1 (0.24)	<.001[f]
Other[g]	246,004	70.5 (4.25)	<.001[f]	22,970	6.6 (0.27)	<.001[f]
White[e]	348,760	13.9 (0.40)	Reference	37,365	1.5 (0.03)	Reference
Ethnicity						
Hispanic	179,553	29.0 (2.12)	<.001[f]	15,890	2.6 (0.12)	<.001[f]
Non-Hispanic	786,819	29.2 (1.00)	<.001[f]	76,170	2.8 (0.06)	<.001[f]
Adults ≥18 y						
Total	716,117	27.8 (0.89)	NA	67,505	2.6 (0.05)	NA
Sex[d]						
Male[e]	281,893	22.3 (0.80)	Reference	20,045	1.6 (0.04)	Reference
Female	434,185	33.1 (1.03)	<.001[f]	47,460	3.6 (0.07)	<.001[f]
Race, excluding ethnicity						
Black	270,279	80.6 (4.96)	<.001[f]	21,940	6.5 (0.20)	<.001[f]
Other[g]	159,930	64.3 (3.44)	<.001[f]	14,970	6.0 (0.24)	<.001[f]
White[e]	272,380	13.7 (0.38)	Reference	29,425	1.5 (0.03)	Reference
Ethnicity						
Hispanic	112,731	26.3 (1.67)	<.001[f]	10,465	2.4 (0.12)	<.001[f]
Non-Hispanic	589,858	27.5 (0.95)	<.001[f]	55,870	2.6 (0.04)	<.001[f]

Abbreviation: NA, not applicable; SE: standard error.
[a] Asthma as the primary diagnosis (ICD-10-CM Code: J45) (15,18); Nationwide Emergency Department Sample, Healthcare Cost and Utilization Project, 2010–2020 (15); and Nationwide Inpatient Sample, Healthcare Cost and Utilization Project, 2010–2020 (16).
[b] Used sample weights provided in the data set to estimate numbers of respondents within select characteristics; may not sum to total because of rounding and missing values.
[c] Crude rate per 10,000 US census 2020 resident population.
[d] Sex categories are male and female as designated in the medical record.
[e] Reference category.
[f] Significant at $P < .05$. P values calculated by using z test.
[g] Includes Asian or Pacific Islander, American Indian or Alaska Native, and other races.

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Table 2. Asthma Emergency Department Visits and Hospitalization Rates[a] by Patient Characteristics Among All Ages, Children Aged 0–17 Years, and Adults Aged ≥18 Years, US, 2020

Characteristic	Emergency department visits			Hospitalizations		
	Estimated number[b]	Rate per 10,000 (SE)[c]	*P* value for *z* score	Estimated number[b]	Rate per 10,000 (SE)[c]	*P* value for *z* score
Children <18 y						
Total	270,330	36.4 (2.69)	NA	27,055	3.6 (0.21)	NA
Sex[d]						
Male[e]	163,367	43.0 (3.23)	Reference	16,065	4.2 (0.25)	Reference
Female	106,938	29.5 (2.14)	<.001[f]	10,990	3.0 (0.18)	<.001[f]
Race, excluding ethnicity						
Black	101,329	89.5 (8.09)	<.001[f]	9,785	8.6 (0.65)	<.001[f]
Other[g]	86,074	86.0 (9.75)	<.001[f]	8,000	8.0 (0.60)	<.001[f]
White[e]	76,374	14.4 (1.10)	Reference	7,940	1.5 (0.09)	Reference
Ethnicity						
Hispanic	66,821	35.2 (4.62)	<.001[f]	5,425	2.9 (0.24)	<.001[f]
Non-Hispanic	196,955	35.7 (2.52)	<.001[f]	20,300	3.7 (0.22)	<.001[f]

Abbreviation: NA, not applicable; SE: standard error.
[a] Asthma as the primary diagnosis (ICD-10-CM Code: J45) (15,18); Nationwide Emergency Department Sample, Healthcare Cost and Utilization Project, 2010–2020 (15); and Nationwide Inpatient Sample, Healthcare Cost and Utilization Project, 2010–2020 (16).
[b] Used sample weights provided in the data set to estimate numbers of respondents within select characteristics; may not sum to total because of rounding and missing values.
[c] Crude rate per 10,000 US census 2020 resident population.
[d] Sex categories are male and female as designated in the medical record.
[e] Reference category.
[f] Significant at $P < .05$. *P* values calculated by using *z* test.
[g] Includes Asian or Pacific Islander, American Indian or Alaska Native, and other races.

Table 3. Asthma Deaths by Select Characteristics Among All Ages, Children Aged 0–17 Years, and Adults Aged ≥18 Years — US, 2021[a]

Characteristic[b]	Number of deaths[c]	Death rate per million (SE)[c,d]	*P* value for *z* score
All ages			
Total	3,517	10.6 (0.18)	NA
Sex[e]			
Male[g]	1,430	8.7 (0.23)	Reference
Female	2,087	12.5 (0.27)	<.001[f]
Age, y			
0–4	26	1.4 (0.27)	<.001[f]
5–17	119	2.2 (0.20)	<.001[f]
18–34[g]	406	5.4 (0.27)	Reference
35–64	1,453	11.5 (0.30)	<.001[f]
≥65	1,513	27.1 (0.70)	<.001[f]
Race and ethnicity			
Hispanic[i]	366	5.8 (0.31)	<.001[f]
Non-Hispanic Black	1,020	24.4 (0.76)	<.001
Non-Hispanic Other[h]	194	6.3 (0.46)	<.001
Non-Hispanic White[g]	1,929	9.8 (0.22)	Reference
Adults ≥18 y			
Total	3,372	13.1 (0.22)	NA
Sex[e]			
Male[g]	1,341	10.6 (0.29)	Reference
Female	2,031	15.4 (0.34)	<.001[f]
Race and ethnicity			
Hispanic[i]	339	7.8 (0.42)	<.001[f]
Non-Hispanic Black	942	29.7 (0.97)	<.001[f]
Non-Hispanic Other[h]	190	8.5 (0.62)	<.001[f]
Non-Hispanic White[g]	1,893	11.8 (0.27)	Reference
Children <18 y			
Total	145	2.0 (0.16)	NA
Sex[e]			
Male[g]	89	2.4 (0.25)	Reference
Female	56	1.6 (0.21)	0.01[f]

Abbreviations: NA: not applicable; SE: standard error.
[a] Centers for Disease Control and Prevention. CDC Wonder (https://wonder.cdc.gov/).
[b] Numbers in select characteristics may not sum to total because of rounding and missing values.
[c] Asthma as the underlying cause of death (ICD-10 codes J45–J46). (https://wonder.cdc.gov/wonder/help/ucd-expanded.html#).
[d] Crude death rate per million, US census 2021 resident population.
[e] Sex categories are male and female as reported in death certificate.
[f] Significant at $P < .05$. *P* values calculated by using *z* test.
[g] Reference category.
[h] Non-Hispanic Asian, non-Hispanic American Indian/Alaska Native, non-Hispanic native Hawaiian/Pacific Islander, and non-Hispanic people of more than 1 race.
[i] Information for Hispanic origin was missing for suppressed number of deaths.
[j] Suppressed because the number of deaths was 9 or fewer.

(continued on next page)

(continued)

Table 3. Asthma Deaths by Select Characteristics Among All Ages, Children Aged 0–17 Years, and Adults Aged ≥18 Years — US, 2021[a]

Characteristic[b]	Number of deaths[c]	Death rate per million (SE)[c,d]	*P* value for *z* score
Race and ethnicity			
Hispanic[i]	27	1.4 (0.27)	.21
Non-Hispanic Black	78	7.7 (0.87)	<.001
Non-Hispanic Other[h]	—[j]	—[j]	NA
Non-Hispanic White[g]	36	1.0 (0.17)	Reference

Abbreviations: NA: not applicable; SE: standard error.
[a] Centers for Disease Control and Prevention. CDC Wonder (https://wonder.cdc.gov/).
[b] Numbers in select characteristics may not sum to total because of rounding and missing values.
[c] Asthma as the underlying cause of death (ICD-10 codes J45–J46). (https://wonder.cdc.gov/wonder/help/ucd-expanded.html#).
[d] Crude death rate per million, US census 2021 resident population.
[e] Sex categories are male and female as reported in death certificate.
[f] Significant at $P < .05$. P values calculated by using z test.
[g] Reference category.
[h] Non-Hispanic Asian, non-Hispanic American Indian/Alaska Native, non-Hispanic native Hawaiian/Pacific Islander, and non-Hispanic people of more than 1 race.
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ORIGINAL RESEARCH

Trends in US Pediatric Asthma Hospitalizations, by Race and Ethnicity, 2012–2020

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PEER REVIEWED

Summary

What is already known on this topic?

Pediatric asthma outcomes vary by race and ethnicity. Some racial and ethnic minority communities have faced a disproportionate asthma burden for a long time.

What is added by this report?

Using estimates of pediatric asthma hospitalizations, we calculated rates and compared changes over time for 6 racial and ethnic groups. This analysis updates prior research and can inform asthma control strategies.

What are the implications for public health practice?

Although hospitalization rates are decreasing among all groups, declines are similar across groups, so previously identified disparities persist. Children from racial and ethnic minority groups, especially non-Hispanic Black children, remain disproportionately affected. Interventions considering the specific needs of members of these groups may be useful in addressing their high rate of asthma hospitalizations.

Abstract

Introduction
Some racial and ethnic minority communities have long faced a higher asthma burden than non-Hispanic White communities. Prior research on racial and ethnic pediatric asthma disparities found stable or increasing disparities, but more recent data allow for updated analysis of these trends.

Methods
Using 2012–2020 National Inpatient Sample data, we estimated the number of pediatric asthma hospitalizations by sex, age, and race and ethnicity. We converted these estimates into rates using data from the US Census Bureau and then conducted meta-regression to assess changes over time. Because the analysis spanned a 2015 change in diagnostic coding, we performed separate analyses for periods before and after the change. We also excluded 2020 data from the regression analysis.

Results
The number of pediatric asthma hospitalizations decreased over the analysis period. Non-Hispanic Black children had the highest prevalence (range, 9.8–36.7 hospitalizations per 10,000 children), whereas prevalence was lowest among non-Hispanic White children (range, 2.2–9.4 hospitalizations per 10,000 children). Although some evidence suggests that race-specific trends varied modestly across groups, results overall were consistent with a similar rate of decrease across all groups (2012–2015, slope = −0.83 [95% CI, −1.14 to −0.52]; 2016–2019, slope = −0.35 [95% CI, −0.58 to −0.12]).

Conclusion
Non-Hispanic Black children remain disproportionately burdened by asthma-related hospitalizations. Although the prevalence of asthma hospitalization is decreasing among all racial and ethnic groups, the rates of decline are similar across groups. Therefore, previously identified disparities persist. Interventions that consider the specific needs of members of disproportionately affected groups may reduce these disparities.

Introduction

Asthma is a chronic condition in which a person's airways become inflamed and narrow in the presence of certain triggers (1). Asthma affects approximately 1 in 15 children in the United States (4.7 million children in 2021) (2). Uncontrolled asthma can have severe, long-term consequences. Children with uncontrolled asthma have a lower quality of life (3) and may experience irrecoverable loss of lung function at an early age (4). Although no cure exists for asthma, proper management can lessen its effects and mitigate the risk of these adverse outcomes.

Racial and ethnic disparities exist in asthma prevalence, health care utilization, and mortality. The existence of such disparities has been known for decades, and they have persisted over time (5,6). A 2014 analysis of trends in racial disparities in childhood asthma outcomes in the US found that population-level disparities, as measured by the rate ratio, were either stable (emergency department [ED] visits and hospitalizations) or increasing (asthma attack prevalence and death) (6). However, this analysis was conducted on data only through 2010, and more recent data have been published.

We assessed the burden of asthma by using population-based rates of hospitalization, focusing on trends among children by racial and ethnic status from 2012 through 2020. Analyzing the most recent data from a nationally representative sample of hospitalizations, which has an improved sampling strategy and a more comprehensive means of data collection than that of prior research, provides an updated picture of the trends in racial and ethnic asthma disparities. Understanding the current state of racial and ethnic asthma outcome disparities will provide evidence that can be used to make informed decisions about future asthma control efforts.

Methods

Data sources

The primary data set we used for this analysis was discharge data from the National Inpatient Sample (NIS), Healthcare Cost and Utilization Project (HCUP), Agency for Healthcare Research and Quality (AHRQ) (7). The NIS is the largest publicly available, all-payer, inpatient health care database covering the US; it consists of a stratified sample of 20% of discharges from nonfederal, community hospitals, excluding rehabilitation and long-term acute care hospitals. The NIS contains data from approximately 7 million inpatient hospitalizations annually. To ensure a self-weighted sample, sampling rates vary for each stratum. More details about the NIS sampling strategy can be found on the HCUP User Support website (https://hcup-us.ahrq.gov/techassist.jsp). The NIS is sampled from the State Inpatient Databases, which participating state partners submit to AHRQ. NIS data sets are published annually, and we analyzed NIS data from 2012 through 2020, the most recent year for which data have been published.

We obtained estimates of the US population from the US Census Bureau Vintage 2020 Population Estimates (8,9). Every year, the US Census Bureau estimates the resident population for each year since the most recent decennial census using measures of population change. The Vintage 2020 estimates are based on the 2010 Census combined with vital and immigration records, without incorporation or consideration of the 2020 Census results (9). In this analysis, we treated these population denominators as counts, not estimates.

Variables of interest

Our outcome of interest was asthma-related hospitalizations among children (aged 0–17 y). We identified asthma hospitalizations as those with a first-listed physician diagnosis beginning with 493 in the *International Classification of Diseases, Ninth Revision, Clinical Modification* (ICD-9-CM) (2012 to 2015) or diagnosis beginning with J45 in the *International Classification of Diseases, Tenth Revision, Clinical Modification* (ICD-10-CM) (2016 to 2020). This distinction was necessitated by a change in diagnostic coding procedures between the end of the third (September) and start of the fourth (October) calendar quarters of 2015. Patient age and sex are provided in the NIS. We categorized patient age into 3 groups (0–4 y, 5–9 y, and 10–17 y) on the basis of previous childhood asthma research (10). Patient sex was listed as either male or female.

We separated patient race and ethnicity into 6 categories: Hispanic, non-Hispanic White, non-Hispanic Black, non-Hispanic Asian, non-Hispanic Native American, and Other. The NIS and the US Census Bureau determine racial status in different ways. In the NIS, collection of race data varies by HCUP partner and may not be reported in the same manner across all facilities. The 2012–2020 NIS categorizes patients into 1 of 6 racial and ethnic categories (White, Black, Hispanic, Asian, Native American, and Other). In all HCUP data sets, Hispanic ethnicity takes precedence over race, meaning that when Hispanic ethnicity is documented separately from racial group, AHRQ classifies patients of Hispanic ethnicity as "Hispanic," regardless of racial group identification. US Census Bureau data must adhere to the 1997 Office of Management and Budget standards, which stipulate that Hispanic ethnicity be determined separately from race (11).

In reconciling these differing methodologies, we opted to retain the HCUP-provided racial and ethnic categories and modify the population estimates. We used the estimated number of Hispanic people, regardless of racial status, as the denominator for that population. We then used the estimates of people identifying as non-Hispanic White alone, non-Hispanic Black alone, non-Hispanic Asian and Pacific Islander alone, and non-Hispanic Native American and Alaska Native alone as the denominators for their respective populations. We chose to group non-Hispanic Asians and non-Hispanic Pacific Islanders together based on the race-bridging methods used by the US Census Bureau (12). We used the number of people estimated to identify in the Vintage 2020 as 2 or more races as the denominator for the HCUP "Other" racial and ethnic group. We subsequently refer to the children in this numerator and denominator pair as "Other."

Statistical analysis

We used SAS version 9.4 (SAS Institute Inc) to weight the NIS data and generate estimates of the total number of pediatric asthma hospitalizations by sex, age group, and racial and ethnic group in each analysis year, as well as to determine the demographic makeup of patients in each year. Using weights for the NIS provided by AHRQ, we used survey procedures in SAS 9.4 to account for the complex survey design of the NIS. For each population subgroup, we then divided the weighted estimate of the number of hospitalizations for each year by the corresponding population denominator to estimate the population-based rates of hospitalizations by sex, age group, and racial and ethnic group. In reporting these rates, we separated the periods 2012–2015 and 2016–2019 because of potential shifts in diagnosis patterns due to the change in diagnostic coding. We also report rates for 2020 separately because the COVID-19 pandemic resulted in noticeable shifts in health care utilization, including a decrease in emergency medicine encounters among children with asthma after the onset of the COVID-19 pandemic (13,14).

To evaluate temporal trends, we used meta-regression (15,16) in which the dependent variable was the calculated hospitalization rate for each combination of race category and year. Key assumptions are correct model specification, independent observations, and normality of random effects (16). We specified the model to have a unique rate for each racial and ethnic group with a linear trend over years and a random effect of year. We assessed the key assumption of correctness of the model specification with residual plots and by considering more complicated models with interaction terms (year × race group [ie, a separate trend for each race group]) and higher order terms (year squared), as well as different random error terms (eg, random effect of race vs random effect of year). The Bayesian Information Criterion (BIC) was used to compare and select models (lower BIC preferred). We fit one model for the years 2012–2015 and a separate model for the years 2016–2019. The regression models included fixed effects for each of the 6 nonmissing race and ethnicity categories (indicator variables) and a linear term for year (continuous year variable). Children assigned a missing or invalid race and ethnicity status were excluded from this portion of the analysis. Analyses incorporated the known variance of the hospitalization counts due to sampling, and a random effect for each year. In sensitivity analyses, we evaluated a model in which each race category had its own trend and models with a random effect for race. Meta-regression analyses were conducted in R version 4.3.1 (17) and the package mixmeta, version 1.2.0 (16).

Results

The total number of pediatric asthma hospitalizations decreased over both halves of the analysis (2012–2015 and 2016–2019, respectively), from 114,325 hospitalizations in 2012 to 87,065 in 2015, and from 80,235 in 2016 to 64,525 in 2019 (Table 1). A sharp decrease in total hospitalizations was seen between 2019 and 2020, with only 27,055 hospitalizations that year. Across all years, hospitalized patients were more frequently male (range, 59.4%–62.5%) and aged 0 to 4 years (range, 40.7%–48.9%). Non-Hispanic Black children made up the highest percentage of patients (range, 32.9%–36.2%), followed by non-Hispanic White children (27.7%–31.9%). Hispanic children made up between 20.1% and 23.3% of patients. Non-Hispanic Asian children represented around 3% of those hospitalized, while non-Hispanic Native American children made up less than 1% of patients. Children categorized in the Other racial and ethnic group represented between 4.9% and 6.2% of the sample each year. In every year, less than 7% of children had no listed race status (ie, missing/invalid), and this percentage was stable across years.

Hospitalization prevalence was consistently higher for male than for female children, although both groups experienced a decline in hospitalization rate over both halves of the analysis (Table 2). All age groups also experienced declines in hospitalization rates. Rates were consistently highest among children aged 0 to 4 years, with lower rates for each successive age group. Non-Hispanic Black children consistently had the highest hospitalization rate, followed by children categorized in the Other racial and ethnic group. In almost all analysis years, rates were lowest among non-Hispanic Asian children and second lowest among non-Hispanic White children, although in 2017, 2018, and 2019 non-Hispanic White children had the lowest prevalence. Hospitalization rates among Hispanic children and non-Hispanic Native American children were similar to one another, being higher than those for non-Hispanic White and non-Hispanic Asian children, but lower than rates among non-Hispanic Black children and children categorized in the Other racial and ethnic group. The Figure shows hospitalization rates by race and ethnicity over both halves of the analysis, as well as for 2020. Overall, hospitalization rates for all groups decreased over both halves of the analysis, and there was a sharp decrease in rates for all racial and ethnic groups between 2019 and 2020.

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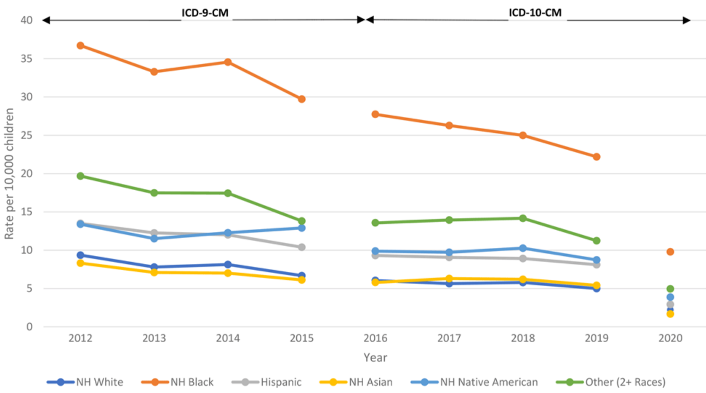

Figure. Estimated rates of pediatric asthma hospitalization, by race and ethnicity, per 10,000 population, US, 2012–2020. Data on the number of hospitalizations are from the National Inpatient Sample, and population denominators are from the Census Bureau Vintage 2020 Population Estimates. The break between 2015 and 2016 represents the change in diagnostic coding from *the International Classification of Diseases, 9th Revision, Clinical Modification* (ICD-9-CM) to the *International Classification of Diseases, 10th Revision, Clinical Modification* (ICD-10-CM). Abbreviation: NH, non-Hispanic.

Results of meta-regression models indicated patterns similar to those described above, with little heterogeneity (I ≈ 0, $P < .90$ for residual heterogeneity). From 2012 to 2015, all racial and ethnic groups except non-Hispanic Asian children had, on average, a higher hospitalization prevalence than non-Hispanic White children (Table 3). Non-Hispanic Black children had the highest average hospitalization prevalence, followed by children categorized in the Other racial and ethnic group. For this earlier period (2012–2015), the common slope was −0.83 (95% CI, −1.14 to −0.52; $P < .001$), indicating that hospitalization rates per 10,000 children decreased by about 0.83 per year (Table 3). While the addition of a race–year interaction term suggested that race-specific trends may vary modestly across racial and ethnic group, overall, the results were consistent with a similar decrease across all racial and ethnic groups, based on Bayesian Information Criterion. Table 4 contains the results of the model with the race–year interaction term. The BIC of the simpler model was 89.18, whereas the BIC of the model with interaction was 101.38.

