

Trends in Asthma Control, Treatment, Health Care Utilization, and Expenditures Among Children in the United States by Place of Residence: 2003-2014



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What is already known about this topic? The prevalence of asthma is significant among US children. In addition, asthma morbidity presents a significant burden on children, with a more pronounced deleterious effect on children residing in poor-urban areas. There have been multitudinous efforts at all levels (federal, clinical, organizational) over the last 2 decades to implement policy recommendations from asthma guidelines with the goal of improving asthma control among children in the United States, and especially among those residing in poor-urban areas.

What does this article add to our knowledge? This study explored national trends in asthma control and treatment over time among all US children and those residing in poor-urban areas to determine where progress has been made and where improvements are still needed. Results suggest lack of improvement in asthma treatment and control since 2003. Health disparities persist among children living in poor-urban areas, but may have not increased over time.

How does this study impact current management guidelines? There is significant room for improvement in asthma control among children and the disparity gap persists among children residing in poor-urban areas.

BACKGROUND: Examining national trends in asthma treatment and control is essential to inform treatment and public health initiatives.

OBJECTIVE: Explore national trends in asthma control and treatment over time among children and those residing in poor-urban areas.

METHODS: This was an analysis of trends from 2003 to 2014 among children (aged 1-17 years) in the Medical Expenditure Panel Survey. Indicators of poor control included use of more than 3 canisters of short-acting β -agonists (SABAs) in 3 months, asthma attack, emergency department/inpatient hospitalization, and

systemic corticosteroids. Treatment included inhaled corticosteroids, controller medications, SABAs, and greater than or equal to 0.7 ratio of controller-to-total prescriptions. Other measures included the number of asthma medications, outpatient visits, asthma-specific drug, and total expenditures per-patient-per-year. **RESULTS:** There were 8.4 million children with asthma in the United States in 2014; 11.1% lived in poor-urban areas. There was a statistically significant decrease in the percentage of children using inhaled corticosteroids, controller medications, daily preventive medications, systemic corticosteroids, SABAs, more than 3 canisters of SABAs (in 3 months), overall asthma prescriptions, and outpatient visits. There was a significant increase in the percentage of children reporting having an asthma attack. Trends for children residing in poor-urban areas were compared with all others; however, limited data and variability in annual estimates prevent clear conclusions.

CONCLUSIONS: Results suggest lack of improvement in treatment and control since 2003 among children with asthma in the United States. There is significant room for improvement in asthma control and disease management among children. © 2019 American Academy of Allergy, Asthma & Immunology (J Allergy Clin Immunol Pract 2019;7:1835-42)

Key words: Health disparities; Children; Asthma; Poor-urban; Inner-city; Trends

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BACKGROUND

Asthma prevalence among children in the United States increased from 8.7% in 2001 to 9.4% in 2010, and then decreased to 8.3% in 2016.¹ In 2015, asthma prevalence among children ranged from 5.8% to 12.1%, depending on the state.² Asthma is one of the most

Abbreviations used

AHRQ- Agency for Healthcare Research and Quality

ED- emergency department

ICS- inhaled corticosteroid

LABA- long-acting β -agonist

MEPS- Medical Expenditure Panel Survey

MSA- Metropolitan Statistical Area

SABA- short-acting β -agonist

SCS- systemic corticosteroid

common chronic conditions among children, with an estimated 6.2 million sufferers younger than 18 years.

Recent asthma guidelines have emphasized the need to attain control as the goal of treatment. Asthma control is defined as the extent to which asthma therapy minimizes asthma symptoms and meets therapy goals.³ It is composed of the impairment domain (asthma-related symptoms and limitations experienced by the patient) and the risk domain (the likelihood of future exacerbations and progressive loss of lung function).³

Understanding trends in asthma control and treatment among children is important because children with poorly controlled asthma symptoms have an increased risk of exacerbations, hospitalizations, emergency department (ED) visits, and oral corticosteroid use, with exacerbations leading to progressive loss of lung function that can last into adulthood.⁴ In addition to clinical morbidity, poorly controlled asthma among children has been shown to result in increased health care utilization and expenditures,⁵ missed school days,⁶ reduced health-related quality of life,⁷ and a significant national public health burden.⁸

In addition to the burden on the general population, research has documented higher asthma prevalence and worse morbidity among residents of poor-urban ("inner-city" in the past) areas for decades.⁹⁻¹¹ Previous research has suggested many potential reasons for this disparity, including access to medical care, patterns of medical care, psychosocial stress, and environmental exposures.¹² This body of research has led to large-scale public health efforts to reduce the burden of asthma in poor-urban areas and has significantly advanced our understanding of asthma and its treatment.¹³ It is unclear how these disparities may have changed over time.

Given the alarming increases in prevalence, deleterious morbidity, public health impact, and health disparities associated with asthma among children in the United States, there have been multitudinous efforts at all levels (federal, clinical, organizational) over the last 2 decades to implement policy recommendations from asthma guidelines with the goal of improving asthma control among children in the United States.^{3,4,13,14} Most national-level studies of asthma control tend to focus on cross-sectional or recent snapshots. There is evidence to suggest that a significant number of children are poorly controlled in the United States in recent analyses (2007-2013).⁸ However, it is not clear whether this is actually an improvement compared with past levels of asthma control. It is also not clear which measures related to asthma control may have improved or deteriorated over time. In addition, although the existence of health disparities among children residing in poor-urban areas has been documented for many decades, it is unclear whether asthma control has differentially declined or improved in this population over

time. Understanding trends in asthma control and treatment over time is essential to provide context for public health efforts to improve asthma control.

