



The national cost of asthma among school-aged children in the United States

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ABSTRACT

Background: Recent research has quantified the national health care resource use (HCRU) and health care expenditure (HCE) burden associated with adult asthma; however, estimates specific to school-aged children are more than 2 decades old.

Objective: To estimate the national HCRU and HCEs attributable to asthma among school-aged children in the United States.

Methods: This was a cross-sectional retrospective analysis of school-aged children (aged 6–17 years) in the nationally representative 2007–2013 Medical Expenditure Panel Survey. All-cause HCRU and HCEs of school-aged children with asthma were compared with school-aged children without asthma, controlling for sociodemographics and comorbidities. HCRU encounters included emergency department (ED) and outpatient visits, hospitalizations, and prescriptions. Expenditures included total, medical, ED, inpatient, outpatient, and pharmacy. Negative binomial regression analyses were used for HCRU and Heckman selection with logarithmic transformation, and smearing retransformation was used for HCEs.

Results: There were 44,320 school-aged children of whom 5,890 had asthma. Children with asthma incurred a higher rate of all-cause annual ED visits (incidence rate ratio [IRR], 1.5; $P < .001$), hospitalizations (IRR, 1.4; $P < .05$), outpatient visits (IRR, 1.4; $P < .001$), and prescription drugs (IRR, 3.3; $P < .001$) compared with school-aged children without asthma. They incurred US\$847 (2015 dollars) more annually in all-cause expenditures ($P < .001$). Private insurance and Medicaid paid the largest share of expenditures. Pharmacy and outpatient costs represented the largest proportion of total expenditures. On the basis of the nationally representative Medical Expenditure Panel Survey sample weights from 2013, the total annual HCEs attributable to asthma for school-aged children in the United States was US\$5.92 billion (2015 dollars).

Conclusion: Childhood asthma continues to represent a prevalent and significant clinical and economic burden in the United States. More aggressive treatment and asthma management programs are needed to address this national financial and resource burden.

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Introduction

Asthma is one of the most common chronic disorders among children. It is estimated that 7.1 million children currently have asthma in the United States, and 4.1 million had an attack or episode from uncontrolled asthma in 2011.^{1,2} The prevalence is increasing, and children have a higher prevalence than adults.³ From 2001 to 2011, the prevalence increased by 28% overall (among adults and children). In 2012, asthma prevalence in children younger than 18 years old varied by state and ranged from 6.4% to 13.9%.

Asthma causes a significant clinical and quality-of-life burden in the United States and can have far-reaching consequences on the lives of children with the condition. Asthma has a deleterious effect on school- and work-related productivity and health-related quality of life of children and adults.^{4–6} In 2011, a total of 3,345 total deaths were attributed to asthma. It is the third leading cause of hospitalization among children younger than 15 years. In 2010, there were approximately 640,000 emergency department (ED) visits for asthma in those younger than 15 years.²

In addition, asthma results in a significant economic burden for children. Understanding the direct cost burden of asthma to children and their families is important from both a clinical and public health or policy perspective. Asthma guidelines emphasize control as the goal of treatment. Successful asthma management requires preventive treatment and follow-up to optimize drug therapy and prevent exacerbations that may be costly. However, many factors influence successful asthma control outside clinical care management. For example, if patients and their families do not have adequate insurance and/or cannot afford the out-of-pocket costs of drug therapy, the best treatment plan may not be successful. Characterizing the direct costs associated with asthma among children can provide insight into important trends about the state of the condition among children in the United States. In addition to understanding the total amount spent on health care for children with asthma, recognizing trends in insurance and payment patterns can help shape policy discussions. Understanding the sources of payments (eg, Medicaid, private insurance, self-pay) provides information on the degree of burden on different payers, including the burden on the child and family (self-pay). Likewise, the proportion of expenditures allocated to emergency or hospital care can reflect the degree of very poorly controlled asthma that could be avoided with better preventive strategies.

Wang et al⁷ assessed the national direct cost burden of asthma among children in the United States. They estimated the direct cost attributable to childhood asthma to be US\$1 billion (in 2003 dollars) in 1996. More recent studies have been performed in adults⁶ or combined populations,⁸ but these do not provide estimates specific to children. Although the study by Wang et al⁷ provides important insight into the national direct costs of asthma specific to children, it was conducted on data that is more than 20 years old. A contemporary examination to better understand the economic burden of asthma on children in the United States is crucial to inform public health, national health research, and policy decision making, given that treatment and disease patterns have changed markedly in the past 20 years.

Methods

Study Design

This study was a retrospective, cross-sectional analysis of annual health care resource use (HCRU) and health care expenditures (HCEs) for school-aged children in the nationally representative 2007–2013 Medical Expenditure Panel Survey (MEPS). School-aged children (aged 6–17 years) with asthma were compared with school-aged children without asthma to determine the association

between asthma and annualized economic outcomes in the United States. In addition, children (aged 6–11 years) and adolescents (aged 12–17 years) with asthma were compared with children and adolescents without asthma to determine whether there were differences across pediatric subgroups.

Data Source and Measurement

The MEPS is a federal survey sponsored by the Agency for Healthcare Research and Quality and is the most comprehensive national data source for medical expenditures associated with US families. MEPS is a nationally representative survey of the US civilian noninstitutionalized population that incorporates survey data from patients and families, medical professionals, insurance providers, and employers to provide a comprehensive portrait of medical resource use, the frequency of use, costs of provided services, how these costs are paid, and the extent and scope of health insurance coverage for US residents. It is an overlapping panel design in which each cohort is followed up for 2 years. Respondents complete the battery of questions in each round (there are 3 rounds per year). The MEPS Household Component contains detailed self-reported information on demographic and socioeconomic characteristics, health conditions, insurance status, smoking status, use and cost of health care services, employment, and missed work days. MEPS collects data on use and expenditures of office- and hospital-based care, home health care, dental services, vision aids, and prescribed medicines. The MEPS Medical Provider Component is a follow-back survey that collects detailed information from a sample of pharmacies and health care professionals used by MEPS respondents. The Medical Provider Component supplements and validates information on medical use, pharmacy events, and expenditures. Further details on MEPS are available at www.meps.ahrq.gov.