Results for the period 2016–2019 were similar to those generated for 2012–2015. All racial and ethnic groups except for non-Hispanic Asian children had, on average, a higher hospitalization prevalence than non-Hispanic White children, regardless of model complexity, although the race-specific coefficients were lower than in 2012–2015 (Table 3). Non-Hispanic Black children still had the highest average prevalence, followed by children categorized in the Other racial and ethnic group. For this later period (2016–2019), the magnitude of the slope was lower (−0.35; 95% CI, −0.58 to −0.12; $P = .003$), but still suggested a decreasing temporal trend of the hospitalization rate per 10,000 children (Table 3). The addition of the race–year interaction term did not provide evidence of variation in race-specific trends; CIs for every race–year interaction term included the null, and the likelihood ratio test was not significant ($P > .05$) for years 2012–2015 and for years 2016–2019. Once again, the BIC strongly favored the simpler model with a common slope for all racial and ethnic groups. Table 4 contains the results of the model with the race–year interaction term; the BIC of the simpler model was 76.90, whereas the BIC of the interaction model was 88.92.

Discussion

Overall, the number of pediatric asthma hospitalizations decreased during both halves of the analysis. In addition, the hospitalization rates for each racial and ethnic group individually decreased during both halves of the analysis. However, no evidence exists that rates for any racial and ethnic group declined faster (or slower) than for non-Hispanic White children. Thus, although the rate differences between the asthma hospitalization rates of non-Hispanic White children and those of non-Hispanic Black children and children categorized in the Other racial and ethnic group are decreasing, the pre-existing disparities, as defined by the rate ratio, are not decreasing. Therefore, the long-documented racial and ethnic disparities in asthma outcomes persist. These results are similar to the findings of Akinbami et al (6), who reported similar rates of decline in population-based rates of asthma hospitalizations among both White and Black children between 2001 and 2010, indicating the Black/White racial disparity had not improved despite overall improvements in the number of hospitalizations. Future analyses expounding on other health disparity measures, including relative changes, can add to our understanding of changes in asthma-related health disparities.

Several potential factors may explain why the overall number and prevalence of hospitalizations declined over the analysis period. Management of asthma exacerbations in emergency medicine settings has improved in the last decade (18), potentially leading to fewer inpatient admissions from EDs. Similarly, improved access to outpatient care may have boosted provider and parent confidence in the ability to manage asthma in outpatient settings, also leading to fewer inpatient admissions from EDs. The cost for pediatric inpatient stays has also increased substantially in the past 2 decades (19), which has perhaps led to reluctance to use inpatient care, especially given the aforementioned improvements in emergency and outpatient care.

Because racial and ethnic asthma disparities have persisted over time, opportunities to use frameworks that consider the unique needs of people from disproportionately affected racial and ethnic minority groups will continue. Many frameworks exist that aim to address health disparities and achieve health equity. Potentially promising frameworks include the Social Determinants of Health (20) (1 of 3 priority areas for Healthy People 2030) and Vital Conditions for Health and Wellbeing (21). Both frameworks address nonmedical factors that nonetheless influence health outcomes and whose negative consequences are most frequently borne by socially disadvantaged groups. One framework specific to asthma is the National Asthma Control Program's EXHALE Technical Package, which emphasizes not only individual-level factors in asthma control, but also the broader environmental conditions that contribute to adverse asthma outcomes (22).

Anchoring future asthma interventions in these and other frameworks that address the specific needs of populations who face greater social disadvantage may help address the existing racial and ethnic asthma disparities. Both individual- and community-level interventions have a role to play. On the individual level, interventions promoting access and engagement with primary care and more consistent use of controller medications have been shown to decrease asthma-related ED visits and hospitalizations (23). Community-based interventions also have a proven impact, such the Children's Hospital of Philadelphia CAPP+ program, which demonstrated that addressing social determinants of health (in this case, housing quality) reduces emergency health care utilization among children with asthma (24). Ultimately, achieving racial and ethnic equity in asthma outcomes will likely require interventions focused on both individual- and community-level determinants that are specifically tailored to the needs of individuals from racial and ethnic groups that are disproportionately affected.

Race and ethnicity are not in and of themselves the main drivers of asthma disparities. Rather, they are markers of other factors, such as socioeconomic status and experiences of interpersonal and structural discrimination, that more directly influence health disparities (25). For example, material hardship and poor housing quality may partially mediate the relationship between race and asthma ED visits (26). Environmental exposures, as well as cultural and psychosocial experiences, that vary across racial and ethnic groups may also play a role in the risk of adverse asthma outcomes (27–29). However, such factors are not inherent in certain racial and ethnic groups per se, but rather reflect larger systems of inequity.

Limitations

Our analyses were limited by the structure and completeness of the NIS. The NIS does not include data from all US states and does not include any data from US territories. However, in every year under study, HCUP partners participating in the NIS collectively covered 98% of the US population, resulting in a nationally representative sample despite the nonparticipating states. One potential source of bias stems from the nonstandardized collection of racial and ethnic status in the NIS. Collection and reporting of racial and ethnic status vary by and within HCUP partners. While some facilities routinely ask patients to self-identify, others may base racial and ethnic status collection on providers' judgement. However, because experiences of interpersonal and structural injustice (which would be primarily based on externally perceived racial and ethnic status) are some of the main factors contributing to racial and ethnic health disparities (25), we assumed this bias had only a negligible effect on our results. There may also be a disconnect in the numerator and population denominators when assigned racial and ethnic status does not match an individual's self-identification in the Census. Still, these facts, along with the differences in race and ethnicity reporting categories between the NIS and the Census Bureau Vintage 2020, likely resulted in some degree of misclassification. We believe these biases are nondifferential, especially for the largest racial and ethnic groups with a direct match between the NIS and the Census Bureau figures (non-Hispanic White, non-Hispanic Black, and Hispanic). Misclassification likely had the largest effect in the Other racial and ethnic group, as the population denominator used (individuals identifying in the Census as belonging to 2 or more racial groups) is not directly comparable. Another potential source of downward bias in all estimates is the incomplete collection of racial and ethnic status and subsequent exclusion of children with a missing racial and ethnic status. This exclusion may also have biased the estimated disparities if missingness is differential by racial and ethnic group, with the greatest potential for bias in estimates for the smaller racial and ethnic groups. Although between 3% and 7% of children in our data set had no identified racial and ethnic status, depending on year, this estimate is substantially improved from those of prior research (4). Given the small and relatively stable percentage of children with missing racial and ethnic status, we do not believe the exclusion of this group had a substantial impact on our results. There is also potential masking resulting from the NIS categorization of Hispanic ethnicity without consideration of Hispanic subgroup. Differences in asthma prevalence between various Hispanic subgroups has been well documented, with Puerto Rican children in particular bearing a disproportionate asthma burden (30). This lack of data into Hispanic patients' ethnic subgroup is likely masking important differences in asthma hospitalizations among Hispanic subpopulations.

Another set of limitations concerns changes in diagnostic coding and health care utilization patterns. Between the third and fourth calendar quarters of 2015, diagnostic coding of health care encounters changed from ICD-9-CM to ICD-10-CM. Relevant to this analysis, this change involved the differentiation of several chronic respiratory illnesses, such as chronic obstructive pulmonary disease, previously classified under the same set of codes as asthma. However, because the newly differentiated illnesses primarily affect adult populations, as well as the lack of dramatic shift in the demographic characteristics of hospitalized children (Table 1), the effect of these coding changes on pediatric populations is likely negligible. Still, we opted to calculate trends before and after this coding change separately to reduce the possibility of bias. Health care utilization shifted dramatically between 2019 and 2020 due to the onset of the COVID-19 pandemic. As AHRQ notes, the overall number of discharges in 2020 decreased by almost 9% compared with 2019 (31). Other authors identified shifts in health care utilization among patients with asthma specifically, noting a sharp decline in asthma-related ED visits in 2020, even more so than for ED visits overall (11,12,32,33). We therefore excluded 2020 from our trend analyses. As more recent years of the NIS are published and used to quantify the impact of the COVID-19 pandemic on health care utilization, future research will be better poised to analyze trends spanning the pandemic years.

Conclusion

Non-Hispanic Black and children categorized in the Other racial and ethnic group remain disproportionately burdened by asthma-related hospitalizations, as they have been for decades. Overall, the prevalence of pediatric asthma hospitalizations is decreasing, and prevalence is also decreasing among all racial and ethnic groups individually, albeit at a similar rate among all groups. While the overall decline is a positive development, the similar rates of decline among all groups has meant the continued persistence of racial and ethnic disparities. As such, interventions based on frameworks that address the unique challenges encountered by groups who face greater social disadvantage may be useful in reducing racial and ethnic asthma disparities.

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Tables

Table 1. Demographic Characteristics of Children[a] Hospitalized for Asthma, US National Inpatient Sample, 2012–2020[b]

Characteristic	2012	2013	2014	2015[b]	2016	2017	2018	2019	2020
Total no.	114,325	100,765	103,260	87,065	80,235	75,905	74,295	64,525	27,055
Sex, %									
Male	62.5	61.9	62.3	61.3	60.9	61.5	60.8	61.0	59.4
Female	37.5	38.1	37.7	38.7	39.1	38.5	39.2	39.0	40.6
Age, %, y									
0–4	48.9	48.1	45.3	46.6	45.7	45.1	46.0	44.6	40.7
5–9	31.9	32.7	35.4	33.6	34.5	33.4	33.1	33.1	33.2
10–17	19.2	19.2	19.3	19.8	19.8	21.5	21.0	22.3	26.1
Race and ethnicity,[c] %									
NH White	31.9	29.8	30.1	29.1	28.3	27.7	28.7	28.3	29.3
NH Black	32.9	33.6	34.0	34.6	35.0	35.0	33.9	34.5	36.2
Hispanic	20.7	21.5	20.8	21.5	21.2	22.0	22.3	23.3	20.1
NH Asian	2.6	2.5	2.5	2.7	2.8	3.3	3.4	3.4	2.5
NH Native American	0.7	0.7	0.8	0.9	0.8	0.8	0.8	0.8	0.9
Other[d]	4.9	5.1	5.1	4.9	5.3	5.9	6.2	5.8	6.1
Missing/invalid	6.3	6.7	6.8	6.2	6.6	5.4	4.8	3.9	4.9

Abbreviation: NH, non-Hispanic.
[a] Defined as aged ≤17 years.
[b] The *International Classification of Diseases, 9th Revision, Clinical Modification* was used through the end of September 2015; starting in October 2015, the *International Classification of Diseases, 10th Revision, Clinical Modification* was used.
[c] Racial and ethnic categories as they appear in the National Inpatient Sample.
[d] The National Inpatient Sample does not define the Other racial and ethnic category.

Table 2. Estimates of Population-Based Rates (Per 10,000 Population) of Pediatric[a] Asthma Hospitalizations, by Demographic Characteristic, US National Inpatient Sample, 2012–2020[b]

Characteristic	2012	2013	2014	2015[a]	2016	2017	2018	2019	2020
	% (95% CI)								
Sex									
Male	19.0 (16.9–21.0)	16.6 (14.7–18.5)	17.1 (15.2–19.1)	14.2 (12.6–15.8)	13.0 (11.5–14.5)	12.4 (11.0–13.9)	12.1 (10.6–13.5)	10.5 (9.3–11.8)	4.3 (3.8–4.9)
Female	11.9 (10.6–13.2)	10.7 (9.4–11.9)	10.8 (9.6–12.1)	9.4 (8.3–10.4)	8.7 (7.6–9.8)	8.1 (7.1–9.1)	8.1 (7.1–9.1)	7.0 (6.2–7.9)	3.1 (2.7–3.5)
Age, y									
0–4	28.0 (24.9–31.0)	24.4 (21.6–27.2)	23.5 (20.8–26.2)	20.4 (18.0–22.7)	18.4 (16.2–20.6)	17.2 (15.2–19.2)	17.3 (15.1–19.4)	14.7 (12.9–16.4)	5.7 (5.0–6.4)
5–9	17.8 (15.9–19.8)	16.0 (14.1–17.9)	17.8 (15.7–19.9)	14.3 (12.6–16.0)	13.5 (11.9–15.1)	12.5 (10.9–14.0)	12.2 (10.7–13.7)	10.6 (9.3–11.9)	4.4 (3.8–5.0)
10–17	6.6 (5.1–6.5)	5.8 (5.1–6.5)	6.0 (4.6–5.8)	5.2 (4.6–5.8)	4.8 (4.2–5.4)	4.9 (4.3–5.5)	4.7 (4.1–5.3)	4.3 (3.8–4.9)	2.1 (1.8–2.4)
Race and ethnicity									
NH White	9.4 (8.4–10.3)	7.8 (7.0–8.6)	8.1 (7.2–9.1)	6.7 (5.9–7.4)	6.0 (5.3–6.7)	5.6 (5.0–6.3)	5.8 (5.1–6.4)	5.0 (4.4–5.6)	2.2 (1.9–2.5)
NH Black	36.7 (31.2–42.2)	33.3 (28.0–38.6)	34.6 (29.3–39.8)	29.7 (25.2–34.2)	27.7 (23.4–32.0)	26.3 (22.1–30.4)	25.0 (20.8–29.2)	22.2 (18.6–25.8)	9.8 (8.2–11.3)
Hispanic	13.5 (11.2–15.7)	12.3 (10.2–14.3)	12.0 (10.1–13.9)	10.4 (8.7–12.1)	9.3 (7.8–10.8)	9.1 (7.6–10.5)	8.9 (7.4–10.4)	8.1 (6.8–9.4)	2.9 (2.4–3.4)
NH Asian	8.3 (6.5–10.1)	7.1 (5.1–9.1)	7.0 (4.9–9.1)	6.1 (4.6–7.6)	5.8 (4.1–7.5)	6.3 (4.5–8.1)	6.2 (4.2–8.2)	5.4 (4.1–6.7)	1.7 (1.3–2.1)
NH Native American	13.4 (9.6–17.1)	11.5 (7.7–15.3)	12.3 (8.9–15.7)	12.9 (8.7–17.1)	9.9 (7.1–12.7)	9.7 (6.4–13.0)	10.3 (7.0–13.6)	8.7 (5.7–11.8)	3.9 (2.4–5.3)
Other (≥2 races)[c]	19.7 (16.2–23.2)	17.5 (14.3–20.7)	17.4 (14.4–20.5)	13.8 (10.7–17.0)	13.6 (10.2–16.9)	13.9 (11.3–16.6)	14.2 (11.4–16.9)	11.2 (9.1–13.4)	4.9 (3.8–6.1)

Abbreviation: NH, Non-Hispanic.
[a] Defined as aged ≤17 years.
[b] The *International Classification of Diseases, 9th Revision, Clinical Modification* was used through the end of September 2015; starting in October 2015, the *International Classification of Diseases, 10th Revision, Clinical Modification* was used.
[c] The numerator for this group is the number of children listed as having a race of Other in the National Inpatient Sample, whereas the denominator is the number of children estimated to identify as "non-Hispanic, 2 or more races," according to the Census Bureau's vintage 2020 population estimates.

Table 3. Meta-Regression Results for Model Without Race by Year Interaction, US National Inpatient Sample, 2012–2015 and 2016–2019

Coefficient	2012–2015[a]		2016–2019[b]	
	Estimate (95% CI)	*P* value	Estimate (95% CI)	*P* value
Intercept	9.19 (8.54 to 9.83)	<.001	6.13 (5.64 to 6.62)	<.001
Year, slope	−0.83 (−1.14 to −0.52)	<.001	−0.35 (−0.58 to −0.12)	.003
Non-Hispanic White	1 [Reference]			
Non-Hispanic Black	25.37 (22.78 to 27.96)	<.001	19.47 (17.43 to 21.50)	<.001
Hispanic	4.05 (2.99 to 5.11)	<.001	3.23 (2.44 to 4.01)	<.001
Non-Hispanic Asian	−0.78 (−1.77 to 0.22)	.13	0.29 (−0.58 to 1.16)	.52
Non-Hispanic Native American	4.51 (7.44 to 10.76)	<.001	4.00 (2.43 to 5.58)	<.001
Other (≥2 races)	9.10 (7.44 to 10.76)	<.001	7.42 (6.07 to 8.77)	<.001

Abbreviation: BIC, Bayesian Information Criterion.
[a] BIC = 89.18.
[b] BIC = 76.90.

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Table 4. Meta-Regression Results for Model With Race by Year Interaction, US National Inpatient Sample, 2012–2015 and 2016–2019

Coefficients	2012–2015[a]		2016–2019[b]	
	Estimate (95% CI)	*P* value	Estimate (95% CI)	*P* value
Intercept	9.11 (8.35 to 9.88)	<.001	6.06 (5.50 to 6.62)	<.001
Year, slope	−0.78 (−1.16 to −0.40)	<.001	−0.31 (−0.59 to −0.02)	.03
Race				
NH White	1 [Reference]			
NH Black	27.47 (22.90 to 32.04)	<.001	21.96 (18.39 to 25.53)	<.001
Hispanic	4.39 (2.44 to 6.34)	<.001	3.35 (2.01 to 4.70)	<.001
NH Asian	−0.96 (−2.67 to 0.77)	.28	0.05 (−1.46 to 1.56)	.95
NH Native American	3.54 (0.29 to 6.78)	.03	3.98 (1.50 to 6.47)	.002
Other (≥2 races)	10.67 (7.73 to 13.62)	<.001	8.50 (5.88 to 11.11)	<.001
Race by year interaction				
Year × NH White	1 [Reference]			
Year × NH Black	−1.27 (−3.54 to 1.01)	.28	−1.52 (−3.31 to 0.27)	.10
Year × Hispanic	−0.20 (−1.15 to 0.75)	.68	−0.08 (−0.77 to 0.61)	.82
Year × NH Asian	−0.10 (−0.73 to 0.94)	.81	0.14 (−0.59 to 0.86)	.72
Year × NH Native American	0.67 (−1.11 to 2.45)	.46	0.02 (−1.33 to 1.37)	.98
Year × Other (≥2 races)	−1.00 (−2.51 to 0.54)	.20	−0.59 (−1.82 to 0.64)	.34

Abbreviations: BIC, Bayesian Information Criterion; NH, non-Hispanic.
[a] BIC = 101.38.
[b] BIC = 88.92.

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ORIGINAL RESEARCH

Sociodemographic Factors of Asthma Prevalence and Costs Among Children and Adolescents in the United States, 2016–2021

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PEER REVIEWED

Summary

What is already known on this topic?

Sociodemographic factors such as race and ethnicity are associated with the prevalence of asthma in children and adolescents.

What is added by this report?

While non-Hispanic Black children and adolescents had a higher prevalence of asthma than non-Hispanic White children and adolescents, non-Hispanic Black children and adolescents with treated asthma had $2,721.28 lower total medical expenditures and $803.19 lower office-based visit expenditures than non-Hispanic White children and adolescents with treated asthma.

What are the implications for public health practice?

This research can help public health practitioners direct additional attention and resources to reduce racial and ethnic disparities in the prevalence and cost of asthma among children and adolescents.

Abstract

Introduction

Asthma is a chronic condition with a high prevalence and cost of care among children and adolescents. While previous research described the association of sociodemographic factors with childhood asthma prevalence, there is limited knowledge of these factors' association with medical expenditures. In this study, we examined disparities in treated asthma prevalence and medical expenditures among US children and adolescents.

Methods

Using nationally representative data from the 2016–2021 Medical Expenditures Panel Survey, we conducted a cross-sectional study of 2,365 children and adolescents (aged 0–17 y) with treated asthma compared with 40,497 children and adolescents without treated asthma. Treated asthma was defined as whether the child or adolescent had a medical event (emergency department visit, hospital inpatient stay, hospital outpatient visit, office-based medical visit, home health, and/or prescribed medicines) due to asthma. We controlled for sociodemographic factors of race and ethnicity, age, sex, health insurance coverage, family poverty status, and census region. We used 2-part models and generalized linear models to estimate annual per-person incremental medical expenditures associated with asthma.

Results

Children and adolescents with treated asthma were more likely than those without treated asthma to be non-Hispanic Black or Hispanic, male, and publicly insured. Children and adolescents with treated asthma had $3,362.56 in additional annual medical expenditures, of which $174.06 was out-of-pocket, compared with children and adolescents without treated asthma. The additional expenditures included $955.96 for prescribed medicines, $151.52 for emergency department visits, and $858.17 for office-based medical visits. Non-Hispanic Black children with treated asthma had significantly lower total ($2,721.28) and office-based visit expenditures ($803.19) than non-Hispanic White children with treated asthma.

Conclusion

Disparities among children and adolescents in the US persist in treated asthma prevalence and associated medical expenditures by sociodemographic factors.

Introduction

Asthma is a chronic respiratory condition characterized by inflammation of the airways, leading to recurrent episodes of wheezing, breathlessness, chest tightness, and coughing. Asthma can affect people of all ages, but it often starts in childhood (1). It is one of the most prevalent and costly chronic conditions among children and adolescents and currently affects more than 4.6 million children and adolescents in the US (2). In 2013, the direct cost of pediatric asthma in the US was $5.92 billion; children and adolescents with asthma used more health care than those without asthma (3). Previous research using 2008–2013 national data estimated that children and adolescents who seek treatment for asthma have an additional $1,737 in annual medical expenditures compared with children and adolescents without asthma (4).

Several sociodemographic factors, such as race and ethnicity and family income, are associated with the prevalence of asthma among children and adolescents (5). Non-Hispanic Black (hereinafter, Black) children and adolescents are more than twice as likely than non-Hispanic White (hereinafter, White) children and adolescents to have asthma (11.6% vs 5.5%), and people below 100% of the federal poverty threshold are significantly more likely than people at or above 450% of the poverty threshold to have asthma (10.4% vs 6.8%) (2). Previous studies showed significantly lower medical expenditures among Black children and adolescents than among White children and adolescents and no significant differences in medical expenditures among different income levels (6,7).