METHODS

This study was a trend analysis of annual cross-sectional data for children aged 1 to 17 years in the nationally representative 2003-2014 Medical Expenditure Panel Survey (MEPS). Trends in asthma control, treatment, health care utilization, and expenditures were examined for children with asthma and also compared for differences by place of residence (poor-urban compared with all others).

Asthma

Children were classified as having asthma if they responded positively to 2 MEPS questions exhibiting evidence of asthma or if they responded positively to having been previously diagnosed with asthma and had evidence of currently treated asthma (current health care utilization with *International Classification of Diseases, Ninth Revision* diagnosis code 493 "Asthma" within the year). The MEPS questions used to identify the presence of asthma included a positive response to "Have you ever been diagnosed with asthma?" and the follow-up question "Do you still have asthma?" Children were classified as having current asthma if the response was positive for the 2 aforementioned questions. If the response was positive to the first but negative to the follow-up question, but there was current health care use with *International Classification of Diseases, Ninth Revision* diagnosis code 493 "Asthma," the child was classified as having current asthma. Children who had a positive response to ever having asthma but a negative response to the follow-up question and no health care use with *International Classification of Diseases, Ninth Revision* diagnosis code 493 "Asthma" were not included in the analysis because their asthma status was ambiguous.

Indicators of asthma control, treatment, health care use, and expenditures

Indicators of poor asthma control included asthma "attack" in previous year (self-reported; survey); use of more than 3 canisters of short-acting β -agonists (SABAs) in the previous 3 months (self-reported; survey); asthma-specific ED visit or hospitalization within the year (utilization-based); use of systemic corticosteroids (SCS: utilization-based); and a controller-to-total medication ratio of greater than or equal to 0.7 (utilization-based). The latter is the ratio of controller medications/(controller + SABA). In previous research, a controller-to-total medication ratio of greater than 0.7 has been shown to be predictive of poorly controlled asthma leading to exacerbations.¹⁵ These measures have been used to indicate poorly controlled asthma in previous publications.^{8,15} Asthma treatment outcomes included responses to 1 question about the use of a daily preventive asthma controller medication, including both oral medications and inhalers. In addition, 4 measures from prescription drug use were included: inhaled corticosteroids (ICSs: including combination products with long-acting β -agonists [LABA]); SABA; and controller medications (including leukotrienes, theophylline, mast cell stabilizers, and ICSs). Health care use included the annual mean number of asthma-specific prescription drugs per patient, asthma-specific outpatient visits (including office-based and outpatient visits), mean annual expenditures on asthma-specific prescription drugs, and mean annual asthma-specific total health care expenditures. Expenditures were expressed in \$2016.

Data source

MEPS is a nationally representative survey of the US civilian noninstitutionalized population that incorporates survey data from patients and families, medical providers, insurance providers, and employers to provide a comprehensive portrait of medical resource utilization, the frequency of utilization, costs of provided services, how these costs are paid, and the extent and scope of health insurance coverage for US residents. Each individual in MEPS is followed for a 2½-year period in an overlapping panel design. Respondents complete several questions in each round, with 4 rounds per year. MEPS constructs annual data files from the panel survey. The 2003–2014 annual data were used for this analysis (2014 was the most recent year for which data were available at the time of analysis).

The MEPS Household Component contains detailed self-reported information on demographic and socioeconomic characteristics, health conditions, insurance status, and utilization and cost of health care services. In addition, MEPS treats asthma as a priority condition and contains several questions specific to asthma. The MEPS Medical Provider Component is a follow-back survey that collects detailed information from a sample of pharmacies and health care providers used by MEPS respondents. The Medical Provider Component supplements and validates information on medical utilization, pharmacy events, and expenditures.

Each annual MEPS-Household Component sample size is about 15,000 households. Data were weighted to produce nationally representative estimates. The set of households selected for each panel of the MEPS-Household Component is a subsample of households participating in the previous year's National Health Interview Survey conducted by the National Center for Health Statistics, which is part of the Centers for Disease Control and Prevention. The National Health Interview Survey sampling frame provides a nationally representative sample of the US civilian noninstitutionalized population and reflects an oversample of blacks, Hispanics, and Asians. For over 50 years, the US Census Bureau has been the data collection agent for the National Health Interview Survey. Further details on MEPS are available at www.meps.ahrq.gov.

Poor-urban tract residence

Previous publications have most often referred to poor-urban areas as “inner-city” using the following definition^{16,17}: residence in a census tract with both (1) large Metropolitan Statistical Area (MSA) (“urban”) and (2) more than 20% of households below the federally defined poverty level (“poor”). Census tract and county Federal Information Processing Standard codes were available for each individual in MEPS as restricted data. “Restricted data” are data that are available only onsite at the Agency for Healthcare Research and Quality (AHRQ) Data Center headquarters in Maryland (or through specific secure arrangement at other federal data processing centers). Data from the National Center for Health Statistics Urban-Rural Classification Scheme for Counties were used to identify the metropolitan status (MSA) of the county of residence by county Federal Information Processing Standard code. These data were merged with the MEPS data (by Federal Information Processing Standard code) to determine metropolitan status (MSA) of the county of residence of the child in MEPS. The National Center for Health Statistics Urban-Rural Classification Scheme for Counties classifies counties by MSA into (1) large metro, central; (2) large metro, fringe; (3) medium metro; (4) small metro; (5) micropolitan; and (6) noncore on the basis of population density and other measures of urbanization. Generally, large metro central is considered the urban core, whereas large metro fringe is thought to be

equivalent to “suburban.” For each child's census tract of residence, the US Census Data were used to determine the percentage of residents below the federal poverty level within that census tract. This was linked by census tract to each child in MEPS to determine the poverty status of the tract of residence. Linkage of the 3 data sources provides a unique combination of nationally representative asthma control and treatment estimates by urban and poverty status of the child's place of residence (MEPS, National Center for Health Statistics Urban-Rural Classification Scheme for Counties, and the US Census).

Statistical methods

Survey-weight-adjusted means and proportions for several variables are presented graphically stratified by year. The main analyses present trends for all children with asthma in the United States from 2003 to 2014. A secondary analysis compares the trends over time for children with asthma residing in poor-urban areas compared with those not residing in poor-urban areas. For the main analyses, linear regression analysis of time on the outcome of interest was used to test for a significant trend over time. In the secondary analysis, the outcome variable is regressed on 2 trend-lines, one for each subgroup: children with asthma residing in poor-urban areas and those not residing in poor-urban areas. In this case, the comparison is children with asthma residing in poor-urban census tracts (as defined above) with children residing outside of poor-urban census tracts (all others). Finally, to test whether the 2 trends were statistically different, the 2 slopes were compared using an *F* Test. All analyses incorporate MEPS sample and variance weights to ensure nationally representative, annualized estimates and used STATA 14. This research was approved by a centralized institutional review board as well as the AHRQ Research Review Board. All analyses were conducted at AHRQ headquarters. Statistical code was given to the AHRQ employee who executed the code and returned the results to the study analyst.

RESULTS

In the United States in 2014, there were 8.4 million children aged 1 to 17 years with asthma (Table 1). Of the children with asthma in 2014, 11.1% lived in poor-urban areas compared with 9.2% of children without asthma who lived in poor-urban areas. The entire MEPS study sample (2003–2014) for this analysis included 13,300 children with asthma, 2,028 living in poor-urban areas and 11,272 living outside of poor-urban areas (with positive person-weights).

General trends for indicators of asthma control over time are presented in Figure 1. The percentage of children with asthma who reported having had an asthma attack increased over time. However, there was a statistically significant decrease in the percentage of children with asthma using more than 3 canisters of SABA and SCS. In addition, the percentage of children with a controller-to-total ratio of greater than or equal to 0.70 increased over time. The percentage of children with asthma using ICS, daily preventive medication for asthma, any controller, or SABA decreased over time (Figure 2). The mean number of outpatient visits and asthma prescriptions also declined (Figure 3). During the same time, the mean number of ED and inpatient visits, asthma prescription drug expenditures, and total asthma-specific health care expenditures per child per year remained relatively stable.

A comparison of the trends over time for children with asthma residing in poor-urban areas compared with non-poor-urban areas is presented in Figure 4. The trends for most outcomes

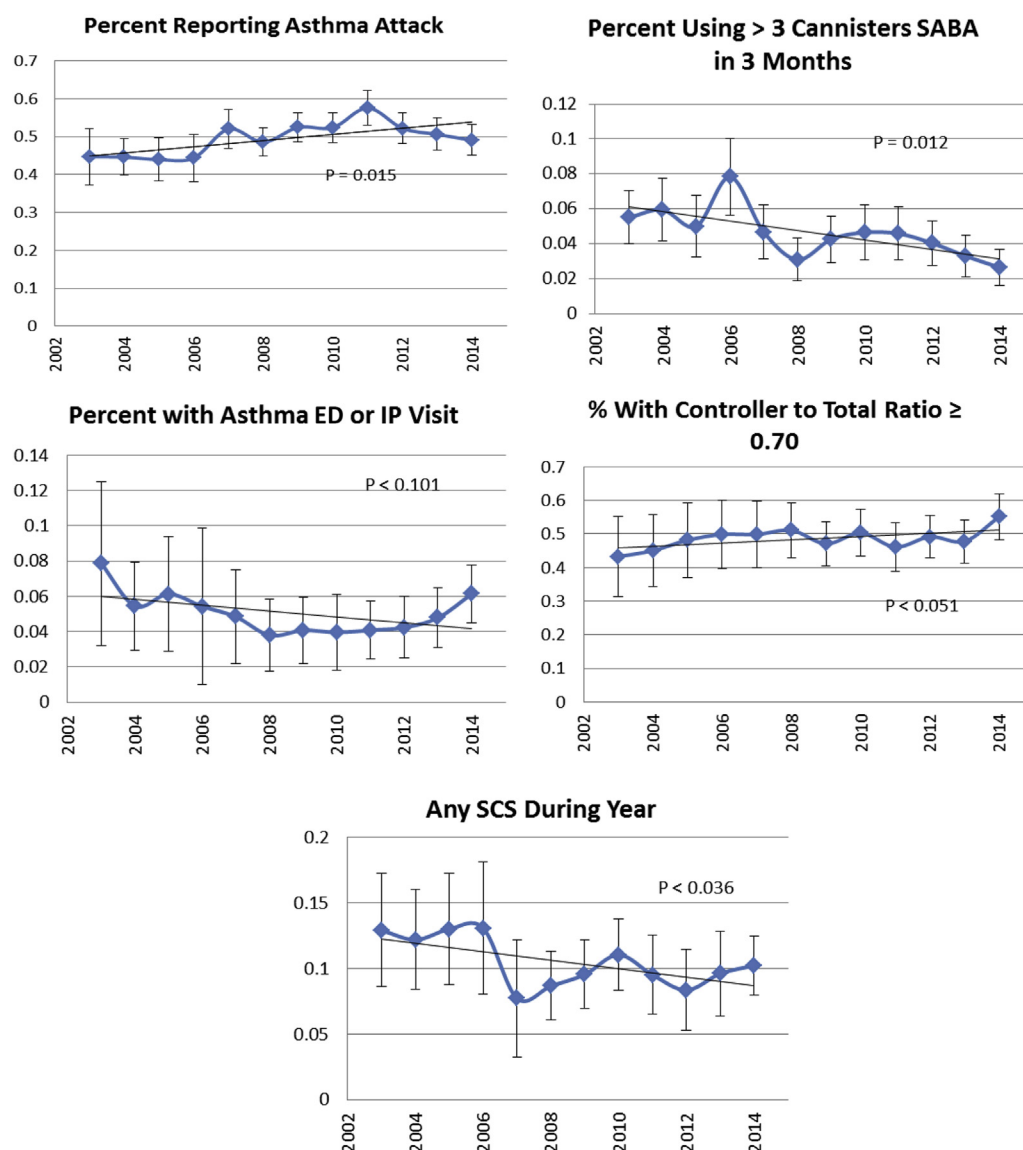
TABLE I. Children with and without asthma by place of residence