Asthma management consists of a broad range of tools that include environmental factors, medication, and health education; however, the role of sociodemographic factors such as race and ethnicity as a marker of social factors that influence incremental medical expenditures for children with treated asthma has not been well examined (8). In this study, we examined the sociodemographic factors surrounding treated asthma in children, defined herein as persons aged 0 to 17 years, and quantified the per-person medical expenditures associated with treated asthma. We also hypothesized that racial and ethnic minority children, compared with White children, would have a higher prevalence of treated asthma and lower incremental expenditures of treated asthma.

Methods

We performed a pooled cross-sectional analysis of data from the 2016–2021 Medical Expenditures Panel Survey (MEPS) (9). MEPS is conducted annually from a subsample of National Health Interview Survey households to obtain detailed data on the medical expenditures of the noninstitutionalized US civilian population. We restricted our sample to children aged 0 to 17 years. First, we used the full-year Household Component of MEPS to obtain our sociodemographic factors of interest and expenditures data. We then combined the data from the Household Component with the relevant survey's Medical Event files to examine emergency department visits, hospital inpatient stays, hospital outpatient visits, office-based medical visits, home health visits, and prescribed medicines use for each respondent. We used the Medical Conditions file to establish that the medical event was due to asthma. MEPS's full-year response rate ranged from 46.0% in 2016 to 21.8% in 2021 (10). We pooled multiple years of data and used the variance linkage file (HC-036) to link data. We also used the complex survey design to create nationally representative estimates for US children. We adjusted all types of expenditures to the corresponding medical price index in 2021 US dollars (11).

Measures

The main outcomes of this analysis were treated asthma and associated medical expenditures. Treated asthma in children was defined by whether a child had at least 1 medical event (emergency department visit, hospital inpatient stay, hospital outpatient visit, office-based medical visit, home health, or prescribed medicine) in the calendar year that was due to asthma based on the Clinical Classifications Software Refined (CCSR) diagnosis code for asthma (RESP009) in the Medical Conditions file and was linked to an event in the Medical Event file (12). In accordance with MEPS analysis guidelines, we excluded informal telephone calls that came from office-based medical visits and hospital outpatient events and informal home health visits from our definition of treated asthma because these events are not associated with treating asthma (13). Starting in 2020, MEPS began including telehealth events that were classified as office-based medical visits or hospital outpatient events, and telehealth events that were used to treat asthma were included in our definition of treated asthma (13). MEPS also has a medical event category of "other medical equipment and services"; however, we excluded this category because it is not linked to the Medical Conditions file (13).

We measured total medical expenditures as the combined medical expenditures for each medical event category (emergency department visit, hospital inpatient stay, hospital outpatient visit, office-based medical visit, home health, and prescribed medicine) in the calendar year for the child/adolescent. We used 4 perspectives for this study: family or out-of-pocket, public payer, private payer, and all possible payers combined. We defined out-of-pocket medical expenditures as the total medical expenditures for the calendar year that were paid out-of-pocket for the medical care of the respondent. We also examined the total expenditures for each type of medical event (emergency department visit, hospital inpatient stay, hospital outpatient visit, office-based medical visit, home health, and prescribed medicine) during the whole calendar year.

Sociodemographic factors

We controlled for the sociodemographic factors of race and ethnicity, age, sex, family income, health insurance coverage, and region. Data on race and ethnicity were self-reported and coded as Hispanic; non-Hispanic Asian, Native Hawaiian, or Pacific Islander only (Asian); non-Hispanic Black only (Black), non-Hispanic White only (White), and non-Hispanic Other race, which includes American Indian, Alaska Native, and multiracial (Other). We categorized age into the following groups: 0 to 4 years, 5 to 14 years, and 15 to 17 years. Sex was defined as male or female. Family poverty status was determined by total family income divided by the applicable federal poverty line based on family size and composition and classified as negative or poor (≤100%), near poor (>100%–125%), low income (>125%–200%), middle income (>200%–400%), and high income (>400%). Health insurance coverage included the following categories: covered by private insurance (private insurance and TRICARE) at any time in the calendar year, covered only by public insurance (Medicaid and Medicare) during the calendar year, or uninsured for the entire calendar year. The regions were defined as Midwest, Northeast, South, and West. Our final sample consisted of 2,365 children (3,697,530 weighted) with treated asthma and 40,497 children (69,795,477 weighted) without treated asthma. This study was exempt from institutional review board review because it was a secondary data analysis of deidentified survey data.

Statistical analysis

We first summarized the descriptive statistics of our sample according to treated asthma status (children with treated asthma vs children without treated asthma); we used χ^2 tests to determine significant differences between the 2 groups. We used a multivariable logistic regression to estimate the association of sociodemographic factors with treated asthma as the outcome, and we calculated odds ratios (ORs) and 95% CIs. We used a 2-part model to estimate total all-payers medical expenditures, total out-of-pocket medical expenditures, total private payer medical expenditures, total public payer medical expenditures, and total medical expenditures for each medical event category. The model shows incremental medical expenditures for treated asthma and race and ethnicity while controlling for all other sociodemographic variables. The 2-part model was necessary because expenditures data are skewed to the left, are heteroskedastic, and have a large proportion of people with $0 in annual medical expenditures. To estimate incremental medical expenditures, we used the "twopm" command in Stata (StataCorp LLC). The first part of the 2-part model was a logit model, and the second part was a generalized linear regression with a log link and a gamma distribution. After running this model, we applied marginal effects to the independent variable of interest to determine its marginal or discrete effect on the continuous or discrete dependent variable, respectively (14). Finally, we used a 2-part model again to analyze the incremental medical event expenditures of treated asthma by each year. All analyses were completed in Stata version 18; significance was set at the .05 level.

Results

Among all races and ethnicities, Black children comprised a larger proportion of children in the population with treated asthma (21.8%) than in the population without treated asthma (13.2%) ($P < .001$) (Table 1). Among age groups, children with treated asthma were less likely to be aged 0 to 4 years (14.8%) than children without treated asthma (27.1%) ($P < .001$). Among children from families with negative or poor incomes, the percentage of children with treated asthma (22.7%) was higher than the percentage of children without treated asthma (16.4%) ($P < .001$). Children with treated asthma were more likely to be male than female (58.9% vs 41.1%), while the difference was smaller in children without treated asthma (50.6% vs 49.4%) ($P < .001$). Children with treated asthma were more likely than children without treated asthma to have public insurance (48.1% vs 36.6%) ($P < .001$) and to reside in the Northeast (19.6% vs 15.7%) and Midwest (24.6% vs 20.9%) ($P = .002$). Finally, treated asthma was more common in the first 3 years of our data (18.4% in 2016, 18.7% in 2017, 19.1% in 2018) than in the last 3 years (16.7% in 2019, 14.2% in 2020, 12.9% in 2021) ($P < .001$).

In the multivariable logistic regression of the sociodemographic factors affecting treated asthma status, children with treated asthma were more likely to be Black (OR = 1.78; 95% CI, 1.45–2.19) or Hispanic (OR = 1.22; 95% CI, 1.01–1.48) than non-Hispanic White, aged 5 to 14 years (OR = 2.22; 95% CI, 1.83–2.68) or 15 to 17 years (OR = 2.05; 95% CI, 1.61–2.59) than aged 0 to 4 years, male (OR = 1.40; 95% CI, 1.22–1.61) than female, publicly insured (OR = 1.28; 95% CI, 1.06–1.54) than privately insured, and from the Midwest (OR = 1.51; 95% CI, 1.21–1.89) or Northeast (OR = 1.47; 95% CI, 1.18–1.83) than from the South, and less likely to have no health insurance than have private insurance (OR = 0.55; 95% CI, 0.32–0.96) (Table 2).

The 2-part model shows that children with treated asthma had additional expenditures for all categories of medical events (Table 3). Children with treated asthma had $3,362.56 (95% CI, $2,654.55 to $4,070.57) in additional annual total medical expenditures, while Black children had $1,256.50 lower (95% CI,

−$1,578.66 to −$934.34) total medical expenditures and Hispanic children had $785.34 lower (95% CI, −$1,140.21 to −$430.47) total medical expenditures than White children. Children with treated asthma had $174.06 (95% CI, $81.39 to $266.73) in additional annual out-of-pocket medical expenditures, while Black children had $226.86 lower (95% CI, −$265.47 to −$188.25) out-of-pocket medical expenditures and Hispanic children had $106.66 lower (95% CI, −$153.44 to −$59.88) out-of-pocket medical expenditures than White children. Children with treated asthma had $955.96 in additional medical expenditures for prescribed medicine (95% CI, $776.99 to $1,134.93) than children without treated asthma, while Black children and Hispanic children had lower medical expenditures for prescribed medicines (−$155.80, 95% CI, −$217.90 to −$93.71; and −$142.02, 95% CI, −$201.12 to −$82.93, respectively) than White children. In addition, children with treated asthma had $858.17 in additional medical expenditures for office-based medical visits (95% CI, $613.85 to $1,102.50) than children without treated asthma while Black children and Hispanic children had lower medical expenditures for office-based medical visits (−$467.25; 95% CI, −$559.46 to −$375.04 and −$172.18; 95% CI, −$287.67 to −$56.68, respectively) than White children. Finally, children with treated asthma had $151.52 in additional medical expenditures for emergency department visits (95% CI, $101.76 to $201.27).

The incremental total, prescribed medicines, office-based medical visits, and emergency department visits medical expenditures for treated asthma was positive and high for all years, while incremental out-of-pocket medical expenditures were not significantly different from 0 in 2020 and 2021 (Table 4).

We found differences in total medical expenditures, emergency department visits, office-based medical visits, and prescribed medicines expenditures by treated asthma status for each race and ethnicity (Figure). Black children with treated asthma had $2,721.28 lower total medical expenditures and $803.19 lower office-based medical visit expenditures than White children with treated asthma.

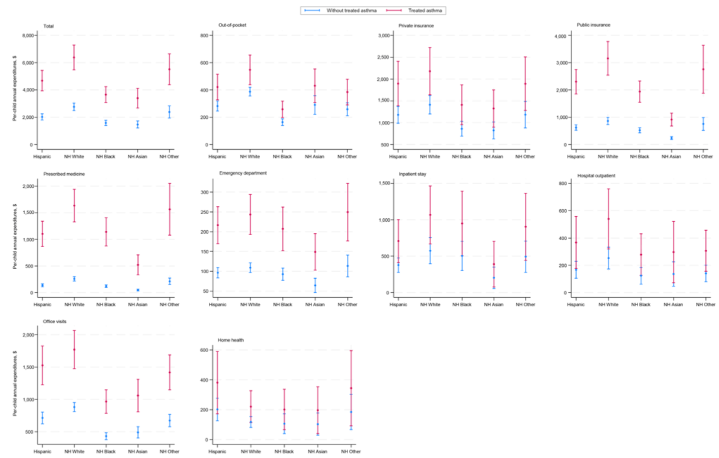

Figure. Total medical expenditures among children and adolescents aged 0 to 17 years, in dollars, by treated asthma and race and ethnicity, 2016–2021 Medical Expenditures Panel Survey. All estimates were pooled and weighted using the complex survey design. Non-Hispanic Other race includes American Indian, Alaska Native, and multiracial. Graphs use different scales. Abbreviation: NH, non-Hispanic.

Discussion

In this study of US children from 2016 through 2021, we found that children with treated asthma had significantly higher medical expenditures ($3,362.56 in 2021 US dollars) than children without treated asthma. Previous research of 2008-2013 MEPS data found an average of $3,266 in incremental medical expenditures attributed to asthma for the total population and $1,737 in 2015 US dollars for children (4). Our incremental medical expenditure estimates for children with treated asthma are higher than previous incremental medical expenditure estimates for all ages of treated asthma, which may suggest that the incremental medical expenditures of treated asthma for children have been increasing over time.

We found that the incremental medical costs of US children with asthma from 2016 through 2021 included $955.96 for prescribed medicines, $151.52 for emergency department visits, $858.17 for office-based medical visits, $685.39 for inpatient hospital stays, $243.22 in hospital-based outpatient visits, and $99.34 in home health visits. Previous estimates of the total US population that used data from the 2008–2013 MEPS found incremental medical expenditures of $1,830 in prescribed medicines, $105 in emergency department visits, $640 in office-based medical visits, $529 in inpatient hospital stays, and $176 in hospital-based outpatient visits for people with asthma (4). The incremental expenditures estimates based on the 2008–2013 MEPS data were smaller than the estimates in our study for every category except for prescribed medicines, which might be explained by children typically having less use of prescribed medicines than the population of all ages

(15). However, in the 2008–2013 MEPS analysis, US children had significantly lower total incremental medical expenditures for asthma compared with adults ($1,737 vs $3,761). In addition, the 2008–2013 MEPS children's incremental expenditure estimate was lower than the $3,362.56 of total incremental expenditures of treated asthma for children in our study, which was based on more recent (2016–2021) data. Another study of US school-aged children (aged 6–17 y) in 2007–2013 found incremental costs of $847 in total medical expenditures, $360 in prescribed medicines, and $132 in emergency department visits due to asthma (16). Our results might reflect increases in the use and/or costs of medical events for children who seek medical treatment for asthma in recent years. Future research can be conducted to estimate the causes of medical use and cost trends for asthma.

Prescribed medicines were a large component of medical expenditures for children with treated asthma. The cost of asthma medication increased by 36% from 2013 to 2018, from $280 to $380 (17). Because we estimated the expenditures of all prescribed medicines and not just asthma medicine, it is possible that children with treated asthma were also taking medicine for other comorbid conditions, as previous research shows higher prevalences of almost all comorbidities for children with asthma compared with children without asthma (18). Additional analyses can examine the types of medicines prescribed for children with asthma and their implications for the cost of treating asthma.

Consistent with previous results, our findings indicate that Black and Hispanic children have a significantly higher prevalence of treated asthma than White children (2). Previous research showed that the asthma burden is greater among non-Hispanic Black children than non-Hispanic White children even after adjusting for confounding factors of demographic characteristics, socioeconomic status, comorbidities, and asthma treatment compliance (19). At the same time, our study showed that Black and Hispanic children with treated asthma had lower total medical expenditures than White children with treated asthma. This matches the patterns of racial and ethnic disparity seen in patients with diabetes (20) and may be due to the reduced use of health services and medication by Black and Hispanic children. Our analysis by medical event showed no significant differences between Black and White children in medical event expenditures, except for office-based visits. Previous research showed that non-Hispanic Black children with asthma had fewer family provider visits for asthma and were less likely to receive a written asthma treatment plan from their health care provider than non-Hispanic White children with asthma (21). Also, previous research showed that Black children with asthma had the lowest likelihood of using the physician's office as the usual place of care among children of all racial and ethnic groups with asthma (22). Research shows heightened medical mistrust among non-Hispanic Black patients compared with non-Hispanic White patients as a reason for reduced primary care use (23). Historical events such as the Tuskegee syphilis study are often cited as reasons for heightened medical mistrust among Black persons (24). Further research can improve our understanding of racial disparities in seeking asthma treatment through physicians' offices.

In our analysis, the prevalence of treated asthma among non-Hispanic Asian children was not significantly different from the prevalence among non-Hispanic White children, but non-Hispanic Asian children had lower medical expenditures than non-Hispanic White children. Previous research based on the 2002–2008 MEPS data showed that non-Hispanic Asian persons had lower medical expenditures than non-Hispanic White persons (25). Another study of 2013–2016 MEPS data showed differences in medical expenditures among Asian subgroups, while Asian persons had lower medical expenditures overall compared with non-Hispanic White persons (26). Both studies suggested that differences in medical expenditures were due to differences in nativity (non–US-born vs US-born) and English language proficiency between non-Hispanic Asian and non-Hispanic White children and families.

We did not find significant disparities in treated asthma prevalence based on family income. This finding matches research that concluded that racial disparities in childhood asthma are not solely the result of socioeconomic disparities between racial groups, because race is a complex construct of genetic, environmental, and social factors (27). Historical practices such as redlining, which classified neighborhoods with higher concentrations of Black and other racial minorities as less financially desirable, led to racial and socioeconomic segregation and are associated with present-day disparities in asthma prevalence and severity (28).

Our study period coincided with the COVID-19 pandemic. The prevalence of treated asthma decreased during 2020 and 2021; this decrease may be attributed to individuals avoiding nonurgent medical services during the pandemic and the decreased availability of outpatient medical visits. Telehealth became more available during the COVID-19 pandemic; however, this increased availability could have affected health care delivery among patients who did not have access to telehealth technology or did not have insurance coverage for telehealth services (29). Previous research found that medication adherence increased during the COVID-19 pandemic, which might have increased expenditures for prescribed medicines (29). Also, emergency department visits for pediatric asthma decreased in the early months of 2020 (29). Additional research on the costs of treating asthma during the COVID-19 pandemic and the role of telehealth can reveal the costs and benefits of telehealth.

Our study found lower average total and out-of-pocket medical expenditures among Black and Hispanic children with treated asthma than among White children with treated asthma. However, this finding does not mean that the economic burden was reduced among Black and Hispanic families. For example, previous research found that parents of Black and Hispanic children were less likely to have annual out-of-pocket medical expenditures of more than $1,000, but they were more likely to report unreasonably high out-of-pocket spending than the parents of White children (30).

We found that out-of-pocket medical expenditures for children with treated asthma were not significantly different than those for children without treated asthma in 2020 and 2021. This finding suggests a decrease in the use of medical events that contributed to increased out-of-pocket expenditures for children with treated asthma or a decrease in out-of-pocket expenditure during these years. Further analysis can examine the types of medical events that contribute to disparities in out-of-pocket medical expenditures between children with and without treated asthma.

We found that public payers generally incurred the highest incremental medical expenditures for asthma among US children, followed by private payers. Children with treated asthma were more likely than children without treated asthma to have public health insurance, which means that public health insurance coverage of asthma care is crucial to eliminating inequities in health expenditures (31). Previous analysis of data from the 2012–2014 Child Asthma Call-Back Survey found that public insurance, compared with private insurance, was associated with cost barriers to seeking a physician for care (32). A study of children who were hospitalized for asthma and had public insurance found that these children had longer stays, higher costs, and higher readmission odds compared with privately insured children (33). Further research can examine the interaction of the types of health insurance and the types of health services that are covered for asthma care.

Limitations

This study has several limitations. First, our data did not assess all the various social determinants of health, such as the built environment, that can affect exposure to indoor and outdoor asthma triggers (34). Second, we did not assess the severity of asthma, which can affect the medical costs of treated asthma (35). Third, we did not examine the total economic burden of asthma among children, which includes days absent from school and was considered in previous research (4). However, after 2016, the MEPS no longer collected data on school absenteeism. Therefore, we could not measure the costs of missed school days due to asthma among children.

Conclusion

Childhood asthma remains a substantial health and economic burden for US families, payers, providers, and the overall society. The incremental costs of treated asthma for children from 2016 through 2021 were higher than in previous estimates, which suggests an urgent need to promote and implement cost-effective asthma control programs. Black and Hispanic children have a higher prevalence of treated asthma than White children, but not necessarily higher medical expenditures. This finding might be driven by disparities in office-based medical visit expenditures and by possible undertreatment of asthma. Further investigation of how to improve access to and the quality of asthma care for disproportionately affected children can help to advance health equity in asthma prevalence and asthma-related medical expenditures.

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Tables

Table 1. Weighted Sample Characteristics of US Children and Adolescents, by Treated Asthma Status, 2016–2021[a]

Characteristic	Children without treated asthma, %	Children with treated asthma, %	Unweighted no. (%)	*P* value[b]
Race and ethnicity				
Hispanic	25.4	27.0	15,447 (25.5)	<.001
Non-Hispanic Asian	5.4	3.7	2,094 (5.3)	
Non-Hispanic Black	13.2	21.8	7,026 (13.7)	
Non-Hispanic White	49.8	41.0	15,688 (49.4)	
Non-Hispanic Other[c]	6.2	6.7	2,607 (6.2)	
Age, y				
0-4	27.1	14.8	10,303 (26.5)	<.001
5-14	55.2	66.1	24,977 (55.7)	
15–17	17.7	19.1	7,582 (17.8)	
Sex				
Male	50.6	58.9	21,969 (51.0)	<.001
Female	49.4	41.1	20,893 (49.0)	
Health insurance coverage				
Any private	60.6	50.4	19,955 (60.1)	<.001
Public only	36.6	48.1	21,508 (37.2)	
Uninsured	2.8	1.4	1,399 (2.7)	
Family poverty status[d]				
Negative or poor[e]	16.4	22.7	11,905 (16.7)	<.001
Near poor	5.5	7.4	2,996 (5.6)	
Low income	15.0	18.0	7,294 (15.2)	
Middle income	30.0	24.7	11,203 (29.7)	
High income	33.1	27.2	9,464 (32.8)	
Region				
Northeast	15.7	19.6	5,968 (15.9)	.002
Midwest	20.9	24.6	8,607 (21.1)	
South	39.0	35.1	17,000 (38.8)	
West	24.3	20.7	11,287 (24.2)	
Year				
2016	16.7	18.4	9,211 (16.8)	<.001
2017	16.6	18.7	8,158 (16.7)	
2018	16.6	19.1	7,449 (16.7)	

[a] Data source: 2016–2021 Medical Expenditures Panel Survey. All estimates are pooled and weighted, adjusting for the complex survey design.
[b] Pearson χ^2 test used to test differences.
[c] Includes American Indian, Alaska Native, and multiracial.
[d] Total family income is divided by the applicable federal poverty line based on family size and composition and classified as negative or poor (≤100%), near poor (>100%–125%), low income (>125%–200%), middle income (>200%–400%), or high income (>400%).
[e] Negative income is when an individual's total expenses exceed their total income.

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Table 1. Weighted Sample Characteristics of US Children and Adolescents, by Treated Asthma Status, 2016–2021[a]

Characteristic	Children without treated asthma, %	Children with treated asthma, %	Unweighted no. (%)	*P* value[b]
2019	16.8	16.7	6,558 (16.8)	
2020	16.6	14.2	5,929 (16.4)	
2021	16.8	12.9	5,557 (16.6)	

[a] Data source: 2016–2021 Medical Expenditures Panel Survey. All estimates are pooled and weighted, adjusting for the complex survey design.
[b] Pearson χ^2 test used to test differences.
[c] Includes American Indian, Alaska Native, and multiracial.
[d] Total family income is divided by the applicable federal poverty line based on family size and composition and classified as negative or poor (≤100%), near poor (>100%–125%), low income (>125%–200%), middle income (>200%–400%), or high income (>400%).
[e] Negative income is when an individual's total expenses exceed their total income.

Table 2. Multivariable Logistic Regression of Factors Influencing Children's and Adolescents' Treated Asthma Status[a]

Characteristic	Odds Ratio (95% CI) [*P* value]
Race and ethnicity	
Hispanic	1.22 (1.01–1.48) [.04]
Non-Hispanic Asian	0.82 (0.52–1.30) [.40]
Non-Hispanic Black	1.78 (1.45–2.19) [<.001]
Non-Hispanic White	1 [Reference]
Non-Hispanic Other[b]	1.29 (0.96–1.72) [.09]
Age, y	
0–4	1 [Reference]
5–14	2.22 (1.83–2.68) [<.001]
15–17	2.05 (1.61–2.59) [<.001]
Sex	
Male	1.40 (1.22–1.61) [<.001]
Female	1 [Reference]
Health insurance coverage	
Any private	1 [Reference]
Public only	1.28 (1.06–1.54) [.01]
Uninsured	0.55 (0.32–0.96) [.04]
Family income	
Negative or poor[c]	1.25 (0.96–1.62) [.10]
Near poor	1.24 (0.91–1.70) [.16]
Low income	1.17 (0.90–1.52) [.24]
Middle income	0.89 (0.73–1.09) [.26]
High income	1 [Reference]
Region	
Midwest	1.51 (1.21–1.89) [<.001]
Northeast	1.47 (1.18–1.83) [.001]
West	1.03 (0.83–1.27) [.80]
South	1 [Reference]

[a] Data source: 2016–2021 Medical Expenditures Panel Survey. All estimates are pooled and weighted, adjusting for the complex survey design.
[b] Includes American Indian, Alaska Native, and multiracial.
[c] Negative income is when an individual's total expenses exceed their total income.

Table 3. Two-Part Model of Incremental Medical Expenditures of US Children, by Race and Ethnicity and Treated Asthma, 2016–2021[a]

Characteristic	Logit estimate (95% CI)	*P* value	GLM estimate (95% CI), $	*P* value
Total				
Treated asthma status				
With treated asthma	—	—	3,362.56 (2,654.55 to 4,070.57)	<.001
Without treated asthma	—	—	Reference	
Race and ethnicity				
Hispanic	—	—	−785.34 (−1,140.21 to −430.47)	<.001
Non-Hispanic Asian	—	—	−1,376.94 (−1,776.66 to −977.22)	<.001
Non-Hispanic Black	—	—	−1,256.50 (−1,578.66 to −934.34)	<.001
Non-Hispanic White	—	—	Reference	
Non-Hispanic Other[b]	—	—	−400.81 (−954.00 to 152.38)	.16
Total private payer				
Treated asthma status				
With treated asthma	1.189 (0.963 to 1.415)	<.001	1,188.74 (597.02 to 1,780.46)	<.001
Without treated asthma	Reference		Reference	
Race and ethnicity				
Hispanic	−0.525 (−0.677 to −0.372)	<.001	−233.54 (−501.20 to 34.12)	.09
Non-Hispanic Asian	−0.536 (−0.813 to −0.260)	<.001	−600.90 (−882.70 to −319.10)	<.001
Non-Hispanic Black	−0.703 (−0.887 to −0.518)	<.001	−560.58 (−800.15 to −321.01)	<.001
Non-Hispanic White	Reference		Reference	
Non-Hispanic Other[b]	−0.486 (−0.721 to −0.250)	<.001	−230.90 (−584.70 to 122.89)	.20
Total public payer				
Treated asthma status				
With treated asthma	1.445 (1.279 to 1.611)	<.001	1,499.60 (1,135.31 to 1,863.90)	<.001
Without treated asthma	Reference		Reference	
Race and ethnicity				
Hispanic	−0.096 (−0.236 to 0.044)	.18	−270.01 (−433.87 to −106.15)	.001
Non-Hispanic Asian	−0.403 (−0.718 to −0.087)	.01	−705.02 (−862.59 to −547.46)	<.001
Non-Hispanic Black	−0.114 (−0.325 to 0.096)	.29	−382.74 (−551.55 to −213.92)	<.001
Non-Hispanic White	Reference		Reference	—
Non-Hispanic Other[b]	0.039 (−0.190 to 0.269)	.74	−120.81 (−423.73 to 182.10)	.43
Total out-of-pocket				
Treated asthma status				
With treated asthma	1.378 (1.236 to 1.521)	<.001	174.06 (81.39 to 266.73)	<.001
Without treated asthma	Reference		Reference	
Race and ethnicity				
Hispanic	−0.398 (−0.482 to −0.314)	<.001	−106.66 (−153.44 to −59.88)	<.001

Abbreviation: GLM, generalized linear model.
[a] Data source: 2016–2021 Medical Expenditures Panel Survey. All estimates were adjusted for the sociodemographic factors included in the analysis. All estimates are pooled and weighted, adjusting for the complex survey design. Expenditures are adjusted to 2021 US dollars.
[b] Includes American Indian, Alaska Native, and multiracial.

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Table 3. Two-Part Model of Incremental Medical Expenditures of US Children, by Race and Ethnicity and Treated Asthma, 2016–2021[a]

Characteristic	Logit estimate (95% CI)	*P* value	GLM estimate (95% CI), $	*P* value
Non-Hispanic Asian	−0.350 (−0.536 to −0.164)	<.001	−98.09 (−173.51 to −22.66)	.01
Non-Hispanic Black	−0.698 (−0.818 to −0.579)	<.001	−226.86 (−265.47 to −188.25)	<.001
Non-Hispanic White	Reference		Reference	
Non-Hispanic Other[b]	−0.365 (−0.505 to −0.224)	<.001	−130.46 (−188.55 to −72.37)	<.001
Prescribed medicine				
Treated asthma status				
With treated asthma	4.468 (4.000 to 4.936)	<.001	955.96 (776.99 to 1,134.93)	<.001
Without treated asthma	Reference		Reference	
Race and ethnicity				
Hispanic	−0.392 (−0.490 to −0.294)	<.001	−142.02 (−201.12 to −82.93)	<.001
Non-Hispanic Asian	−0.839 (−1.003 to −0.675)	<.001	−256.41 (−307.71 to −205.10)	<.001
Non-Hispanic Black	−0.631 (−0.752 to −0.511)	<.001	−155.80 (−217.90 to −93.71)	<.001
Non-Hispanic White	Reference		Reference	
Non-Hispanic Other[b]	−0.258 (−0.444 to −0.073)	<.001	−47.89 (−137.68 to 41.91)	.30
Office-based medical visits				
Treated asthma status				
With treated asthma	1.205 (1.026 to 1.384)	<.001	858.17 (613.85 to 1,102.50)	<.001
Without treated asthma	Reference		Reference	
Race and ethnicity				
Hispanic	−0.470 (−0.582 to −0.359)	<.001	−172.18 (−287.67 to −56.68)	.004
Non-Hispanic Asian	−0.521 (−0.709 to −0.333)	<.001	−406.62 (−521.22 to −292.02)	<.001
Non-Hispanic Black	−0.734 (−0.856 to −0.613)	<.001	−467.25 (−559.46 to −375.04)	<.001
Non-Hispanic White	Reference		Reference	
Non-Hispanic Other[b]	−0.368 (−0.564 to −0.172)	<.001	−216.08 (−331.89 to −100.28)	<.001
Emergency department visits				
Treated asthma status				
With treated asthma	0.918 (0.751 to 1.085)	<.001	151.52 (101.76 to 201.27)	<.001
Without treated asthma	Reference		Reference	
Race and ethnicity				
Hispanic	−0.071 (−0.198 to 0.056)	.27	−13.45 (−32.03 to 5.12)	.16
Non-Hispanic Asian	−0.420 (−0.678 to −0.162)	<.001	−47.35 (−70.12 to −24.59)	<.001
Non-Hispanic Black	−0.043 (−0.203 to 0.117)	.60	−17.63 (−38.78 to 3.52)	.10
Non-Hispanic White	Reference		Reference	
Non-Hispanic Other[b]	0.137 (−0.066 to 0.340)	.19	4.58 (−26.01 to 35.17)	.77
Inpatient stays				

Abbreviation: GLM, generalized linear model.
[a] Data source: 2016–2021 Medical Expenditures Panel Survey. All estimates were adjusted for the sociodemographic factors included in the analysis. All estimates are pooled and weighted, adjusting for the complex survey design. Expenditures are adjusted to 2021 US dollars.
[b] Includes American Indian, Alaska Native, and multiracial.

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Table 3. Two-Part Model of Incremental Medical Expenditures of US Children, by Race and Ethnicity and Treated Asthma, 2016–2021[a]

Characteristic	Logit estimate (95% CI)	*P* value	GLM estimate (95% CI), $	*P* value
Treated asthma status				
With treated asthma	1.244 (0.957 to 1.531)	<.001	685.39 (291.11 to 1,079.67)	.001
Without treated asthma	Reference		Reference	
Race and ethnicity				
Hispanic	−0.201 (−0.422 to 0.020)	.07	−205.46 (−401.31 to −9.62)	.04
Non-Hispanic Asian	−0.716 (−1.261 to −0.170)	.01	−386.02 (−628.81 to −143.22)	.002
Non-Hispanic Black	−0.265 (−0.527 to −0.004)	.046	−72.73 (−304.04 to 158.57)	.54
Non-Hispanic White	Reference		Reference	
Non-Hispanic Other[b]	0.220 (−0.109 to 0.549)	.19	−84.91 (−360.70 to 190.88)	.55
Hospital outpatient				
Treated asthma status				
With treated asthma	0.686 (0.518 to 0.855)	<.001	243.22 (66.15 to 420.30)	.007
Without treated asthma	Reference		Reference	
Race and ethnicity				
Hispanic	−0.326 (−0.498 to −0.155)	<.001	−89.82 (−152.11 to −27.54)	.005
Non-Hispanic Asian	−0.231 (−0.585 to 0.123)	.20	−122.60 (−229.28 to −15.92)	.02
Non-Hispanic Black	−0.696 (−0.896 to −0.497)	<.001	−135.35 (−189.84 to −80.86)	<.001
Non-Hispanic White	Reference		Reference	
Non-Hispanic Other[b]	−0.175 (−0.416 to 0.066)	.15	−117.63 (−191.95 to −43.31)	.002
Home health				
Treated asthma status				
With treated asthma	0.879 (0.515 to 1.244)	<.001	99.34 (−5.21 to 203.90)	.06
Without treated asthma	Reference		Reference	
Race and ethnicity				
Hispanic	−0.385 (−0.744 to −0.026)	.04	87.52 (6.47 to 168.58)	.03
Non-Hispanic Asian	−0.598 (−1.313 to 0.118)	.10	−14.95 (−101.39 to 71.49)	.73
Non-Hispanic Black	−0.593 (−1.027 to −0.158)	.008	−12.12 (−91.00 to 66.77)	.76
Non-Hispanic White	Reference		Reference	
Non-Hispanic Other[b]	0.204 (−0.318 to 0.727)	.44	69.57 (−58.42 to 197.56)	.29

Abbreviation: GLM, generalized linear model.
[a] Data source: 2016–2021 Medical Expenditures Panel Survey. All estimates were adjusted for the sociodemographic factors included in the analysis. All estimates are pooled and weighted, adjusting for the complex survey design. Expenditures are adjusted to 2021 US dollars.
[b] Includes American Indian, Alaska Native, and multiracial.

Table 4. US Annual Per-Child Incremental Medical Expenditures of Treated Asthma, 2016–2021[a]

Category	Estimate (95% CI), $	*P* value[b]
Total		
Pooled	3,362.56 (2,654.55 to 4,070.57)	<.001
2016	3,016.90 (1,864.87 to 4,168.94)	<.001
2017	4,327.59 (2,609.10 to 6,046.08)	<.001
2018	3,687.54 (2,387.72 to 4,987.35)	<.001
2019	3,085.89 (1,894.30 to 4,277.48)	<.001
2020	3,257.84 (1,213.67 to 5,302.01)	.002
2021	3,049.68 (1,419.40 to 4,679.96)	<.001
Total private payer		
Pooled	1,188.74 (597.02 to 1,780.46)	<.001
2016	1,260.57 (337.14 to 2,184.00)	.008
2017	3,360.82 (959.22 to 5,762.42)	.006
2018	4,088.02 (1832.01 to 6,344.02)	<.001
2019	871.83 (81.25 to 1,662.42)	.03
2020	649.17 (−630.26 to 1,928.60)	.32
2021	19.81 (−420.62 to 460.24)	.93
Total public payer		
Pooled	1,499.60 (1,135.31 to 1,863.90)	<.001
2016	1,639.72 (903.30 to 2,376.13)	<.001
2017	2,177.15 (945.44 to 3,408.85)	.001
2018	948.75 (578.72 to 1,318.78)	<.001
2019	1,571.21 (793.35 to 2,349.07)	<.001
2020	1,641.26 (704.41 to 2,578.11)	.001
2021	2,142.29 (1,094.65 to 3,189.93)	<.001
Total out-of-pocket		
Pooled	174.06 (81.39 to 266.73)	<.001
2016	195.82 (72.92 to 318.72)	.002
2017	199.68 (78.14 to 321.22)	.001
2018	368.12 (5.14 to 731.11)	.047
2019	224.44 (52.42 to 396.46)	.01
2020	10.28 (−87.95 to 108.51)	.84
2021	129.60 (−94.31 to 353.50)	.26
Prescribed medicine		
Pooled	955.96 (776.99 to 1,134.93)	<.001
2016	854.74 (609.15 to 1,100.33)	<.001
2017	1,378.30 (838.16 to 1,918.44)	<.001
2018	1,161.92 (757.98 to 1,565.86)	<.001

[a] Data source: 2016–2021 Medical Expenditures Panel Survey. All estimates were adjusted for the sociodemographic factors included in the analysis. All estimates are pooled and weighted, adjusting for the complex survey design. Expenditures are adjusted to 2021 US dollars.
[b] Determined by Pearson χ^2 test.

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Table 4. US Annual Per-Child Incremental Medical Expenditures of Treated Asthma, 2016–2021[a]

Category	Estimate (95% CI), $	*P* value[b]
2019	957.07 (650.21 to 1,263.94)	<.001
2020	633.51 (398.85 to 868.18)	<.001
2021	1,006.50 (598.91 to 1,414.10)	<.001
Office-based medical visits		
Pooled	858.17 (613.85 to 1,102.50)	<.001
2016	791.53 (413.46 to 1,169.60)	<.001
2017	989.58 (570.86 to 1,408.29)	<.001
2018	1,023.65 (483.54 to 1,563.76)	<.001
2019	607.73 (293.53 to 921.93)	<.001
2020	783.24 (228.12 to 1,338.37)	.006
2021	1,090.21 (300.40 to 1,880.02)	.007
Emergency department visits		
Pooled	151.52 (101.76 to 201.27)	<.001
2016	160.21 (63.96 to 256.46)	.001
2017	215.70 (108.55 to 322.85)	<.001
2018	129.54 (30.72 to 228.36)	.01
2019	158.20 (58.30 to 258.10)	.002
2020	135.12 (17.17 to 253.08)	.03
2021	78.97 (18.43 to 139.51)	.01
Hospital inpatient stays		
Pooled	685.39 (291.11 to 1,079.67)	.001
2016	349.50 (−228.45 to 927.45)	.24
2017	962.20 (−124.84 to 2,049.24)	.08
2018	838.26 (146.63 to 1,529.89)	.02
2019	833.57 (65.12 to 1,602.02)	.03
2020	1,530.18 (−639.16 to 3,699.52)	.17
2021	295.25 (−260.48 to 850.98)	.30
Hospital outpatient		
Pooled	243.22 (66.15 to 420.30)	.007
2016	164.73 (35.64 to 293.82)	.01
2017	221.02 (4.32 to 437.72)	.046
2018	383.09 (42.63 to 723.55)	.03
2019	108.36 (−79.77 to 296.49)	.26
2020	223.55 (−163.00 to 610.09)	.26
2021	257.25 (−20.28 to 534.79)	.07
Home health		

[a] Data source: 2016–2021 Medical Expenditures Panel Survey. All estimates were adjusted for the sociodemographic factors included in the analysis. All estimates are pooled and weighted, adjusting for the complex survey design. Expenditures are adjusted to 2021 US dollars.
[b] Determined by Pearson χ^2 test.

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Table 4. US Annual Per-Child Incremental Medical Expenditures of Treated Asthma, 2016–2021[a]

Category	Estimate (95% CI), $	*P* value[b]
Pooled	99.34 (−5.21 to 203.90)	.06
2016	320.37 (−29.94 to 670.69)	.07
2017	−28.32 (−146.42 to 89.79)	.64
2018	153.39 (−142.27 to 449.06)	.31
2019	197.39 (−79.06 to 473.84)	.16
2020	118.43 (−134.77 to 371.64)	.36
2021	329.55 (−498.06 to 1,157.16)	.43

[a] Data source: 2016–2021 Medical Expenditures Panel Survey. All estimates were adjusted for the sociodemographic factors included in the analysis. All estimates are pooled and weighted, adjusting for the complex survey design. Expenditures are adjusted to 2021 US dollars.
[b] Determined by Pearson χ^2 test.

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GIS SNAPSHOTS

Asthma Hot Spots in New York Before and During the COVID-19 Pandemic

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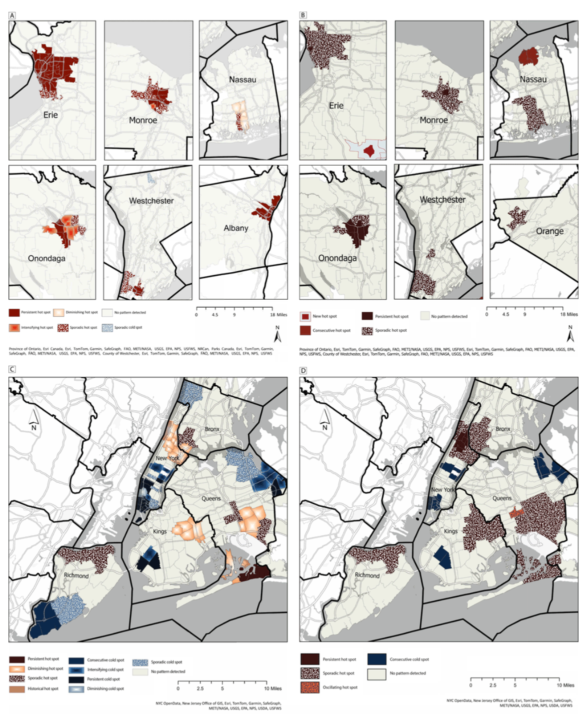

Panels A and B show results of Emerging Hot Spot Analysis (Esri) by zip code level for counties outside New York City with a high asthma burden, before and during the COVID-19 pandemic. Hot spots were detected in urban areas, including Albany (Albany County), Buffalo (Erie County), Rochester (Monroe County), Syracuse (Onondaga County), around Hempstead (Nassau County), and around Yonkers (Westchester County). The analyses for Dutchess and Orange counties did not yield significant results in the 2016 to 2019 time period. The analyses for Dutchess and Albany counties did not yield significant results in the 2020 to quarter 2, 2022 time period. Results for Albany County may be affected by missing data caused by a known lag in reporting by area hospitals during the pandemic. A: Emerging Hot Spot Analysis of zip code-level quarterly asthma emergency department visits per 10,000 population in high-asthma-burden counties, New York State, 2016 to 2019. B: Emerging Hot Spot Analysis of zip code-level quarterly asthma emergency department visits per 10,000 population in high-asthma-burden counties, New York State, 2020 to quarter 2, 2022. Panels C and D show results of Emerging Hot Spot Analysis by zip code level and by county for New York City before and during the COVID-19 pandemic. The dark gray lines represent county borders, and the light gray lines represent zip code borders. The area of zip codes in New York City is shaded according to the emerging hot spot result legend. Panel C shows quarterly asthma emergency department visits per 10,000 population in high asthma burden counties, 2016 to 2019. Panel D shows quarterly emergency department visits per 10,000 population in high asthma burden counties, 2020 to quarter 2, 2022.

Background

Asthma, a chronic lung disease, is controllable with guidelines-based clinical care and proper self-management (1). The New York State (NYS) Department of Health Asthma Control Program analyzes county and zip code–level emergency department (ED) and hospital discharge data, regularly producing stable 3-year combined estimates that identify high-burden areas for targeted interventions under the NYS Children's Asthma Initiative (2,3). Since early 2020, routine surveillance has revealed a sharp decline in rates of asthma-related ED visits and hospitalizations. The COVID-19 pandemic severely affected NYS (3,4). Disruptions in care because of limited access to health care facilities and fear of virus transmission likely contributed to the change in rates (5,6).

Traditional mapping of average rates can pinpoint high-burden zip codes in specific time periods. Plotting trends with these copious amounts of data points produces hard-to-interpret visualizations, limiting early identification of emerging areas of concern. The Space Time Pattern Mining approach in ArcGIS Pro's Emerging Hot Spot Analysis (Esri) analyzes this hard-to-represent information in a 2-dimensional map representation of multidimensional temporal and geographic relationships. To evaluate the practical use of this method, we used it to analyze asthma ED visit data.