Place of Residence	Without asthma			With asthma		
	Sample (MEPS 2003-2014)*	Total in the United States (MEPS 2014)†	% (MEPS 2014)‡	Sample (MEPS 2003-2014)*	Total in the United States (MEPS 2014)†	% (MEPS 2014)‡
Poor-urban tract	13,731	5,592,100	9.2%	2,028	930,882	11.1%
Not poor-urban	87,233	55,348,462	90.8%	11,272	7,453,604	88.9%
Total	100,964	60,940,562	100%	13,300	8,384,486	100%

*Number of individuals with positive person-weights in MEPS 2003-2014 data.

†Weighted number of individuals in MEPS 2014 data using national extrapolation weights.

‡Weighted percentages of individuals in MEPS 2014 data.

FIGURE 1. Trends in indicators of asthma control among children with asthma in the United States (2003-2014). ICD-9, *International Classification of Diseases, Ninth Revision*.

were not statistically significantly different for children residing in poor-urban areas compared with children residing elsewhere. However, the percent of children using more than 3 canisters of SABA appears to have declined more steeply for children residing

in poor-urban areas than for children residing in non-poor-urban areas since 2003 ($P = .045$). It should be noted that the starting level for children residing in poor-urban areas was much higher than for those residing in non-poor-urban areas.

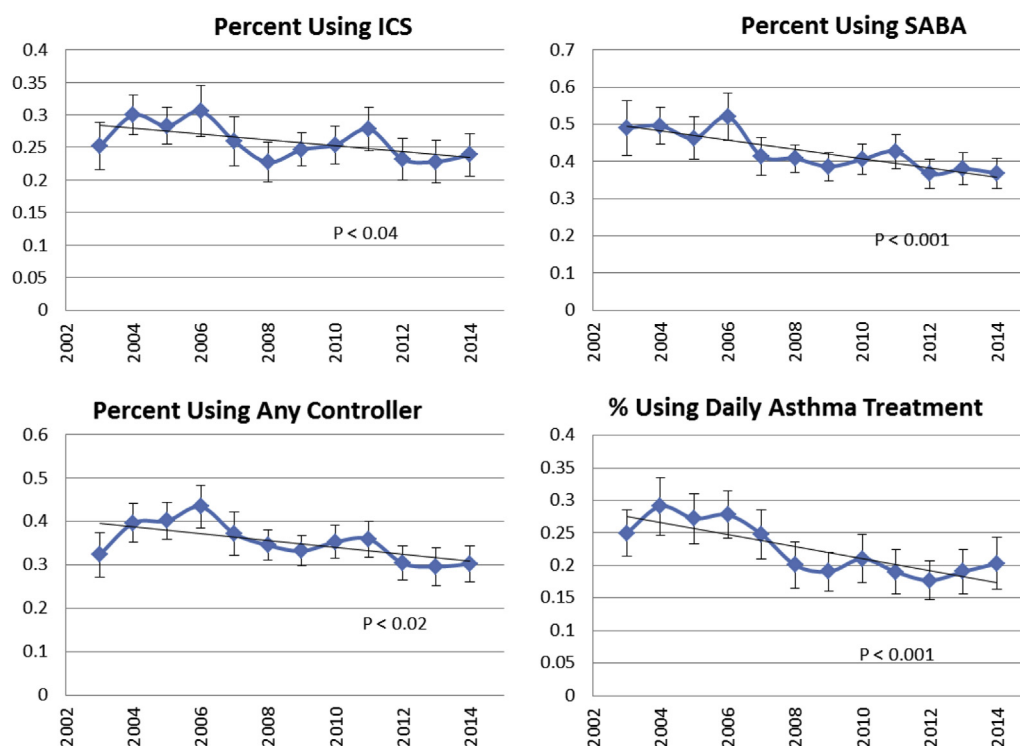


FIGURE 2. Trends in asthma medication use among children with asthma in the United States (2003-2014). *Data presented where available. Some questions were not asked before 2003 (Daily Preventive Asthma Treatment).