Data and Methods

We obtained all ED visits for NYS residents with a discharge diagnosis of asthma (ICD-10-CM code of J45) (7) from January 1, 2016, through June 30, 2022, from the Statewide Planning and Research Cooperative System and aggregated them by patient residence zip code (8). By using US Census Bureau population estimates, we computed quarterly ED visit rates and joined them to an NYS zip code shapefile in ArcGIS Pro version 3.2.1 (Esri) for analysis. The Space Time Pattern Mining approach in Emerging Hot Spot Analysis assesses patterns by using the Getis-Ord Gi* statistic (Esri) to evaluate clustering of trends evaluated by the Mann-Kendall trend test. The result locates significant ($P < .10$, as specified by the tool) clustering of trends for defined locations and provides a snapshot of trend activity at regular intervals (9,10). We created 2 distinct periods for analyses: prepandemic (2016–2019) and pandemic (2020–June 2022). NYS Children's Asthma Initiative interventions are prioritized within 13 identified high-burden counties; therefore, we selected county-level analysis (Appendix). We used the Create Space Time Cube from the Defined Locations tool in ArcGIS Pro to form 13 pairs of space–time cubes per county by time period, with bins composed of quarterly zip-code–level asthma-related ED rates (11).

We ran the Emerging Hot Spot Analysis Tool for each cube (12,13) and used a fixed distance for spatial comparisons, calculated by the tool for each cube analyzed. The analysis requires a minimum of 10 time intervals and 30 spatial divisions. Results characterize each zip code into 1 of 17 predefined categories (9). Persistent and intensifying hot or cold spots require a threshold of 90% of all time–space bins per cube meeting significance (9).

Highlights

Results showed more significant hot spots in NYS urban areas than in nonurban areas for both periods. Overall, ED rates during the pandemic were lower than prepandemic estimates. As opposed to signaling increases or decreases in rates overall, we characterized the variation in local patterns during each time period. We identified prepandemic asthma hot spots for 19 zip codes in Buffalo (Erie County), 12 in Rochester (Monroe County), 11 in Syracuse (Onondaga County), 7 in Albany (Albany County), 6 around Yonkers (Westchester County), and 5 around Hempstead (Nassau County) (Figure, Panel A). Dutchess and Orange Counties had no significant hot or cold spots identified.

During the pandemic, similar hot spot patterns appeared in Buffalo, Rochester, and Syracuse; however, many previously persistent hot spots were later classified as sporadic (Figure, Panel B). Zip code 12746 (Orange County) emerged as a new sporadic hot spot. Westchester hot spots spread to include 9 zip codes classified as sporadic. Hot spots in Nassau County increased to 9 with no cold spots identified. No significant patterns were detected for Dutchess or Albany Counties.

New York City (NYC) showed more hot spots and fewer cold spots during the prepandemic (Figure, Panel C) compared with the pandemic period (Figure, Panel D). The cold spot reduction was observed in northeastern Queens and southern Richmond counties, and an increasing number of hot spots were observed in New York, Bronx, Kings, and Queens counties. In upper New York County, zip codes 10026, 10027, 10030, 10031, 10037, and 10039 were diminishing hotspots prepandemic and became persistent hotspots during the pandemic.

Action

Traditional analyses are widely used by asthma partners to identify high-burden areas. High ED rates are concentrated around urban areas in NYS, consistent with literature describing the effects of urban factors on asthma (14). Emerging hot spot mapping provides additional tools for assessing and visualizing spatial patterns. However, results should be interpreted with caution and considered in combination with results from traditional analyses.

Hot spot model results may vary depending on the selection of geographic boundaries. Analysis of all zip codes in NYS or NYC or the 2 together, for example, did not yield the same results as individual county-level analysis. Areas known to have the highest rates via traditional methods were not always classified as hot spots (3). Reductions in some quarterly ED rates during the pandemic resulted in greater variation during this time period. The structure of fixed hot spot-result categorization contributed to areas being labeled as undesignated in high-burden counties. For example, the persistent hot spot definition requires that a location be a significant hotspot for 90% of all time-step intervals, a requirement that was not met within the zip code because of fluctuations in quarterly rates, especially during 2020, together with the use of the county boundary and fixed distance bands for geographic clustering criteria (9). For example, zip codes 10453, 10466, and 10467 in Bronx County had several quarterly rates above the maximum values in Queens and Richmond counties, but were not categorized by the tool as hot spots.

Maps produced by using Esri's Emerging Hot Spot Analysis tool can provide additional insight into patterns of asthma-related health care use in NYS's high-burden counties. The technique may be applied to other chronic conditions and to identify geographies where socioeconomic inequalities contribute to a disproportionate burden of adverse health outcomes (15). This additional insight will be an important tool in the evaluation of local-level interventions.

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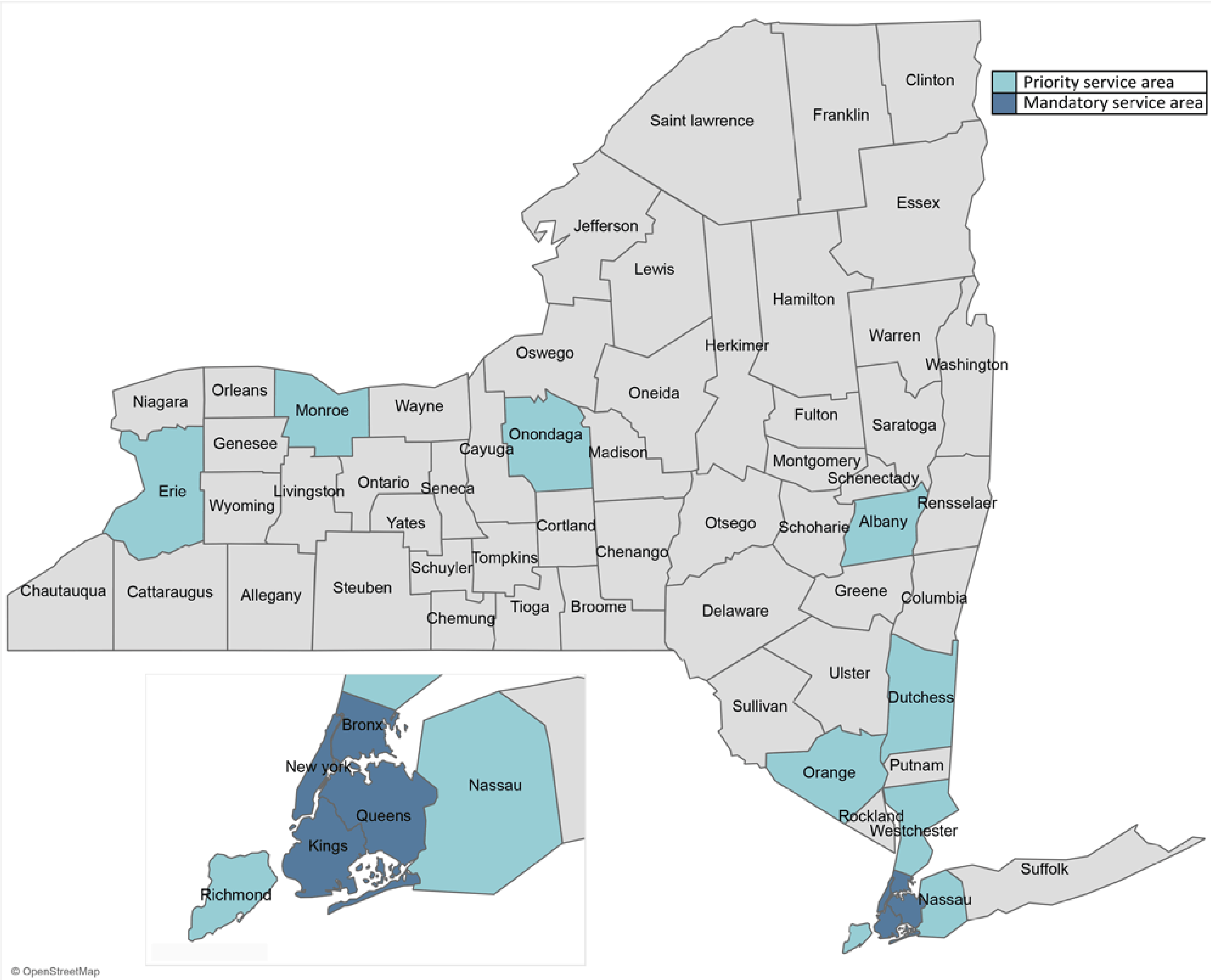
Appendix



Supplemental Figure. New York State Asthma Control Program service areas in counties with the highest asthma burden. The New York State Children's Asthma Initiative extends to every county in New York, focusing on mandatory and priority service areas comprising 13 of the highest-burden counties.

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RESEARCH BRIEF

2024 Public Health Actions to Reduce the Burden of Asthma: Influenza and COVID-19 Vaccination Uptake Among People with Asthma

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Summary

What is already known on this topic?

Optimal asthma management, including vaccination, can help people with asthma during respiratory virus seasons to protect against infection and severe symptoms.

What is added by this report?

The study highlights significant differences in vaccination rates for people with asthma across demographic categories. Access challenges were not commonly reported as reasons for not getting vaccinated.

What are the implications for public health practice?

Findings identify differences in influenza and COVID-19 vaccination rates based on demographic factors. The results of this study can inform the development and implementation of tailored educational and communication efforts to improve vaccination rates in these populations.

Abstract

This study sought to identify COVID-19 and influenza vaccination rates and barriers among people with asthma. The Asthma and Allergy Foundation of America (AAFA) conducted an online survey from April to May in 2022 among a convenience sample of 350 individuals with asthma. Most survey respondents reported that they had received an influenza vaccine for the 2021–2022 flu season (77%) and at least 1 dose of a COVID-19 vaccine (87%). Age, gender, race and ethnicity, and household income were significantly associated with influenza vaccination. Age and urban–rural classification were associated with COVID-19 vaccination. Access issues were not commonly reported as vaccination barriers, highlighting educational opportunities.

Objective

The onset of the COVID-19 pandemic in March 2020 resulted in major disruption to everyday life. Additionally, the threat of a “tripledemic” — marked by a high number of cases of COVID-19, influenza, and respiratory syncytial virus (RSV) — continued into 2023 (1). Previous literature shows that respiratory infections can be more serious for individuals with asthma, as infection can exacerbate asthma symptoms and lead to poorer health outcomes (2,3). Therefore, practicing optimal asthma management during respiratory virus seasons can be beneficial for people with asthma (4). Vaccines have been shown to help protect people with asthma against respiratory infections and lessen symptom severity if an infection occurs (5). However, previous literature from other countries suggests that influenza and COVID-19 vaccination rates in adults with asthma is suboptimal (6,7). Although national vaccine surveillance data are widely available (8), little is known about influenza and COVID-19 vaccination uptake among people with asthma in the US. We sought to gauge vaccination rates among people with asthma in the US and understand what, if any, demographic differences exist in vaccination rates and barriers in this population.

Methods

The Asthma and Allergy Foundation of America (AAFA), a patient advocacy organization, conducted an online survey from April 6 to May 31, 2022, to assess influenza and COVID-19 vaccination behaviors and barriers among people with asthma and allergies. A convenience sample of people with self-reported diagnoses of asthma and allergies, as well as caregivers (eg, parents, guardians) of people diagnosed with these conditions, was surveyed for participation. Participants were recruited through AAFA’s e-newsletters and social media posts. To qualify for the survey, participants needed to live in the US and be a legal adult in their state of residence. Participants also needed to be a person with, or a caregiver to a person with, a self-reported diagnosis of asthma or allergies. Respondents were screened for eligibility through self-reported responses. The research protocol was reviewed and determined exempt by Advarra Institutional Review Board.

This analysis focused on adults with asthma because of an increased risk of poor asthma outcomes from respiratory infection. Participants responded on their own behalf. Data on adults with asthma were identified for analysis based on self-reported diagnosed conditions. Outcome variables included vaccination status for the 2020–2021 and 2021–2022 influenza seasons, and initial and subsequent COVID-19 vaccinations. To assess vaccination barriers, unvaccinated respondents selected barriers from a list which were then categorized into perceptual (eg, beliefs about vaccine safety or efficacy) and technical (eg, access, scheduling issues) categories. Descriptive statistics on vaccination rates and barriers were analyzed by using SPSS version 29.0 (IBM). Chi-square tests of independence and Fisher exact tests were used to examine relationships between vaccination rates and barriers and self-reported age, gender, race and ethnicity, annual household income, and urban–rural classification. Statistical significance was set at $P \leq .05$ for Pearson χ^2 and Fisher exact tests to identify relationships between vaccination rates and demographic factors.

Results

Of the 1,664 people who began the survey, 537 completed the survey for a completion rate of 32%. Among completed respondents, 350 were adults living with asthma, predominantly identifying as White, women, suburban residents, and having an annual household income exceeding $50,000 (Table 1).

More than three-quarters of respondents with asthma received an influenza vaccine for the 2020–2021 (78%) and the 2021–2022 (77%) influenza seasons. Vaccination rates for the 2020–2021 influenza season were higher among respondents aged 58 to 76 years than among those aged 26 to 57 years ($P < .001$). For the 2021–2022 influenza season, vaccination rates were higher among respondents aged 58 to 76 years than among those aged 26 to 57 years ($P < .001$), among men than among women ($P = .05$), among White respondents than among Hispanic or Latino/a respondents ($P = .04$), and among respondents with an annual household income of $100,000 or more than among those with an annual household income less than $50,000 ($P = .01$) (Table 2).

Most respondents with asthma reported receiving 1 or more doses of a COVID-19 vaccine (87%), completing a primary series for COVID-19 (85%), and completing a primary series for COVID-19 with a booster dose (73%). Initial COVID-19 vaccination rates were higher for respondents aged 58 to 76 years compared with those aged 26 to 57 years ($P < .001$) and for respondents in urban and suburban areas compared with those in rural areas ($P = .003$). The same differences were seen for full COVID-19 vaccination in age ($P < .001$) and urban–rural classification ($P = .01$). COVID-19 booster rates were higher for respondents with an annual household income of $100,000 or more compared with those with an annual household income under $50,000 ($P = .001$) and for respondents in urban and suburban areas compared with those in rural areas ($P = .009$) (Table 2).

Among respondents with asthma who did not receive an influenza or COVID-19 vaccine, no significant demographic differences were found in citing perceptual or technical barriers. Technical barriers were less commonly selected as barriers for influenza vaccines and were not selected by any respondents as barriers for COVID-19 vaccines (Table 3).

Discussion

We investigated influenza and COVID-19 vaccination rates among a subgroup of people with asthma, and although influenza and COVID-19 vaccination rates among this group exceeded national averages (8), we found significant demographic differences. Respondents aged 58 to 76 years were more likely to be vaccinated for influenza and COVID-19 compared with younger respondents, and respondents in urban and suburban areas were more likely to be vaccinated for COVID-19 compared with those in rural areas. These demographic differences mirror national demographic differences in vaccination rates (8). Reasons for variation may include earlier COVID-19 vaccine eligibility for older adults and better access to vaccine resources in urban and suburban communities.

We also examined barriers to vaccination among unvaccinated respondents with asthma. Perceptual barriers (eg, beliefs about vaccine safety or efficacy) outweighed technical barriers (eg, access, scheduling issues), aligning with findings from a previous study among Canadian adults with asthma (9). These results indicate opportunities for education on vaccine safety and efficacy, particularly for people with asthma.

Our study has limitations. We relied on a convenience sample that may be more likely to be vaccinated than the total population of people with asthma. Additionally, most survey respondents were higher-income, White women and therefore not representative of the national population of people with asthma, which is more diverse in income, race and ethnicity, and gender (10). Statistical testing was limited by sample size variations across demographic groups, potentially obscuring significant differences that may be seen in a more diverse sample. Lastly, the survey relied on self-reported data, which is prone to several biases including social desirability and recall bias.

Despite these limitations, the study contributes valuable insights into vaccination behaviors among people with asthma, a group susceptible to severe illness from respiratory infections. It represents the first attempt, to the authors' knowledge, to analyze influenza and COVID-19 vaccination behaviors in this population in the US. Future research can aim for nationally representative samples to better understand demographic differences in this population, as generational and cultural beliefs can further influence vaccination behavior (11,12). Additionally, future research can examine differences in vaccination rates between people with and without asthma to understand differences in these populations.

Our study offers insights into vaccination behaviors of a subgroup of people with asthma to inform future research. The findings also highlight opportunities for improved vaccine communication strategies to reduce prevalence and severe outcomes of respiratory diseases across demographic groups among people with asthma.

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Tables

Table 1. Demographic Characteristics of Survey Respondents, by Asthma Status, Online Survey of the Asthma and Allergy Foundation of America, April 6 to May 31, 2022

Characteristic	Total (N = 537)	Asthma (n = 350)	No Asthma (n = 187)
	No. (%)		
Age, y			
≤25	11 (2)	7 (2)	4 (2)
26–41	126 (23)	66 (19)	60 (32)
42–57	226 (42)	133 (38)	93 (50)
58–76	162 (30)	135 (39)	27 (14)
≥77	12 (2)	9 (3)	3 (2)
Gender			
Man	47 (9)	39 (11)	8 (4)
Woman	478 (89)	303 (87)	175 (94)
Nonbinary or gender nonconforming	2 (0)	1 (0)	1 (1)
Prefer not to answer	10 (2)	7 (2)	3 (2)
Race and ethnicity			
Indigenous American, American Indian, or Alaska Native	12 (2)	11 (3)	1 (<1)
Asian	14 (3)	7 (2)	7 (4)
Black or African American	28 (5)	21 (6)	7 (4)
Hispanic or Latino/a	37 (7)	23 (7)	14 (7)
Middle Eastern or North African	4 (1)	2 (<1)	2 (1)
Native Hawaiian or Pacific Islander	1 (<1)	1 (<1)	0
White	404 (75)	262 (75)	142 (76)
Other	8 (1)	5 (1)	3 (2)
Prefer not to answer	29 (5)	18 (5)	11 (6)
Annual household income, $			
<50,000	76 (14)	61 (17)	15 (8)
50,000–99,999	152 (28)	113 (32)	39 (21)
≥100,000	194 (36)	101 (29)	93 (50)
Prefer not to answer	115 (21)	75 (21)	40 (21)
Urban–rural classification			
Urban	101 (19)	79 (23)	22 (12)
Rural	117 (22)	70 (20)	47 (25)
Suburban	302 (56)	188 (54)	114 (61)
Prefer not to answer	17 (3)	13 (4)	4 (2)

Table 2. Influenza and COVID-19 Vaccination Rates Among People with Asthma, by Respondent Characteristics, Online Survey of the Asthma and Allergy Foundation of America, April 6 to May 31, 2022[a]

Characteristic	No.	Received an influenza vaccination for the October 2020–May 2021 influenza season, n (%)	Received an influenza vaccination for the October 2021–May 2022 influenza season, n (%)	Received ≥1 dose of a COVID-19 vaccine, n (%)	Fully vaccinated for COVID-19, n (%)[b]	Fully vaccinated and received a booster dose for COVID-19, n (%)
Total[c]	350	272 (78)	269 (77)	304 (87)	299 (85)	257 (73)
Age, y						
≤25	7	6 (86)	7 (100)	7 (100)	7 (100)	7 (100)
26–41	66	40 (61)	40 (61)	51 (77)	48 (73)	40 (61)
42–57	133	96 (72)	94 (71)	108 (81)	107 (80)	87 (65)
58–76	135	121 (90)	119 (88)	130 (96)	129 (96)	115 (85)
≥77	9	9 (100)	9 (100)	8 (89)	8 (89)	8 (89)
P value	—	<.001[d]	<.001[d]	<.001[d]	<.001[d]	.30[d]
Gender						
Man	39	34 (87)	35 (90)	34 (87)	34 (87)	32 (82)
Woman	303	235 (78)	230 (76)	266 (88)	261 (86)	222 (73)
P value	—	.22	.05	>.99[d]	.60	.19[d]
Race and ethnicity						
Indigenous American, American Indian, or Alaska Native	11	9 (82)	7 (64)	10 (91)	10 (91)	8 (73)
Asian	7	4 (57)	4 (57)	5 (71)	5 (71)	5 (71)
Black or African American	21	15 (71)	16 (76)	19 (91)	19 (91)	17 (81)
Hispanic or Latino/a	23	14 (61)	13 (57)	18 (78)	18 (78)	15 (65)
White	262	211 (81)	212 (81)	234 (89)	230 (88)	202 (77)
Other[e]	8	5 (63)	6 (75)	6 (75)	6 (75)	5 (63)
P value	—	.09[d]	.04[d]	.15[d]	.27[d]	.80[d]
Annual household income, $						
<50,000	61	43 (70)	40 (66)	48 (79)	48 (79)	37 (61)
50,000–99,999	113	93 (82)	89 (79)	104 (92)	102 (90)	84 (74)
≥100,000	101	84 (83)	86 (85)	89 (88)	89 (88)	86 (85)
P value	—	.08	.01	.12	.24	.001
Urban–rural classification						
Urban	79	65 (82)	63 (80)	74 (94)	72 (91)	66 (84)
Rural	70	50 (71)	48 (69)	53 (76)	53 (76)	39 (56)
Suburban	188	148 (79)	151 (80)	169 (90)	167 (89)	147 (78)
P value	—	.20	.12	.003	.01	.009

Abbreviation: — , not applicable.
[a] *P* values based on χ^2 test of independence and Fisher exact test; significance set at $P \leq .05$.
[b] "Fully vaccinated" was defined as having completed a primary series of COVID-19 vaccinations.
[c] Respondent characteristics may not add up to total due to exclusion of "prefer not to answer" categories from analysis, as well as categories in which n < 5.
[d] Fisher exact test was used because ≥20% of expected cell values were n < 5.
[e] Includes Middle Eastern or North African, Native Hawaiian or Pacific Islander, and other.