Although the percent of children using SCS during the year had a steeper declining slope over time for children residing in non-poor-urban areas than for those residing in poor-urban areas, it did not reach statistical significance. The change in the percentage of children using different types of medications over time did not appear to be statistically significantly different between children residing in poor-urban areas compared with those residing in non-poor-urban areas (see Figure E1 in this article's Online Repository at www.jaci-inpractice.org). The declining trends in measures of health care utilization were not statistically significantly different between the 2 groups (see Figure E2 in this article's Online Repository at www.jaci-inpractice.org).

DISCUSSION

Results from this nationally representative study of children with asthma from 2003 to 2014 suggest that many treatment patterns and trends in asthma control, although mixed, have not improved over this time frame. The levels of controller treatment and the percentage of children who have indicators of poorly controlled asthma remained suboptimal in 2014 and there is significant room for improvement. The trends for children who reside in poor-urban areas were not statistically significantly different than the trends for children who reside outside of poor-urban areas for most outcomes. However, given the wide variability in some of the annual estimates and the limited data studied, strong conclusions may not be evident.

The results show that there were some concerning developments in the use of controller medications and indicators of asthma control over this time. Although SABA and SCS use decreased, the percentage of children using ICSs, controller

medications, and daily preventive medications also decreased. In addition, there was a statistically significant increase in asthma attacks. On the positive side, there was a decrease in the excessive use of SABA (>3 canisters in 3 months). Many watershed events took place over this period that may have influenced the use of ICS in particular and asthma medication trends in general. ICS/LABA combinations were approved in the United States in 2001. In 2003, the Salmeterol Multicenter Asthma Research Trial was terminated early because of interim analyses showing increased respiratory-related deaths and life-threatening events; the increase was significant for blacks and for those not using ICS.¹⁸ The Food and Drug Administration imposed a "Black Box" warning for LABA in 2005. It is possible that these events precipitated the decline in the use of ICS (all formulations). This is consistent with the decreased use of controller medications and the self-reported use of daily preventive medications, which displayed a significant declining trend. The mean number of annual asthma prescriptions appears to peak in 2006, only to decline thereafter. The LABA controversy may have resulted in a reduction in the use of ICS/LABA that was not offset by increased use of other controller medications (including single-agent ICS) to a degree that has never recovered. It is possible that the decreased use of controllers is associated with the relative increase in asthma attacks. Future research is warranted to explore the impact of these trends.

Outcomes indicative of asthma control were mixed. Children with asthma experienced improvement on some measures indicative of asthma control since 2003: the percentage of children using more than 3 canisters of SABA in 3 months and overall use of SCS declined. At the same time, however, asthma attacks appeared to increase. Given the mixed nature of the outcomes, it is possible that these trends reflect changes in

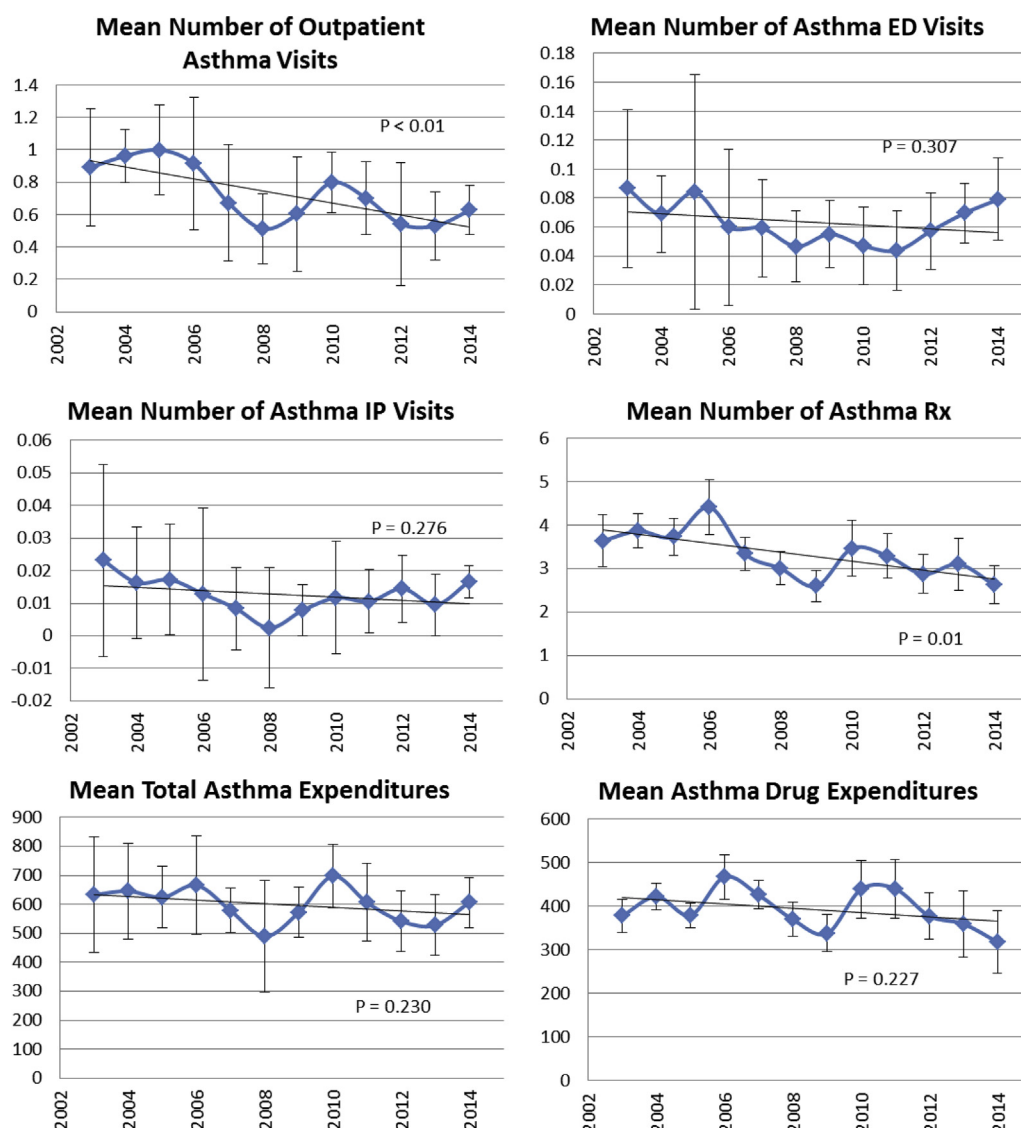


FIGURE 3. Trends in asthma-specific health care utilization among children with asthma. *Rx*, Prescriptions.

prescribing patterns rather than clear trends in asthma control. Nonetheless, there remains a large percentage of children with asthma in the United States who have indicators of poorly controlled asthma and suboptimal treatment as has been documented in previous research.⁸ For example, our results show that in 2014 only 24% of children with asthma used ICS (all formulations), 30% used any controller, 10% used SCS, and 6% had an ED or inpatient visit.

The trends in medication use for children residing in poor-urban areas were generally consistent with trends for children residing elsewhere (Figure E1). For example, the use of ICS and controller medications increased and SABA use decreased similarly from 2003 to 2014 for both groups. Similarly, the trends were generally consistent across groups for outcomes related to asthma control (Figure 4). The trends in ED/inpatient visits, percent reporting asthma attack, and percent with a controller-to-total ratio of greater than or equal to 0.70 were similar. On a positive note, there was a significantly greater decrease in

excessive use of SABA (>3 canisters in 3 months) over time in the poor-urban group. There were also some notable exceptions to these more positive or neutral trends. Finally, the trends in health resource utilization were also largely not statistically significantly different across groups (Figure E2).

Research has documented higher asthma prevalence and worse morbidity among residents of poor-urban ("inner-city" in the past) areas for decades.⁹⁻¹¹ A recent study focused on the existence and magnitude of health disparities among children residing in poor-urban areas compared with children residing elsewhere found significant differences in indicators of asthma control and treatment.¹⁹ This body of research has led to large-scale public health efforts to reduce the burden of asthma in poor-urban areas.¹³ As a result, it is crucial to examine how effective public health efforts have been over time. Our results did not show a statistically significant difference in trends over time for children living in poor-urban areas compared with those living elsewhere. However, more rigorous analysis may be