Table 3. Reasons for Not Receiving an Influenza or COVID-19 Vaccination Among Unvaccinated Respondents, Online Survey of the Asthma and Allergy Foundation of America, April 6 to May 31, 2022[a]

Characteristic	Unvaccinated for 2021–2022 Influenza (N = 81)[b]	Reason for Not Receiving an Influenza Vaccine, Perceptual, n (%)[c]	Reason for Not Receiving an Influenza Vaccine, Technical, n (%)[c]	Unvaccinated for COVID-19 (N = 46)[b]	Reason for Not Receiving a COVID-19 Vaccine, Perceptual, n (%)[d]	Reason for Not Receiving a COVID-19 Vaccine, Technical, n (%)[d]
Age, y						
≤25	0	0	0	0	0	0
26–41	26	22 (85)	4 (15)	15	15 (100)	0
42–57	39	31 (79)	8 (21)	24	24 (100)	0
58–76	16	13 (81)	3 (19)	4	4 (100)	0
≥77	0	0	0	1	1 (100)	0
P value	—	<.93[e]		—	—	
Gender						
Man	4	4 (100)	0	4	4 (100)	0
Woman	73	59 (81)	14 (19)	36	36 (100)	0
P value	—	>.99[e]		—	—	
Race and ethnicity						
Indigenous American, American Indian, or Alaska Native	4	4 (100)	0	1	1 (100)	0
Asian	3	3 (100)	0	2	2 (100)	0
Black or African American	5	5 (100)	0	2	2 (100)	0
Hispanic or Latino/a	10	7 (70)	3 (30)	5	5 (100)	0
White	50	42 (84)	8 (16)	216	216 (100)	0
Other[f]	2	1 (50)	1 (50)	2	2 (100)	0
P value	—	.41[e]		—	—	
Annual household income, $						
<50,000	21	18 (86)	3 (14)	11	11 (100)	0
50,000–99,999	24	19 (79)	5 (21)	9	9 (100)	0
≥100,000	15	13 (87)	2 (13)	12	12 (100)	0
P value	—	.83[e]		—	—	
Urban–rural classification						
Urban	16	12 (75)	4 (25)	5	5 (100)	0
Rural	22	21 (95)	1 (5)	16	16 (100)	0
Suburban	37	29 (78)	8 (22)	18	18 (100)	0
P value	—	.17[e]		—	—	

Abbreviation: — , not applicable.
[a] *P* values based on χ^2 test of independence and Fisher exact test; significance set at $P \le .05$.
[b] Totals for respondent characteristics may not add up to overall total due to exclusion of “prefer not to answer” categories from analysis, as well as categories in which n < 5.
[c] Responses were categorized as technical if respondent selected “I do not have easy access to an influenza shot clinic” or “I haven’t found the time to schedule an appointment.” All other responses were categorized as perceptual.
[d] Responses were categorized as technical if respondent selected “I have scheduled an appointment for the vaccine for a future date,” “I have had trouble finding appointment(s) to get a vaccine,” “I have trouble navigating the process to sign up for a vaccine,” or “It is difficult for me to travel to a vaccination site.” All other responses were categorized as perceptual.
[e] Fisher exact test was used because ≥20% of expected cell values were n < 5.
[f] Includes Middle Eastern or North African, Native Hawaiian or Pacific Islander, and other.

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PROGRAM EVALUATION BRIEF

Implementation and Evaluation of a School Nurse Toolkit to Reinforce Best Practices for Asthma Care in Schools

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PEER REVIEWED

Summary

What is already known on this topic?

Resources reinforcing the standards of care for asthma can strengthen self-efficacy and use of asthma management practices among school nurses.

What is added by this report?

An asthma toolkit was promoted to school nurses in Michigan. School nurses viewed the toolkit and reported implementing changes to improve asthma management practices in their schools.

What are the implications for public health practice?

Reaching school nurses through promotional activities can encourage school nurses to apply the standards for care to support students with asthma in school.

Abstract

A toolkit, developed by a multidisciplinary team of national and statewide professionals, was promoted among school nurses in Michigan to support use of the standards of care for asthma in schools. We evaluated the effectiveness of the toolkit to assist school nurses in providing support for students with asthma. We used a multimethod approach to assess use of the toolkit, changes in nursing practices as a result of using the toolkit, and challenges encountered when implementing the standards for asthma care. During a 12-month period, from July 2022 through June 2023, increases in time on web page and monthly page views aligned with efforts to promote toolkit use. School nurses reported using the toolkit and implementing practice changes pertaining to training and education, ensuring proper use of and access to asthma medications, and advocating for self-carry of asthma medications. Challenges to implementing the standards of asthma care were time, parental engagement, institutional support, and identifying students with asthma. We found that our promotional efforts prompted school nurses to access the toolkit, which helped school nurses to effectuate practice changes to improve support for students with asthma in schools.

Introduction

The prevalence of current asthma in Michigan among children and adolescents aged 5 to 17 years is 8.8% (1). Of these children and adolescents, 35.3% missed 1 or more days of school due to asthma from 2017 to 2021 (2). Children and adolescents who are Black or in low-income households are disproportionately affected by asthma (2). From 2017 to 2021, 18.4% of Michigan children and adolescents aged 5 to 17 years with current asthma had an asthma-related visit to an emergency department or urgent care in the past 12 months; however, 30.9% of Black children and adolescents and 26.0% of children and adolescents in households with less than $50,000 in annual income had an asthma-related emergency department or urgent care visit in the past 12 months (2). Complex interactions among varying levels of social, structural, biological, and behavioral determinants contribute to asthma-related disparities (3).

In June 2022, the Michigan State Board of Education updated a model policy for supporting students with asthma that set forth recommendations for schools to establish asthma-friendly environments to improve students' attendance and participation in activities and promote academic success and well-being (4). Building on the Whole School, Whole Community, Whole Child model (5), which provides conceptual support and practical guidance central to best practices, the policy designated school nurses as important members of a child's support network to coordinate asthma management activities; integrate communication among students, caregivers, and health care providers; and ensure all school personnel have received appropriate training in asthma management and emergency response (4,5).

School nurses fill the gap between health care and education, provide both acute and chronic care, treat and assess behavioral health concerns, and connect students and families to community resources (6). Although school nurses are well positioned in their role to support students with asthma, inadequate time to devote to asthma management, due in part to competing student needs and multiple roles, impedes completion of these activities (7). Additionally, school nurses in Michigan practice in various models, and they may be responsible for covering more than 1 building or an entire school district. As such, a medically qualified person may not always be available to meet the emergent needs of students, and the oversight is shifted to school staff, teachers, and administrators (7).

Historically, Michigan has ranked lowest among states in its school nurse-to-student ratio (8). However, due in part to recent increases in school budgets (9), the number of employed school nurses has quadrupled since 2019, increasing from some 200 nurses to an estimated 800 nurses (Evilia Jankowski, MSA, BSN, NCSN, State School Nurse Consultant, Michigan Department of Education, October 5, 2023, email correspondence). Younger and less experienced school nurses have been reported to be less likely than older and more experienced school nurses to perform asthma management activities (10). Regardless of experience, however, asthma-focused education can strengthen self-confidence in asthma management among school nurses (10,11), and this self-confidence has been associated with increased performance of asthma management activities (10).

To support school nurses' use of best practices for asthma management, a multidisciplinary team of national and statewide professionals convened to develop an asthma toolkit (12). The toolkit, *Supporting Students with Asthma at School: Standards of Care*, presents information for understanding asthma and applicable laws and details performance standards to support students with asthma (12). These standards include coordination of care, assembling health care plans, and training school personnel.

Purpose and Objectives

The conceptualization of this evaluation was a collaborative effort between the Michigan Department of Education (MDE) and the Michigan Department of Health and Human Services (MDHHS) Asthma Prevention and Control Program. We designed the evaluation to assess the effectiveness of the toolkit to assist school nurses in providing support for students with asthma in schools. Our evaluation questions were 1) To what extent did school nurses use the toolkit? 2) What practice changes were implemented as a result of using the toolkit? and 3) What were the perceived challenges to implementing standards for asthma care in schools?

Intervention Approach

On August 4, 2022, the toolkit was uploaded to the School Health Services page on the MDE website (12). The Michigan State School Nurse Consultant (SSNC) (E.J.) promoted the toolkit throughout the 2022–2023 school year. The SSNC introduced the toolkit at the Michigan School Nurse Summer Institute meeting in August 2022. The toolkit was promoted in the SSNC's newsletter sent to school nurses in January 2023, during the SSNC's monthly office hours in March 2023, and at the Michigan Association of School Nurses annual conference in May 2023.

Evaluation Approach

The MDHHS institutional review board determined the evaluation to be exempt from full review and oversight. We used a multimethod approach, which consisted of collecting quantitative and qualitative data from several sources to facilitate a complete understanding of the extent to which the toolkit was used.

We used Google analytics to track the extent to which the home page of the toolkit was accessed from July 2022 through June 2023 on the MDE web page. The home page of the toolkit includes links to various components of the toolkit and a link to access and download a complete version of the toolkit document. We tracked time on page in seconds; the number of page views, defined as the number of times a web page was seen by all users; and the number of unique page views, defined as the average number of times a web page was seen by each user.

School nurses were invited to complete an online survey, administered by SurveyMonkey (www.surveymonkey.com), once in January 2023 and again in February 2023. We used the SSNC's newsletter to invite the 800 school nurse subscribers to complete the survey. Two survey questions were used to assess toolkit use and practice changes made. The first question was, "Have you used the Asthma Toolkit to help guide you on asthma care and management for students in school?" Response options were yes and no. The second question was open-ended: "Based on your use of the Asthma Toolkit, have you made any process or practice changes in the way students with asthma are supported? If yes, briefly describe the changes made."

In May 2023, the SSNC led a Kahoot! (www.kahoot.com) among school nurses attending the Michigan Association of School Nurses annual conference. A Kahoot! is a game-based platform used to collect real-time information from a group of people through a web browser on a mobile device. During the Kahoot!, 3 statements were used to collect information. The first was a true-or-false statement: "I have utilized the Asthma Toolkit on the MDE website." The second was open-ended: "Share one practice change implemented since accessing the Asthma Toolkit." The third was also open-ended: "What is the biggest challenge to implementing the standards of care for supporting students with asthma in school?" Responses to open-ended questions were limited to 250 characters.

We used Microsoft Excel to conduct a descriptive analysis of count data. We calculated frequencies and means for time on page, number of page views and unique page views, and we calculated frequencies for the number of respondents who used the toolkit. For qualitative analysis, we identified and developed themes on the basis of respondents' comments, and we created and condensed categories on the basis of commonalities among the themes. We used Microsoft Excel to assign comments to a column and themes to a row to track when a theme was mentioned. One person (D.W.) coded the information and developed the coding scheme, which was reviewed and discussed with 3 team members (E.J., J.D., T.V.). Comments from the survey and Kahoot! were analyzed and reported separately.

Results

Time on page totaled 6,124 seconds (1 hour, 42 minutes) and averaged 510 seconds (8 minutes, 30 seconds) per month. The least amount of time on page was 87 seconds in July 2022, the month before the toolkit was uploaded, and the greatest time on page was 1,049 seconds (17 minutes, 29 seconds) in March 2023. Page views totaled 819, averaged 68 per month, and ranged from 38 to 150. Unique page views totaled 648, averaged 54 per month, and ranged from 7 to 125. August and September had the greatest number of page views, and increases in page views generally aligned with efforts to promote toolkit use. The frequency of unique page views followed a similar pattern (Figure).

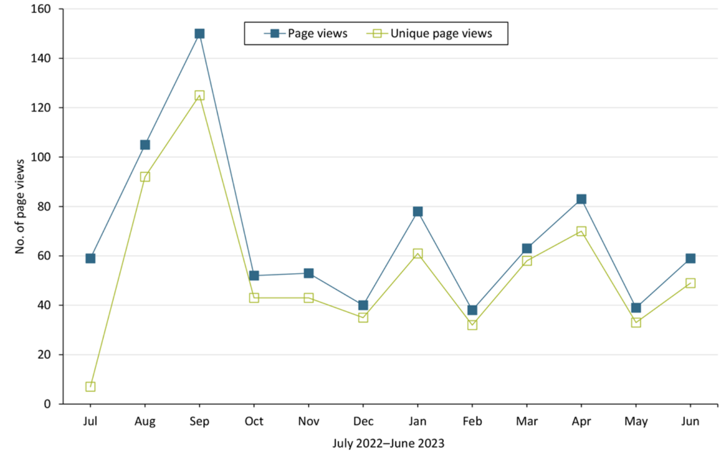

Figure. The number of page views (the number of times a web page was seen by all users) and unique page views (the average number of times a web page was seen by each user) of the Michigan Department of Education (MDE) web page linking to an asthma toolkit, July 2022 to June 2023, Michigan. The toolkit, *Supporting Students with Asthma at School: Standards of Care,* which presents information for understanding asthma and applicable laws and details performance standards to support students with asthma, was uploaded to the MDE website on August 1, 2022.

Survey

Of the 800 school nurses who subscribed to the SSNC's newsletter, 71 completed a survey (9% response). Of the 71 respondents, 42 (59%) indicated they used the toolkit, and of these, 11 (26%) provided information on practice changes made. We identified 2 themes based on comments: training and education and asthma action plans. Respondents reported using the information to educate administrators, staff, and families, using resources from the toolkit for training, and improving their own skills in recording asthma episodes. They also reported implementing the use of standardized asthma action plans and requesting and obtaining asthma action plans for each student with asthma.

Kahoot!

Of the 176 meeting attendees, 140 participated in the Kahoot! (80% response). Of the 140 participants, 97 (69%) indicated that they used the toolkit, and of these, 73 (75%) provided information on practice changes as a result of toolkit use. Of these responses, 5 themes emerged: training and education (n = 25 respondents who made comments that pertained to a theme); asthma action plans or care plans (n = 19); use of asthma medications and spacers (n = 16); self-carry of asthma medications (n = 7); and other responses (n = 6).

School nurses reported using the guidance to train staff, some specifically referencing the tier-level training and infographic resources in the toolkit; educate staff, students, and families on asthma, such as proper inhaler use and asthma signs and symptoms; and improve their own knowledge, such as being more skilled in creating health care plans for students. Practice changes also included requesting asthma action plans to ensure all students with asthma had an asthma action plan on file, standardizing asthma action plans, or modifying care plans to be in accordance with performance standards. School nurses described changes made to ensure students had access to inhalers at school and during school-related events, as well as encouraging spacer use and following up with students after rescue inhaler use. School nurses reported advocating for self-carrying medications in their school, ensuring staff were aware of students who self-carry medications, or sharing asthma action plans with teachers to allow students to safely self-carry medications; 1 respondent described asking students who self-carry medications to demonstrate proper inhaler use. Other practice changes related to completing asthma assessments, providing support for asthma trigger reduction, collecting data, checking oxygen saturation regularly, and encouraging medical provider visits.

When school nurses were asked to describe their biggest challenge to implementing the standards for asthma care in school, of the 97 participants who used the toolkit, 57 (59%) provided a brief description of challenges. Time (eg, being busy), parents (eg, parental involvement, communication, support, obtaining asthma action plans), support (eg, staff compliance, administrator buy-in, physician response, being understaffed), and being able to identify students with asthma were reported challenges. Of the 43 respondents who did not use the toolkit, 22 (51%) briefly described challenges as time, parents (eg, parental involvement, communication, cooperation, support), and communication and collaboration.

Implications for Public Health

We aimed to identify the types of practice changes made as a result of toolkit use. Our findings suggest the toolkit reinforced practices for training of staff on the tier levels for asthma management and emergency response training and with educating staff, students, and families on asthma and proper use of asthma medications. School nurses also reported standardizing asthma action plans, increasing the number of students' asthma action plans on file, and advocating for self-carry of asthma medications in schools. Some school nurses improved their own skills with recording asthma episodes and developing care plans. We gained a limited understanding of challenges encountered by school nurses when implementing the standards of care for asthma; these challenges were noted in previous research (7,13). Introducing a model for school nurse–led management can help schools meet the health needs of students with asthma, especially those with multiple and complex barriers to health and academic success, and provide professional support for school nurses to moderate challenges (14).

Evaluation findings confirmed that our promotional efforts prompted school nurses to access the toolkit. School nurses reported using the toolkit, and the uptick in web page visits and time on page generally corresponded with promotional activities. Replication of this approach could be used to promote additional toolkits developed for school nurses to support students with other health conditions.

Our study has several limitations. Findings are not generalizable to all school nurses due to low response rates. Additionally, survey and Kahoot! respondents were reached through the SSNC's newsletter and a Michigan Association of School Nurses conference and may not reflect the entire population of school nurses. A school nurse could have participated in the survey and Kahoot! and may be represented more than once. We did not collect information on demographic characteristics of school nurses in Michigan. Practice changes were based on self-report and could not be externally validated, and our understanding of aspects of the toolkit that school nurses deemed most useful was limited. Additionally, the scope of the evaluation did not examine whether practice changes led to improved asthma outcomes for students.

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ORIGINAL RESEARCH

Projected Cost Savings of a Community Health Worker Model for Asthma Home Visits in the Massachusetts Pediatric Medicaid Population

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PEER REVIEWED

Summary

What is already known on this topic?

Interventions for children with asthma that include home visits by community health workers (CHWs) can improve asthma-related health and economic outcomes.

What is added by this report?

By using 2019 claims data, we projected annual savings per patient in health care costs associated with expansion of the CHW-led asthma home visiting model to all pediatric Massachusetts Medicaid (MassHealth)-eligible patients with uncontrolled asthma.

What are the implications for public health practice?

Expanding the CHW model to all MassHealth-eligible pediatric patients with uncontrolled asthma can improve asthma outcomes and save costs. By increasing asthma services for Black and Hispanic residents with low incomes, expansion may also reduce disparities in asthma outcomes.

Abstract

Introduction

The community health worker–led asthma home visiting model (CHW model) improved asthma outcomes and reduced health care costs among Massachusetts children with asthma. We projected cost savings associated with the expansion of the CHW model among pediatric Massachusetts Medicaid (MassHealth)-eligible patients with uncontrolled asthma (≥2 asthma-related emergency department visits per year).

Methods

We estimated 2019 costs associated with asthma-related hospitalizations and emergency department visits for MassHealth pediatric patients with uncontrolled asthma who also had 365 days of Medicaid eligibility in 2019. We based estimated cost savings on previously published results from a study of a comparable patient population.

Results

The projected asthma-related cost savings from expansion of the CHW model were $566.58 per patient, or $774,514.86 total, for the 1,367 MassHealth-eligible children with uncontrolled asthma in our analysis.

Conclusion

Expansion of the CHW model is an effective way to increase asthma services and reduce Medicaid costs for MassHealth patients, a population made up disproportionately of Black and Hispanic residents with low incomes.

Introduction

Massachusetts has a high pediatric asthma burden. In 2021, 9.7% of all Massachusetts children had current asthma compared with 6.5% of US children overall (1). For the combined period from 2019 to 2021, asthma was categorized as "not well controlled" or "very poorly controlled" (2) in almost 40% of children with current asthma, based on self-reported data on factors associated with asthma management from the Massachusetts Behavioral Risk Factor Surveillance System Child Asthma Call-back Survey (3). Inequities exist in the use of asthma-related health care among the Massachusetts population. By using combined data from 2019 through 2021, the rates of asthma-related emergency department (ED) visits for Hispanic and non-Hispanic Black children aged 19 years or younger were significantly higher than the rates for non-Hispanic White children (4). Additionally, in 2018, the age-adjusted rates of asthma-related hospitalizations and ED visits for the combined population of children and adults in Massachusetts were approximately 3 to 4 times higher among non-Hispanic Black and Hispanic residents than non-Hispanic White residents (5,6). Similar inequities in pediatric asthma outcomes also exist nationally (7): by using combined data from 2018 through 2020, among children with current asthma, the percentage of children whose asthma was uncontrolled was approximately 7 to 10 percentage points higher among Black and Hispanic children than White children (7).

Asthma self-management — the ability of individuals and families to effectively manage asthma symptoms — is a vital component of asthma control. Structural racism and other systems of oppression contribute to inequities in health-related social needs (eg, food, housing, income, transportation), which too often lead to inequitable access to adequate health care and barriers to asthma control (8). Black and Hispanic children and their caregivers are often more likely than their White counterparts to have gaps in knowledge, skills, resources, and support for asthma self-management (9,10). Community health workers (CHWs) can help fill these gaps by providing culturally aware asthma self-management education and resources as a component of asthma home-visiting programs (11). Because of their lived experience in the communities they serve, CHWs are uniquely able to provide linguistically and culturally appropriate care. They play an important role by helping to address health-related social needs and by understanding the social determinants of health that affect their communities.

The health and economic benefits of the CHW model, a multicomponent, low-cost, asthma home visiting intervention for children with asthma and their caregivers, have been well established (11,12). These include an increase in the number of symptom-free days, a decrease in asthma-related health care use (eg, hospitalizations, ED visits), reduced exposure to environmental triggers, and improved caregiver quality of life (12–15). The CHW model is an important component of a comprehensive approach to reducing asthma-related racial disparities — racial inequities in asthma outcomes and inequities in conditions that cause asthma and make it more difficult to manage. The model can help reduce some of the barriers that families, particularly Black and Hispanic families, face in accessing culturally relevant and linguistically appropriate asthma care, barriers that result from the continuing structural racism that operates in the health care system (16,17).

In addition to assessment and education about the impact of the home environment on a child's asthma, CHWs provide asthma services in the home. Doing so removes transportation-related barriers, making it easier for Black and Hispanic families that disproportionately live far from health care centers or must navigate public transportation systems to receive asthma services (18,19). The CHW model also increases the time spent receiving asthma care.

Despite a well-established evidence base, the number of CHW-led asthma home-visiting programs available in Massachusetts is limited, in part because sustainable financing for such services is not well established (20). However, a potential funding mechanism may be emerging: the recent 2023 MassHealth 1115 Demonstration waiver includes a potential sustainable funding mechanism for CHWs who support innovative service delivery models (21).

The objective of our study was to identify the hypothetical financial impact of a large-scale expansion of the CHW model across the MassHealth-eligible population of children with uncontrolled asthma, defined as 2 or more asthma-related ED visits per year, by quantifying the associated reduction in asthma-related health care costs. Based on the available evidence that the CHW model is associated with better asthma control (11), we also expected that these estimated cost reductions would be associated with improvements in asthma outcomes. Although published studies (11,12) have looked at the financial impact of the CHW model in small groups of patients with asthma, our study estimated the potential cost savings resulting from a hypothetical large-scale expansion of the model throughout the pediatric Massachusetts Medicaid eligible population. Our goal was to provide evidence to support efforts to establish sustainable financing mechanisms for expansion by demonstrating the potential cost savings associated with the CHW model.

Methods

Data source

Our primary data source was eligibility and medical insurance claims data for 2019 from MassHealth's internal data warehouse, a clearinghouse of MassHealth medical claims and eligibility data that uses the IBM Cognos Analytics (IBM Corp) software platform for data access and querying. Data elements, including patient demographics, MassHealth eligibility, and information on specific services provided (eg, diagnosis codes, place of service, date of service, amount paid by MassHealth) are stored in discrete, structured fields (race and ethnicity data fields were largely incomplete in this data set.) The Massachusetts Executive Office of Health and Human Services approved and coordinated access to the data warehouse for our project team. The team extracted relevant data elements from the data warehouse by using the IBM Cognos reporting tool and transferred the data to SAS Studio (SAS) for analysis.

Study population

The study population we identified for our analysis consisted of MassHealth-eligible pediatric patients with uncontrolled asthma (N = 1,367), defined as children aged 17 years or younger who had at least 2 asthma-related ED visits in 2019 where asthma was the primary or secondary diagnosis. To ensure that a complete set of calendar-year claims was included in our analysis, we further restricted our study population to children who had a full 365 days of MassHealth eligibility in 2019. We considered only ED visits with a primary or secondary diagnosis of asthma to ensure a high level of confidence that the visits were related to the child's asthma control status. The Massachusetts Department of Public Health (MDPH) institutional review board determined that our study did not constitute human subject research according to federal regulations and did not require further review.

In our analysis, we calculated the potential cost savings of expanding the CHW model to our study population of 1,367 children with uncontrolled asthma based on the cost savings realized in a previous MDPH interventional study, Reducing Ethnic/Racial Asthma Disparities in Youth (READY) (11). Inclusion criteria for our study population, drawn from the MassHealth data warehouse, were similar to those for the children in a cohort (N = 22) of READY participants that had uncontrolled asthma (identified based on 2 or more ED visits during a 1-year period before the start of the asthma home visiting intervention). We used the aggregate and previously published findings from the READY study cohort to estimate the decrease in costs for asthma-related hospitalizations and ED visits associated with hypothetical CHW model expansion in our study population (11). Although the CHW model can take many forms, our analysis focused primarily on the model as it was applied in the READY study. The READY study was an intervention that evaluated the health and economic effects of the CHW model in Boston and Springfield, Massachusetts, among a population that was 93.3% insured by MassHealth. Ours was a simulation study of a subset of MassHealth-eligible children with uncontrolled asthma statewide. In the READY study, CHWs led in-home asthma management and environmental trigger-remediation education over 5 visits spanning 6 months, plus a follow-up telephone call at 12 months. CHWs provided asthma self-management education (eg, proper inhaler technique), environmental trigger remediation education (eg, green cleaning, integrated pest management practices), and low-cost trigger remediation supplies (eg, HEPA vacuum cleaners, mattress covers). Unlike the READY study, our study was not an intervention (ie, no asthma home visits were conducted). Instead, we estimated the impact of expanding the CHW model used in the READY study to a broader population of MassHealth-eligible children with uncontrolled asthma.

Measures

We determined average per-person health care costs to MassHealth in 2019 for our study population by using medical claims data for ED visits and hospitalizations where asthma was the primary or secondary diagnosis. These costs were then used to calculate expected health care expenditures if the CHW model were expanded to our study population. To establish the potential cost savings of a hypothetical large-scale expansion of the CHW Model in the Medicaid population, we used the published aggregated results from the READY study to estimate the expected reduction in asthma-related health care costs associated with CHW model expansion among our study population. The percentage reduction in asthma-related ED visit and hospitalization costs observed in the relevant cohort of the READY study was approximately 70% for ED visits and 51% for hospitalizations. These calculations were based on the change in asthma-related ED visit and hospitalization costs reported for the children in the selected cohort of the READY study for 1 year before and 1 year after the intervention. Among participants in the relevant cohort of that study, asthma-related hospitalization costs were $2,543.76 pre-intervention and $1,243.14 post-intervention. Asthma-related ED costs were $1,512.87 pre-intervention and $454.39 post-intervention. We used these cost savings to calculate the expected cost savings for our hypothetical CHW model expansion.

Statistical analysis

We conducted a simulation analysis of a hypothetical expansion of the CHW model in our study population. This analysis assumed that the same percentage reduction in asthma-related hospitalization and ED costs observed in the READY study would occur if the CHW model was applied to the statewide MassHealth-eligible pediatric population with uncontrolled asthma. We did not use the original patient-level data set from the READY study in our analysis; instead, we used the published aggregated results from the READY study to project the estimated cost savings associated with model expansion.

We used SAS to perform all calculations and analyses. Descriptive statistics for our study population were calculated along with estimated cost savings. In the READY study, Mann–Whitney U tests were performed to compare changes in annual medical expenses before and after the application of the CHW model intervention (11).

Results

Of the 546,466 children with MassHealth eligibility for 1 day or more in 2019, 78,641 (14%) were eligible for 365 days in 2019 (Figure). Of these, 9,785 (12%) had an asthma diagnosis in 2019.

Of these 9,785 children with asthma and 365 days of eligibility in 2019, 1,367 (14 %) had 2 or more asthma-related ED visits in that same year. Our study population of 1,367 was distributed relatively equally across age categories (1 – 4 y, 26.0%; 5 – 8 y, 23.4%; 9 – 12 y, 22.8%; 13 – 17 y, 27.8%). Most were male (58.3%). Race was identified as 26.3% Non-Hispanic White, 10.1% Hispanic, and 7.9% Non-Hispanic Black, but was unknown for more than half of the study population (51.3%). (Table 1).

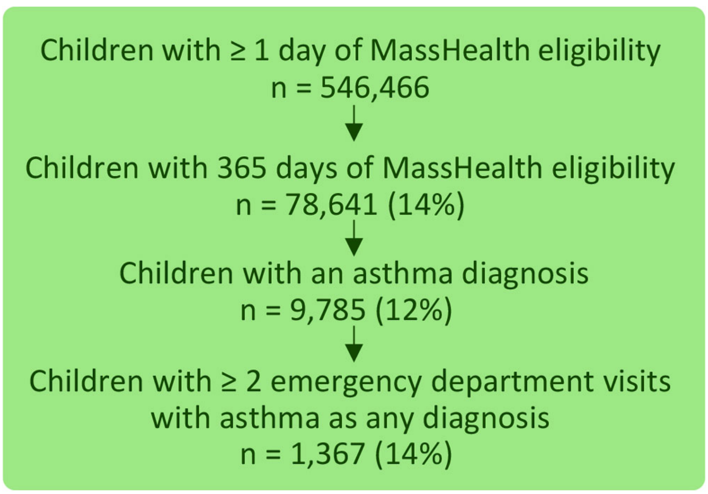

Figure. Sample selection results from 2019 MassHealth (Massachusetts Medicaid) medical and eligibility claims, accessed via their data warehouse.

The potential annual per-patient cost savings to MassHealth, post-expansion, for asthma-related ED visits in our study, calculated by taking the estimated annual per-patient cost of $490.69 and applying a 70.0% reduction, was $147.38, a total per-patient cost savings of $343.31 (Table 2). The estimated annual cost savings for asthma-related hospitalizations post-expansion, calculated by taking the estimated asthma-related hospitalization per-patient cost of $436.68 and applying a 51.1% reduction, was $213.41 per patient, a savings of $223.27. The combined (ED and hospitalization) asthma-related cost savings for pediatric MassHealth eligible patients with uncontrolled asthma were estimated to be $566.58 per patient or a total of $774,514.86 applied to the 1,367 children in our study.

Discussion

By using 2019 MassHealth claims data and combining it with results from the READY study, we estimated that over a 1-year period, $566.58 per patient or a total of $774,514.86 (in 2019 US dollars) in MassHealth expenditures could be saved across the 1,367 children in our study group through expansion of the CHW model. Although past analyses have estimated the cost savings associated with the CHW model in studies of small cohorts, ours is the first to our knowledge that estimates the potential savings across a broad population of Medicaid-eligible children with asthma. Our analysis adds to previous findings from the READY study that the CHW model would have important benefits for pediatric asthma outcomes (eg, a reduction in the average number of asthma symptom days, an increase in the percentage of children with well-controlled asthma, reduced exposure to environmental triggers) (11). Although the READY study included only families from Boston Medical Center and Baystate Medical Center in Springfield rather than a representative sample of the entire MassHealth population, our study population and the READY study population were largely comparable. Although 100% of our study group were MassHealth-eligible patients, only 93.3% of the READY study population were. Beyond this, we saw minor differences between the average age of the READY study population and ours (READY study, 6.2 years; our study, 8.4 years). As previously noted, race and ethnicity data available in MassHealth claims are largely incomplete, which restricted our ability to compare the racial breakdown of the READY study population and ours. Additionally, we could not adjust for differences in the READY study population and ours because we could not access individual patient data from the READY study.

Although the racial and ethnic composition of the 1,367 participants in our analysis is largely unknown, we did not use a stand-in variable, such as income or socioeconomic status. As acknowledged across leading public health frameworks and shown by a robust body of literature, race and racism affect health outcomes such as asthma, independent of the association between race and other socioeconomic factors such as income and cultural differences (8,22–24).

Efforts were made to validate these results, whenever possible. For example, based on available data on higher rates of asthma prevalence among residents of Massachusetts with low incomes (25), we expected that asthma prevalence in this MassHealth population would be slightly higher than that of the general population. This was the case when we compared our 12% asthma prevalence estimate from the MassHealth claims data with the 2019 Massachusetts statewide BRFSS asthma prevalence estimate of 9.5% (26). This finding helped establish the face validity of our MassHealth asthma prevalence estimate, which informed our cost projection estimates.

Limitations

Our study had several limitations. Because of the resource-intensive nature of a large-scale expansion of the CHW model across our study population, our study only simulated the effects of this expansion (our proposed intervention was not conducted in our study population). First, as a hypothetical intervention, our results may differ in actual application. Second, estimates of cost savings may not extend to a different year, state, or patient population or to costs associated with a different insurance provider, potentially limiting the generalizability of our findings. Third, we applied data from the primarily Black and Hispanic READY study population to a population in which race was largely unknown. However, given the highly adaptable nature of the CHW model to the unique, lived experiences of the patients and communities served, we anticipate that applying the CHW model to a population with a different racial or ethnic composition would produce similar results. The program structure and implementation (eg, CHW staffing, training, level of CHW integration into primary care teams) also may vary across specific applications of the CHW model in ways that affect the benefit derived from the intervention. For example, interventions that are fully staffed by CHWs, receive adequate funding, and have more complete integration of CHWs into the primary care team may be associated with greater reductions in asthma-related health care use and greater cost savings.

An additional limitation of our study design is the assumption that all children covered by MassHealth with uncontrolled asthma would benefit equally from the CHW model. We recognize that some children may not benefit from this intervention for systemic, cultural, or patient-specific reasons (eg, earned distrust in the medical establishment, inflexible caretaker work schedules, other personal barriers that limit participation). Beyond this, how we define benefit — as a quantified measure of cost within the health care system — also has its limitations, because our definition fails to acknowledge the other less easily quantifiable emotional or social benefits that affect quality of life and that have been demonstrated with the CHW model (27).

Another important limitation is that our analysis did not factor in the costs associated with scaling up the CHW model. Instead, we focused solely on the reduction in asthma-related ED and hospitalization costs. Given that the costs of CHW model expansion can vary greatly over time and across communities, depending on a variety of factors (eg, staffing needs, unit costs of supplies, transportation costs), estimating the costs of expansion was outside the scope of our analysis. Our study only provides an estimate of the expected reduction in health care costs associated with the expansion and is not meant as a cost–benefit analysis. It may be useful for future researchers to build on this analysis to develop a more inclusive estimate of the cost savings associated with the expansion of the CHW model by factoring in costs associated with expansion.

Although our study had several limitations, we aimed to be as conservative as possible when estimating expected health care cost reductions, and we may have underestimated savings. First, we may have underestimated the size of the population that would be affected by this intervention. We defined children with uncontrolled asthma as those with 2 or more asthma-related ED visits per year in which asthma was the primary or secondary diagnosis, excluding children with asthma listed only as part of an additional diagnosis. We also made a full 12 months of MassHealth eligibility in 2019 an inclusion criterion, excluding those with less time of eligibility.

Beyond the conservative estimates of the patient population, we also conservatively estimated included costs. Restricting the health care costs considered in this analysis to only ED visits and hospitalizations where asthma was the primary or secondary diagnosis potentially excluded visits that were asthma-related, leading to an underestimation of costs that could be reduced by the CHW intervention. In addition, children with asthma may also have family members with asthma who could benefit from the intervention but whose cost savings would not have been captured in our analysis (13). We did not include pharmacy claims because they were incomplete in our data set. We also did not include the cost of clinician visits because we did not find them to be meaningfully affected by the CHW model in the READY study. Greater reductions in health care costs were observed in other similar studies by Gomez et al (15) and Campbell et al (12), which included other types of health care costs (eg, clinician visits, medication) associated with the CHW model, suggesting that our narrower focus on reductions in asthma-related ED visit and hospitalization costs may have led to more conservative estimates of cost savings associated with the CHW model. However, based on the inequities that we have identified in use of these health care services in Massachusetts, we feel that the exclusive use of asthma-related ED visits and hospitalizations as measures of health care use was reasonable. Despite our narrow focus, we believe that the identified reduction in asthma-related ED and hospitalization costs alone offers sufficient support for significant expansion of the CHW model.

Although we did not see a significant increase in clinician visit costs in the READY study, at a broader level health care use may shift toward an increase in primary care visits and their associated costs, which could offset some of the cost savings reported here. However, we anticipate that any such shifts would be minor and would not substantively affect the cost savings associated with this intervention from a clinical perspective, because the shift could indicate better asthma control.

Conclusion

Evidence strongly suggests that large-scale expansion of the CHW model to children with uncontrolled asthma who are eligible for Medicaid would lead to cost savings. This expansion is also expected to improve asthma outcomes for the MassHealth population of children with uncontrolled asthma (11,13,14), which disproportionately contains Black and Hispanic children (28). Expansion of the CHW model is one part of a comprehensive approach to asthma care that has the potential to reduce racial disparities in asthma outcomes by increasing access to linguistically and culturally appropriate asthma care.

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Tables

Table 1. Demographic Characteristics, Participants With Asthma in the READY Study (N = 254)[a] and in the Study of Massachusetts Medicaid (MassHealth)-Eligible Children With Uncontrolled Asthma (N = 1,367)[b]

Variable	READY study population[a]	MassHealth-eligible children with uncontrolled asthma[b]
Insurance type[c]		
Medicaid	237 (93.3)	1,367 (100.0)
Private	15 (5.9)[d]	0
Information missing	2 (0.8)[d]	0
Age, y		
1 – 4	Not reported	355 (26.0)
5 – 8		320 (23.4)
9 – 12		312 (22.8)
13 – 17		380 (27.8)
Age, y, mean	6.2	8.4
Sex		
Male	149 (58.7)	797 (58.3)
Female	105 (41.3)	570 (41.7)
Race or ethnicity[d]		
American Indian or Alaskan Native	Not reported	5 (0.4)
Asian or Pacific Islander	Not reported	15 (1.1)
Hispanic	125 (49.2)	138 (10.1)
Non-Hispanic Black	122 (48.0)	108 (7.9)
Non-Hispanic White	7 (2.8)	360 (26.3)
Multiracial	Not reported	40 (2.9)
Unknown	0	701 (51.3)

Abbreviation: READY, Reducing Ethnic/Racial Asthma Disparities in Youth.
[a] Massachusetts Department of Public Health study evaluating the health and economic effects of the community health worker model, a multicomponent, low-cost, asthma home visiting intervention for children with asthma, conducted in Boston and Springfield, Massachusetts, among a population that was 93.3% insured by MassHealth. Children who completed community health worker visit 1 were the only group of patients for whom demographic information was published (11). Values for some measures in the READY study were not published. Values are n (%) unless otherwise noted.
[b] Simulation study of hypothetical cost savings for a statewide subsample of children eligible for Massachusetts Medicaid (MassHealth) coverage in 2019, identified from MassHealth eligibility and medical claims extracted from the MassHealth data warehouse. The study population was defined as children with a full 365 days of MassHealth eligibility and at least 2 asthma-related emergency department visits in 2019 where asthma was the primary or secondary diagnosis.
[c] In the READY interventional study, insurance type was based on caregiver self-report. In the simulation study of statewide cost savings, all participants were MassHealth-eligible.
[d] Race and ethnicity data fields were largely incomplete in the MassHealth data warehouse.

Table 2. Estimated Pre-Intervention and Postintervention Costs, Study of MassHealth-Eligible Children With Uncontrolled Asthma (N = 1,367)[a], Compared With Actual Costs of Children With Uncontrolled Asthma (N = 22) From the READY Study[b]

Study	Asthma-related ED visit costs per patient, 2019 US$		Asthma-related hospitalization costs per patient, 2019 US$	
	Pre-intervention	Postintervention	Pre-intervention	Postintervention[c]
READY study population[b] (N = 22), mean	1,512.87	454.39	2,543.76	1,243.14
All MassHealth-eligible children[a] (N = 1,367), mean	490.69	147.38	436.68	213.41

Abbreviations: ED: emergency department; READY, Reducing Ethnic/Racial Asthma Disparities in Youth.
[a] Study of hypothetical cost savings for a statewide subsample of children eligible for Massachusetts Medicaid (MassHealth) coverage in 2019 identified from MassHealth eligibility and medical claims extracted from the MassHealth data warehouse. The study population was defined as children with a full 365 days of MassHealth eligibility and at least 2 asthma-related emergency department visits in 2019 where asthma was the primary or secondary diagnosis (11). If a patient in the population of MassHealth-eligible children with asthma did not have an asthma-related hospitalization, their asthma-related hospitalization costs were considered 0. Costs of 0 were included when calculating the mean asthma-related hospitalization cost value.
[b] Massachusetts Department of Public Health study evaluating the health and economic effects of the CHW model, a multicomponent, low-cost, asthma home visiting intervention for children with asthma, conducted in Boston and Springfield, Massachusetts among a population that was 93.3% insured by MassHealth (Massachusetts Medicaid) (11). Pre-intervention costs for the READY study population were defined as the costs for a 1-year period before the first CHW visit in the intervention. Post-intervention costs were defined as the costs for a 1-year period starting after the last CHW visit of the intervention.
[c] Post-intervention costs for the overall MassHealth pediatric population were estimated based on the assumption that the proposed intervention (ie, the CHW-led asthma home visiting model) would lead to cost reductions proportional to those observed in the uncontrolled asthma cohort of the READY study. MassHealth medical claims for 2019 were obtained from the MassHealth data warehouse (an internal resource).

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TOOLS FOR PUBLIC HEALTH PRACTICE

Evaluation Resources for Asthma Programs and Beyond

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PEER REVIEWED

Summary

What is already known on this topic?

Although program evaluation is central to public health, many professionals are untrained in this practice.

What is added by this report?

We summarize the work of the National Asthma Control Program's evaluation team and its wide selection of tools. These tools are publicly available and useful for a wide array of public health professionals, extending beyond the asthma field.

What are the implications for public health practice?

Tools described support evaluation capacity building and the distribution of foundational evaluation tools.

Abstract

Evaluation can ensure the quality of public health programs. Systematic efforts to identify and fully engage everyone involved with or affected by a program can provide critical information about asthma programs and the broader environment in which they operate. To assist evaluators working at programs funded by the Centers for Disease Control and Prevention (CDC's) National Asthma Control Program (NACP), we developed a package of tools that build on the CDC's 1999 Framework for Program Evaluation in Public Health. The resulting suite of evaluation tools guides evaluators through a structured but flexible process, engaging a diverse array of interest holders and actively involving them in evaluation planning and implementation, all while strengthening their capacity to meaningfully contribute to the evaluation process. For our newest tool, our team reviewed the recent evaluation literature to create an enhanced version of the 1999 framework that describes important elements of professional evaluation practice. Although the original framework describes the steps to take in conducting an evaluation and the standards for a high-quality evaluation, our enhanced framework includes an explanation of how evaluators should approach their work: by incorporating critical reflection, interpersonal competence, situational awareness, and cultural responsiveness. In this article, we highlight many of the evaluation resources our team has created since the NACP's inception, culminating in a free e-text called *Planting the Seeds of High-Quality Program Evaluation in Public Health*. Public health professionals working in many types of programs — not just asthma — may find these resources useful.

Background

Evaluation, the "process of determining the merit, worth, or value of something, or the product of that process" (1), is central to public health practice and is an essential service of public health (2). It is a means for asking and answering important questions about how we can improve the public's health and be accountable for public funds. Evaluation is also included in several public health professional competency sets (3,4). Accordingly, the demand for evaluation is high, especially among agencies within the US Department of Health and Human Services, where evaluation has become a tool that public health practitioners and their partners use to make evidence-informed decisions (5).

Despite the importance of evaluation, research studies suggest that many public health professionals who enter the field through formal academic routes (eg, master's degree in public health from accredited institutions) may graduate without completing a course in evaluation (6,7). Post graduation, the availability of professional development opportunities and funds to support them is limited. As a result, public health agencies and organizations often do not have ready access to staff with the skills and knowledge needed to competently plan and conduct evaluations or to commission and monitor evaluation contracts. It is this gap that we, evaluators in the Centers for Disease Control and Prevention's (CDC's) National Asthma Control Program (NACP), set out to fill, both through tailored technical assistance for our partners and the creation of a variety of resources.

As NACP celebrates 25 years of public service, we recognize the importance of documenting what has been accomplished during those years. This article is not only a historical account of the evaluation team's time in NACP, but also a reflection on a selection of the publicly available tools and materials that have been developed. We hope that this article will serve as one of those tools to further support the work that you perform or give you a moment's pause while you discover something new.

Evaluation as a Tool for Systematically Learning How to Improve Programs

Evaluation conducted in keeping with professional standards is a responsive and collaborative undertaking. All 4 of what we consider foundational documents for the evaluation field call on evaluators to engage with interest holders to guide their work. These are the American Evaluation Association's (AEA) Guiding Principles, the Program Evaluation Standards (created by the Joint Committee on Standards for Education Evaluation and used broadly in the field to define standards for high-quality evaluation), AEA's Public Statement on Cultural Competence, and the AEA Evaluator Competencies (8–11). In developing evaluation capacity-building materials for its funded partners, the NACP relied heavily on these documents and mirrored their collaborative approach.