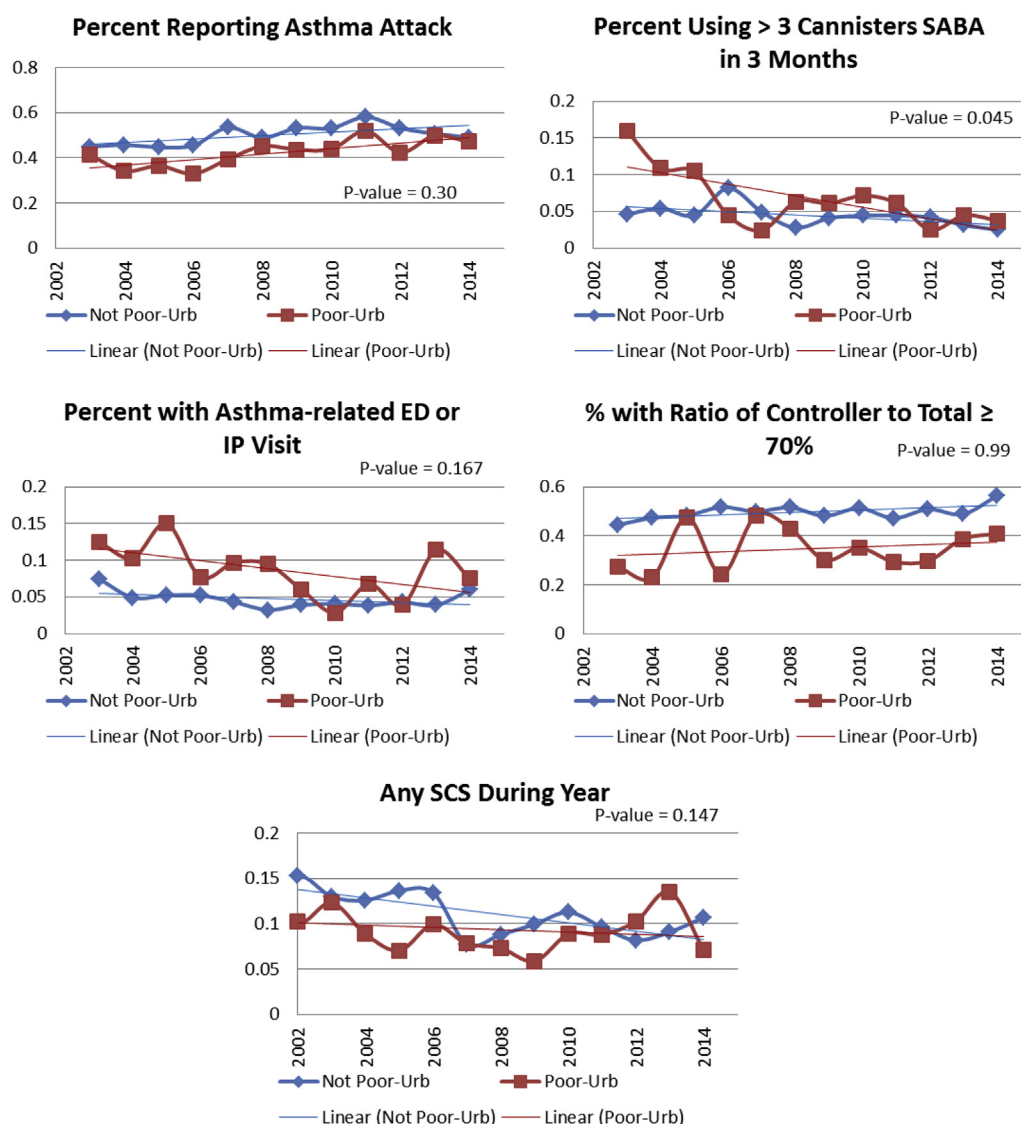


FIGURE 4. Trends in indicators of asthma control among children with asthma in the United States by place of residence (2003-2014). *Urb*, Urban. **P* values for test of nonparallel linear trend comparison.

necessary to provide clear conclusions. Although this study examined differences in trends by place of residence, future research on the differential trends across other disparities such as race, ethnicity, or income (and potential interactions with residence) is essential to understand changes in health disparities. Incorporation of these or other factors was beyond the scope of this broad descriptive analysis, but is a limitation that tempers the contribution of our findings. Likewise, not all medication classes were considered. The exclusion of children younger than 1 year as well as combining all ages together may be a limitation.

There are also limitations associated with the study design and data source. This was a compilation of annual cross-sectional data files and, therefore, could examine only associations, not causation. Some of the asthma outcomes were based on self-report. These measures may be subject to misclassification and/or recall bias. In addition, the MEPS was completed on behalf of children by a parent or proxy. This may have affected the accuracy of

responses. The indicators of poor control and treatment chosen in this study were based on what was available in the MEPS that have been used in previous research. There may be other important measures of asthma control such as spirometry and asthma control questionnaires. However, these were not available in the MEPS. A full comparison to all other poverty-urbanicity categories was not conducted, but is an important area for future research. For example, health disparities may exist when comparing rural poor and nonurban minority populations to others.

This study tested for changes in linear trends over time. It is possible that the time trends follow other (nonlinear) functional forms. In addition, many other factors could contribute to changes in trends over time that were not explicitly captured in this study. For example, changes in the environment (eg, effects from clean air legislation) or improvement in living conditions (eg, less crowding and urban spread) or improved awareness about smoking, among many others.

Despite these limitations, MEPS offers the advantage of being nationally representative and enabling linkage to US Census data to determine poor-urban status.

Results from this nationally representative study of children with asthma from 2003 to 2014 suggest that many treatment patterns and trends in asthma control have not significantly improved over this time frame. Trends in asthma control and treatment are largely negative since 2003 and remained suboptimal into 2014. There is significant room for improvement in asthma disease management and treatment.

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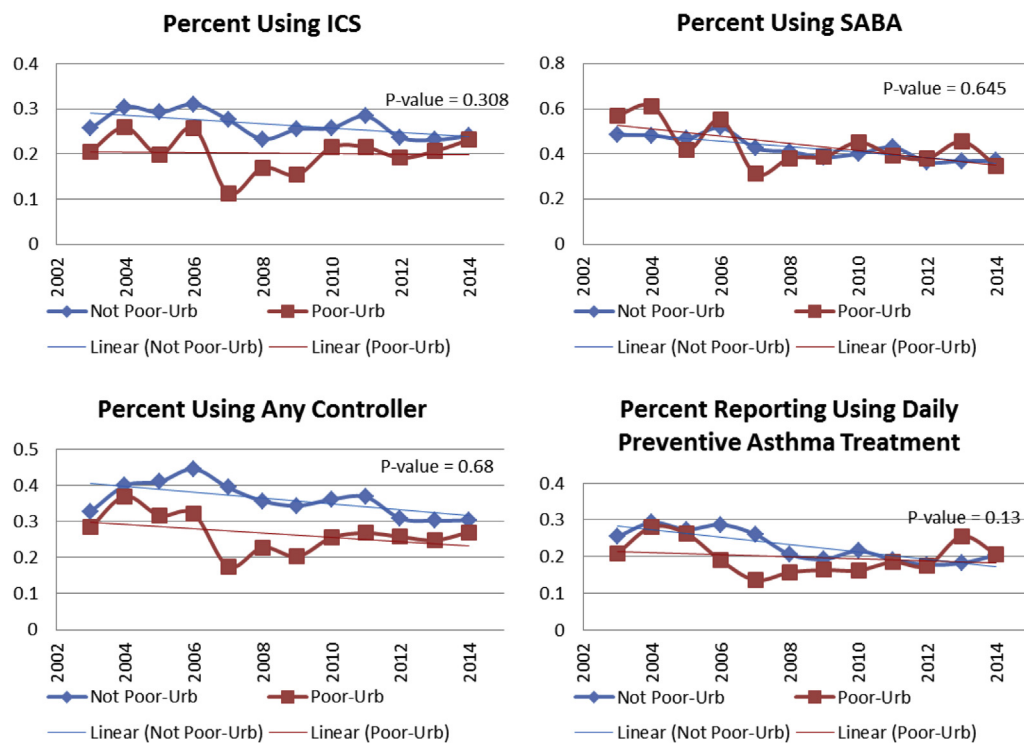