NACP partners include the staffs of state, local, and territorial health departments and their many partners as well as staffs of national nongovernment organizations. Staff members responsible for evaluation activities in these organizations have varying backgrounds and levels of evaluation experience and expertise. Many come with epidemiology or research backgrounds and bring some of the technical skills required for evaluations, but they are often unfamiliar with the context in which those skills are to be applied.

In NACP's early days, few resources were available to respond to partners' requests for guidance on what was often, for them, a new responsibility. A new tool at the time was CDC's Framework for Program Evaluation in Public Health (CDC Framework) (12). This framework set forth a flexible 6-step process for evaluating all aspects of public health programming. The framework emphasized the inclusion of interest holders — people affected by the program or its evaluation — and the importance of using an evaluation's processes and findings to guide program improvement. Partly because of its apparent simplicity, the graphic depicting the evaluation steps and standards became an icon for many public health professionals. Even so, partners reported that they had difficulty applying the framework.

In response, NACP hired a team of evaluators to help build evaluation capacity internally and in the asthma programs it funded. Initially, staff members delivered introductory trainings focused on demystifying evaluation (13). As partners expanded the scope of their evaluation activities, we recognized a need for more comprehensive capacity building. The evaluation team tapped NACP program staff members who had an interest in evaluation to help tailor our approach to the programs' needs, and we started to build out a suite of resources. Over the ensuing decade and a half, we created the tools to build these resources (Table 1). As you read, we encourage you to imagine how you might use evaluation generally and these tools specifically to demonstrate your program's value and identify ways to improve your impact on the public's health.

Tools for Learning and Growing Through Evaluation

Initially, NACP evaluation team members, dubbed evaluation technical advisors (ETAs), set out to develop a user-friendly guide that would walk novice evaluators through the full evaluation process; they would learn evaluation — build their evaluation capacity — as they used the tools. To ensure relevance, we worked with asthma program partners who served as advisors and reviewers, a process we continue. We called the guide, which evolved into a series of modules, *Learning and Growing Through Evaluation*. The title was intended to reinforce the idea that evaluation is a tool that can identify a program's strengths and areas for growth.

We published the first module of *Learning and Growing Through Evaluation* in 2009, at the start of a new cooperative agreement (14,15). Module 1 introduced the concept of strategic evaluation planning, that is, working with interest holders to anticipate information needs throughout the 5-year cooperative agreement and creating a comprehensive portfolio of evaluations to meet those needs. At the time, longer-term evaluation planning like this was uncommon in the field, so we created a strategic evaluation plan (SEP) template that included fill-in-the-blank sections along with guidance on how to complete the plan. For example, one key task in creating a SEP is prioritizing evaluation investments among the many potential program elements that could be evaluated. The template aligns with sections in the module that describe various prioritization methods and offers sample criteria, like cost and equity.

The SEP template includes a timeline that encourages interest holders to map when evaluation findings will be needed against when they will be available. This can avoid timing missteps, like wrapping up an evaluation a month after a related grant application is due or starting to think about an evaluation near the end of a grant cycle, long past when relevant people and information are available. The timeline facilitates a cross-evaluation strategy whereby data collected in one evaluation might be leveraged in another. Finally, the SEP timeline helps program developers plan their evaluation capacity-building activities, looking ahead at evaluation needs to ensure that appropriate staffing or staff training are available when needed.

The first module also provides an evaluation plan template and guidance for evaluating the activities that were identified in the SEP as warranting evaluation. Unlike many evaluation plan templates that cover little more than data collection and analysis, the individual evaluation plan template lays out a blueprint for implementing all 6 steps of an evaluation. It starts with an interest holder assessment and engagement table and ends with guidance on documenting the evaluation's implementation and acknowledging contributors.

The second *Learning and Growing* module moves beyond planning to provide strategies and tools for implementing and managing evaluations (16). It offers tips on addressing common challenges such as budgeting, and it introduces an action plan template that documents strategies for responding to an evaluation's finding. We tailored subsequent modules to the strategies and activities asthma programs were using in their work, such as partnerships (17) and surveillance (18). The sixth and most recent module covers economic evaluation (19). Each module contains relevant tools and examples to facilitate evaluation processes while building evaluation capacity.

Early on, we were fortunate to collaborate with the US Environmental Protection Agency to develop a series of training webinars (20) that partners could access anytime, providing an avenue for continuous and sustainable engagement with the steps of the evaluation framework. The webinars range in length from 15 to 65 minutes, and some of the shorter webinars are ideal for funding recipients to share with their partners who need only a brief introduction to evaluation. Although the webinars provided general overviews of evaluation, we saw a need to understand and develop materials tailored to partner capacity.

With ETAs participating in monthly calls with partners, we had some insight into the types of evaluation activities partners were conducting, which in turn informed our materials development. To formalize this process, we created an evaluator self-assessment (21). ETAs and evaluators working in funded programs completed the self-assessment and flagged areas where professional development and additional tools would be helpful. A benefit of the assessment was that it highlighted instances in which novice staff members already possessed important skills, adding to their confidence in a new role. We also discovered the wealth of expertise among our partners, allowing us to draw on them as teachers for our community of practice.

One of the primary ETA roles is to review our partners' evaluation plans — to add an external perspective to that of interest holders closely connected to the program. We discovered that evaluators had a difficult time understanding the differences among evaluation questions, research questions, and survey questions. We searched the evaluation literature and compiled an initial list of the characteristics of good evaluation questions, that is, questions that are likely to produce useful information. We then workshopped the list with several groups of experienced evaluators to establish agreed-upon criteria. From this, we created the Good Evaluation Questions Checklist (22). Evaluators and interest holders can use the checklist to sharpen the focus of their evaluations, review the evaluation's standards, and document the rationale for their planning decisions.

Next, we took on the challenge of translating the literature on culturally responsive evaluation, which is "a holistic framework for centering evaluation in culture" (23). We partnered with CDC's Division for Heart Disease and Stroke Prevention to create the guide, *Practical Strategies for Culturally Competent Evaluation* (24), and an accompanying tip sheet (25). The tools support evaluators in responding to the specific cultural contexts in which programs are working. Practicing evaluation in a culturally responsive way is important on principle and, instrumentally, it improves the validity of evaluative inferences. The Cultural Competence Assessment Tool (CCAT) (26) is a related tool that helps staff in state and local health departments assess their capacity to appropriately apply the US Department of Health and Human Services' Culturally and Linguistically Appropriate Services standards (27).

One of our current focuses is on producing evaluation briefs (28–30), which provide short overviews of common evaluation topics. For example, when CDC added a performance monitoring component to its cooperative agreements, we noticed that partners had a hard time understanding how evaluation and performance monitoring work together. In response, we created a 4-page primer on the topic. Another current focus has been the co-development of an evaluation training series based on our materials in conjunction with the Climate and Health Program.

Moving Upstream

To date, the primary audience for our resources has been practicing public health professionals. Our tools are designed to be practical: to enable anyone to competently perform a wide range of technical evaluative tasks and to give them tools for understanding and responding to the often-political contexts in which evaluations occur. In 2019, when we set out to update our *Learning and Growing through Evaluation* modules, we saw the opportunity to augment our materials with the theoretical and conceptual foundations of the evaluation field, to create a tool that would fill that gap in many public health professionals' academic training. To this end, we published a free online evaluation textbook, *Planting the Seeds for High-Quality Program Evaluation in Public Health* (31).

The e-text marries theory and practice in a way that practitioners can easily apply. Though it is suitable for use in undergraduate and graduate courses, each chapter is informative for many audiences, from novice to advanced. Chapters end with review questions and skill-building exercises, and they include many of the tools and templates introduced in the modules. After reading the e-text, people who are brand new to evaluation will have a solid foundation for practice. Those who are more advanced will acquire skills and knowledge about evaluation approaches and techniques that they likely have not encountered. Our goal was to empower readers to have a better understanding of what is entailed in carrying out high-quality evaluations and what they can do to support and sustain high-quality evaluation practices in their organizations.

In creating the e-text, we recognized the need to update the original CDC Framework to include important advances in the discipline of evaluation. In our enhanced evaluation framework (Figure) we surrounded the steps and standards from the original framework with the characteristics that are important for evaluators to embody as they carry out their work: critical reflection, cultural responsiveness, situational awareness, and interpersonal competence. As evaluators, our ability to be aware of ourselves, others, and the broader environments in which we are working — the *how* of our practice — is equally as important as the technical steps we take. Our enhanced framework also recognizes the need to assess context (adding a step 0) and build evaluation capacity to ensure all interest holders can equitably engage in the evaluation process.

Figure. Enhanced evaluation framework.

Our enhanced framework resonated with many participants in a session at the 2022 AEA conference. Participants contributed their strategies and suggestions for implementing the 4 *hows* of evaluation practice (Table 2). As CDC's Framework did in 1999, the e-text and our enhanced framework establish a new stepping-off point for using evaluation as a tool to make our public health programs more effective and equitable.

Evidence of growth

Although we conducted an evaluation of our tailored technical assistance, we have not formally evaluated our collection of resources. Nevertheless, we have seen evidence of their influence among our partners in funded asthma programs and in the broader evaluation field. From the outset, our materials have framed evaluation as an opportunity to learn and grow rather than as a compliance activity done to meet a funder requirement. The response from our partners suggests that they see utility in this approach. In the spirit of learning, partners regularly contribute to AEA365, AEA's blog; they often share their work at AEA's annual meeting; and 4 state asthma programs voluntarily participated in a study on evaluative thinking, which was featured in *New Directions for Evaluation*, one of AEA's flagship journals (32). And even though CDC's cooperative agreements no longer include staffing requirements, most, if not all, funded partners dedicate a portion of their funding awards to support evaluation staffing.

NACP partners are applying what they learn to improve their programs. According to performance monitoring data NACP collected for its 5-year cooperative agreement that ended in 2019, partners took 426 actions based on their evaluation findings. Almost half of these actions related to improving, expanding, or sustaining specific interventions; other actions related to improving program infrastructure (surveillance, partnerships). We have published stories about our partners' evaluation work in a document called *Learning as We Grow* (33,34); it is both a celebration of their work and a guide for others who are building out their evaluation capacity.

The reach of our materials has extended beyond the NACP. For example, in 2021, Thomas and Campbell included our Checklist for Assessing Your Evaluation Questions in their evaluation textbook, *Evaluation in Today's World* (35); the text also referenced *Practical Strategies for Culturally Competent Evaluation*. Lovato and Hutchinson link to our webinars in their *Evaluation for Leaders* course (36). We have also received informal feedback from people who have put our tools to the test. Our materials have been called user friendly, concise, and accessible, and, in an especially gratifying email from a funded partner, they were described as "an exemplary demonstration of how to put the power of evaluation in the hands of people doing essential work within state health departments, and beyond."

Challenges and looking forward

Our tools are designed and vetted to ensure that they are user friendly and make evaluation approachable; however, even with these supports, evaluation can be challenging. The participatory approach fundamental to our enhanced framework takes time. Evaluation interest holders must be engaged and committed to a learning process. The day-to-day demands of implementing programs often seem to leave little time for conducting high-quality evaluations and acting on their findings.

We emphasize that evaluation is a tool for learning and growing, and still it can be difficult to dispel the notion that evaluation is a compliance activity, or an activity designed only to expose flaws rather than program strengths. Our hope is that as our partners and others in public health use our tools, they will develop an appreciative lens, seeing the assets and potential their programs possess. We hope they will see evaluation as a useful and grounding tool, especially during public health emergencies like the COVID-19 pandemic.

The tools developed and highlighted here will continue to be free and publicly available, serving as resources and guides to bolster evaluation practice. As evaluators in the NACP, we will continue to listen, respond, and adapt. We will continue to shine the light on evaluation as a tool to "make visible oppression and possibility," in the words of evaluation scholar Donna Mertens (37). Evaluation is not a solo task. It is a difficult and time-consuming endeavor, a rewarding endeavor, that requires people from all walks of life to come together. As we look toward the future, we will be forever grateful for the colleagues who have, and who will, continue to learn and grow with us.

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Tables

Table 1. Inventory of Evaluation Tools Developed by CDC's National Asthma Control Program (NACP)[a]

Tool	Description and Use
Learning and Growing Through Evaluation: State Asthma Program Evaluation. https://www.cdc.gov/national-asthma-control-program/php/program_eval/guide.html	A series of 6 modules that provide step-by-step instructions and tools to facilitate the entire evaluation process. The modules help people responsible for leading and participating in evaluations build evaluation capacity and assure findings will be useful.
Module 1: Planning Evaluations. https://www.cdc.gov/national-asthma-control-program/php/program_eval/eval_guide/AsthmaProgramGuide_Mod1.pdf	Focuses on planning evaluations. Includes guidance on and templates for individual evaluation plans as well as a multi-year strategic evaluation plans. Select other tools and templates include: • Program Activity Profile • Potential Criteria for Evaluation Prioritization • Evaluation Question Development Table • Evaluation Design and Data Collection Summary Table
Module 2: Implementing Evaluations. https://www.cdc.gov/national-asthma-control-program/php/program_eval/eval_guide/AsthmaProgramGuide_Mod2_1.pdf	Provides users with a myriad of strategies to assist in the successful implementation of an evaluation. Includes tools and appendixes with detailed information on: • Ways to Work with Interest holders • Checklist for Successful Implementation of an Individual Evaluation Plan • Meeting Evaluation Challenges • Evaluation Management Toolkit • Budgeting for Evaluation • Developing an Action Plan
Module 3: Evaluating Partnerships. https://www.cdc.gov/national-asthma-control-program/php/program_eval/eval_guide/AsthmaProgramGuide_Mod3.pdf	This module focuses on the specific challenges that come with assessing collaborations. It includes tools and appendixes, including: • Partnership Concept Map for the NACP • Evidence Base on Effective Partnerships • Crosswalk of Partnership Concepts with Sample Evaluation Questions and Tools • Health Equity and Evaluation • Potential Practices for Incorporating Equity into Partnership Evaluation
Module 4: Evaluating Asthma Surveillance. https://www.cdc.gov/national-asthma-control-program/php/program_eval/eval_guide/AsthmaProgramGuide_Mod4.pdf	Based on CDC's Updated Guidelines for Evaluating Public Health Surveillance Systems, this module tailors the evaluation process for asthma surveillance systems. It includes: • Sample Surveillance Evaluation Questions • Sample Criteria of Merit and Indicators for Asthma Surveillance Evaluations • Example of Indicators and Associated Performance Standards
Module 5: Evaluating Services and Systems Interventions. https://www.cdc.gov/national-asthma-control-program/php/program_eval/eval_guide/asthmaprogramguide_mod5.pdf	This module focuses on evaluation of coordinated activities designed to achieve outcomes at the individual or population level. Tools included address: • Overarching intervention evaluation question types — process question • Overarching intervention evaluation question types — outcomes questions

Abbreviation: CDC, Centers for disease Control and Prevention.
[a] At the time of this publication, all materials are available through asthma evaluation website (https://www.cdc.gov/national-asthma-control-program/php/program_eval/index.html). If you have any issues reaching the materials or would like to provide questions or feedback on specific materials, please contact the corresponding author, Samuel Dunklin at qaf3@cdc.gov.

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Tool	Description and Use
	• Evidence continuum and types of evaluation • Using social science theory in evaluation • Relationship of logic model elements, evaluation questions, criteria of merit, and indicators
Module 6: Economic Evaluation for Asthma Programs. https://www.cdc.gov/national-asthma-control-program/php/program_eval/eval_guide/asthmaprogramguide_mod6.pdf	This module shows how to add economic evaluation to an overall evaluation portfolio. It includes: • Potential Interest Holders by Evaluation Perspective • Commonly Used Analytic Methods in Economic Evaluation • Analytic Methods and Associated Summary Measures • Distinguishing Characteristics of Economic Evaluation • Components of Resources Consumed and Outcomes Realized in a Public Health Programs • Templates for Managing Cost Data
Evaluator Self-assessment. https://www.cdc.gov/evaluation/tools/self_assessment/index.htm	This tool encourages evaluators to systematically reflect on and inquire about their own capacity to conduct high-quality program evaluations. Users can identify professional development needs and strengths to further develop. [Originally developed by NACP, CDC's Office of Policy, Performance and Evaluation now hosts this tool.]
Good Evaluation Questions Checklist. https://www.cdc.gov/national-asthma-control-program/media/pdfs/2024/05/AssessingEvaluationQuestionChecklist.pdf	Based on the program evaluation standards, the checklist facilitates discussions among interest holders to assure that the evaluation questions selected for an evaluation are appropriate to guide the evaluation. It also serves to document the rationale and process for selecting questions.
Program Evaluation Tip Sheet: Integrating Cultural Competence into Evaluation: https://www.cdc.gov/national-asthma-control-program/media/pdfs/2024/05/cultural_competence_tip_sheet.pdf	This guide and tip sheet enable user to respond to persistent disparities in health outcomes with sensitivity and flexibility and work effectively in diverse contexts. These tools apply the program evaluation standards to highlight opportunities for integrating cultural competence throughout the six steps of the CDC Framework for Program Evaluation.
Cultural Competence Assessment Tool for State Asthma Programs and Partners (CCAT). https://www.cdc.gov/national-asthma-control-program/media/pdfs/2024/05/CCAT.pdf	The CCAT is a practical resource designed to promote and enhance cultural competence among partner organizations. Based on the Culturally and Linguistically Appropriate Service (CLAS) Standards, the CCAT is a self-assessment tool designed to assist programs in assessing the cultural competence of their own programs. Using a flexible, team-based approach, programs use the CCAT internally, with the aim of identifying program strengths and areas for improvement in cultural competence.
Practical Evaluation Using the CDC Evaluation Framework — A Webinar Series for Asthma and Other Public Health Programs. https://www.cdc.gov/national-asthma-control-program/php/program_eval/webinars.html	Nationally recognized experts present a general introduction to program evaluation; note challenges in conducting useful evaluations as well as methods for overcoming those challenges; and introduce the 6 steps of the CDC Framework for Program Evaluation. Webinars range from 15–65 min; PDFs of slides and scripts are posted.
Learning & Growing through Evaluation: Modules 1-6. https://www.cdc.gov/national-asthma-control-program/php/program_eval/guide.html	These documents highlight real world examples of how asthma programs have improved their programs with evaluation. Each entry describes the program or activity being evaluated, how the evaluation team conducted the evaluation, what the program learned during the evaluation, and how the program improved by using the results of the evaluation.
Planting the Seeds of High-Quality Program Evaluation in Public Health. https://www.cdc.gov/asthma/program_eval/PlantingSeeds_eTextbook-508.pdf	This free evaluation e-textbook is designed for public health professionals responsible for evaluation activities and for public health students. It is suitable for use in undergraduate and graduate public health programs and includes an overview of evaluation theory as well as practical tools and templates. It also provides an enhanced version of CDC's evaluation framework that emphasizes the importance of how evaluations are conducted.

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Table 1. Inventory of Evaluation Tools Developed by CDC's National Asthma Control Program (NACP)[a]

Tool	Description and Use
Learning & Growing through Evaluation: Briefs. https://www.cdc.gov/national-asthma-control-program/php/program_eval/briefs.html	These tools provide quick overviews on important evaluation topics: • The *Enhanced Evaluation Framework* brief concisely describes the four how's of practice detailed in the e-text. • *Foundational Documents for the Program Evaluation Field* introduces people new to evaluation to the four foundational documents that provide guidance to the program evaluation field on how to evaluate programs well and ethically: The American Evaluation Association's (AEA) Guiding Principles for Evaluators, The Joint Committee for Standards in Educational Evaluation's program evaluation standards, AEA's Public Statement on Cultural Competence in Evaluation, and AEA's evaluator competencies. • *Performance Measurement & Program Evaluation: A Suite of Evaluative Insights* helps new and seasoned evaluators to better understand how performance measurement and program evaluation are related. The brief provides insights about the usefulness of these inquiry methods and describes how they complement one another.

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Table 2. Strategies to Implement the How's of the Enhanced Evaluation Framework

How	Strategies to Implement
Interpersonal competence is a set of social skills for constructive interactions during the evaluation process, including communication, conflict resolution, and facilitation skills.	1. Establish trust 2. Understand power and privilege in context 3. Understand how power and privilege affect an evaluation 4. Address conflicts 5. Facilitate difficult conversations 6. Help partners to articulate their views and understand other points of view 7. Guide shared problem-solving and consensus building
Cultural responsiveness acknowledges and gives attention to the values, beliefs, and customs of a particular group or community. In an evaluation, cultural responsiveness means attending to the cultural aspects of a program and its interest holders in a respectful way while also being aware of one's own cultural identity.	1. Be adaptable 2. Create a diverse evaluation team: intersectionality of identities/cultures, lived experiences, different worldviews 3. Encourage programs to include program participants and their families on their advisory board 4. Understand the cultural values of interest holders, value co-creation 5. Learn and appreciate each program's cultural context and acknowledge that we may view and interpret the world differently from many evaluation interest holders 6. Question organizational practices that do not necessarily work for all
Situational awareness is the ability of an evaluator to understand how contextual factors such as the program's history, size, and complexity; the purpose of the evaluation (eg, formative, summative); evaluator experience, resource constraints; politics; and other factors affect evaluation design and use. Being situationally aware enables an evaluator to adapt and respond to these contextual factors by negotiating and implementing an evaluation that fits the intended uses.	1. Scan and assess context at regular intervals 2. Anticipate need to change and stay flexible 3. Accept and plan for leadership and staff changes 4. Maintain strong partner relationships and check-ins
Critical reflection involves a "sustained and intentional process of identifying and checking the accuracy and validity" of one's assumptions about their knowledge, values, beliefs, interpretations.	1. Take time before, during, and after a project to reflect on my role and identity, biases toward or within that project 2. Talk openly and learn what shapes other's views 3. Collaborate with an external evaluator with different perspectives 4. Walk and talk with friend whom you can trust to provide critical feedback, often called a critical friend 5. Invite other perspectives from those with lived experience, end users, etc., on data analysis/sense-making