FIGURE E1. Trends in asthma medication use among children with asthma in the United States by place of residence (2003-2014). *Urb*, Urban. **P* values for test of nonparallel linear trend comparison.

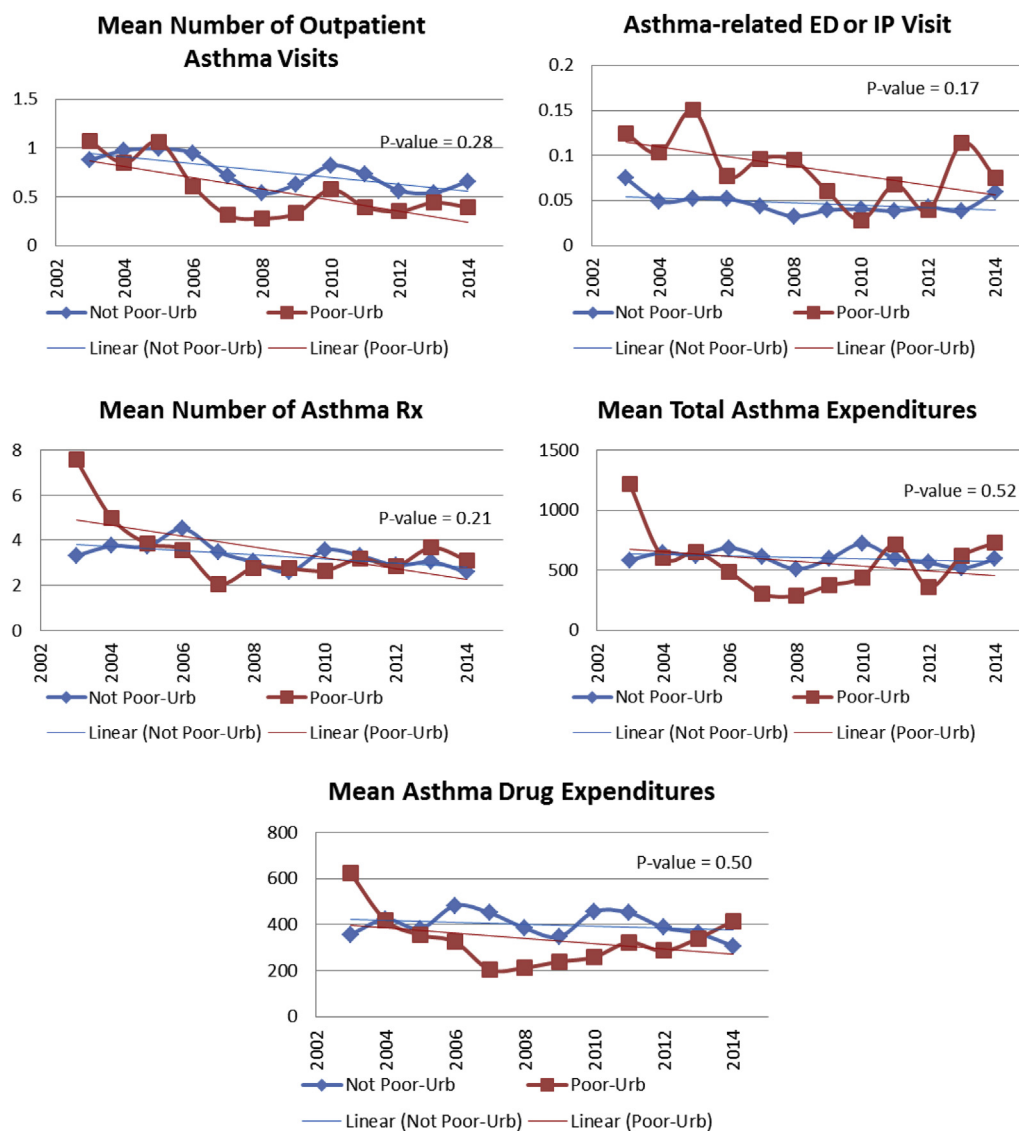


FIGURE E2. Trends in asthma-specific health care utilization among children with asthma by place of residence (2003-2014). Urb, Urban.
**P* values for test of nonparallel linear trend comparison.

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