Variables of Interest

The main independent variable of interest was the presence of asthma. Two questions in combination with health care use were used to identify the presence of current asthma. These questions were answered by the reference parent or caregiver on behalf of the child. The first question was, “Have you ever been diagnosed with asthma?” A follow-up question was, “Do you still have asthma?” If the response was positive for both questions, the child was considered to have current asthma. School-aged children who responded negatively to still having asthma but who had health care use with *International Classification of Diseases, Ninth Revision (ICD-9)* diagnosis code 493 for asthma were also classified as having current asthma. School-aged children who had a positive response to having asthma but a negative response to currently having asthma and no health care use with the *ICD-9* diagnosis code of 493 were excluded from the analysis because of the ambiguity of their asthma status. School-aged children who had a negative response to both questions and no health care use with an *ICD-9* code of 493 were considered to not have asthma and were defined as the comparison group.

Additional characteristics considered important in influencing the association between asthma and outcomes were included in the analyses as covariates. These characteristics included age, sex, race, ethnicity, insurance type, region, family income category, number of chronic conditions (NCC) for child excluding asthma, education of main caregiver, health status of main caregiver (Medical Outcomes Study 12-Item Short Form [SF-12] Mental Component Score [MCS-12] and Physical Component Score [PCS-12]), family members' mean NCC, and smoking family member. The NCC variable was constructed from all reported chronic *ICD-9* codes to capture comorbidity burden. The total number of

Table 1
Sociodemographic and Comorbidity Characteristics for 44,320 School-aged Children (Aged 6–17 Years)

Characteristic	No asthma	Asthma	P value
Age, mean (SE), y	11.56 (0.03)	11.51 (0.07)	.42
Age of asthma diagnosis, mean (SE), y	NA	4.41 (0.11)	NA
Duration of asthma, mean (SE), y	NA	7.10 (0.12)	NA
NCC, mean (SE) (excluding asthma)	0.30 (0.01)	0.61 (0.02)	<.001
Sex			
Female	50 (0.00)	41 (0.01)	<.001
Male	50 (0.00)	59 (0.01)	<.001
Race			
White	77 (0.01)	70 (0.01)	<.001
Black	14 (0.01)	22 (0.01)	<.001
American Indian	1 (0.00)	1 (0.00)	.76
Asian	5 (0.00)	3 (0.00)	.001
Multiple races	3 (0.00)	4 (0.00)	.004
Ethnicity			
Hispanic	22 (0.01)	19 (0.01)	<.001
Non-Hispanic	78 (0.01)	81 (0.01)	<.001
Insurance			
Private	61 (0.01)	59 (0.01)	.034
Public	31 (0.01)	37 (0.01)	<.001
Uninsured	7 (0.00)	4 (0.00)	<.001
Region			
Northeast	17 (0.01)	19 (0.01)	.001
Midwest	21 (0.01)	21 (0.01)	.94
South	37 (0.01)	40 (0.01)	.01
West	25 (0.01)	19 (0.01)	<.001
Poverty category			
Poor	18 (0.01)	22 (0.01)	<.001
Near poor	6 (0.00)	6 (0.00)	.28
Low income	16 (0.00)	16 (0.01)	.88
Middle income	32 (0.01)	30 (0.01)	.02
High income	28 (0.01)	27 (0.01)	.25
Smoking in home (any family member)			
Current smoker	25 (0.01)	28 (0.01)	.002
No current smoker	75 (0.01)	72 (0.01)	.002
Reference parent educational level (n = 43,615)			
Not finish HS	15 (0.01)	13 (0.01)	.03
HS degree, GED, some college	56 (0.01)	57 (0.01)	.28
College degree	20 (0.01)	19 (0.01)	.62
Graduate school	10 (0.01)	11 (0.01)	.29
Reference parent age and SF-12 scores (n = 43,879)			
Age, mean (SE), y	42 (0.12)	41 (0.22)	.19
PCS-12 score, mean (SE)	52 (0.11)	50 (0.26)	<.001
MCS-12 score, mean (SE)	51 (0.11)	49 (0.24)	<.001
NCC of other family members, mean (SE)	0.87 (0.01)	1.35 (0.03)	<.001

Abbreviations: GED, general educational development; HS, high school; NA, not applicable; NCC, number of chronic conditions; MCS-12, Mental Component Score; PCS-12, Physical Component Score; SF-12, Medical Outcomes Study 12-Item Short Form. Data are presented as percentage (SE) of patients unless otherwise indicated. Some categories may not sum to 100% because of rounding.

reported chronic conditions minus asthma were totaled to create a count variable called NCC. For the family members' mean NCC, asthma was not excluded. In this case, all chronic conditions for all family members were totaled and divided by the number of family members. Poverty category was based on the federal poverty level: poor (<100%), near poor (100% to 125%), low income (125% to 200%), middle income (200% to 400%), or high income (>400%). The SF-12 is a 12-item measure of generic health status summarized by the PCS-12 and MCS-12 scores.

Outcome Variables

Outcomes of interest included asthma-specific and all-cause annual HCRU and HCEs at the individual and aggregated to the national level. HCRU encounters included ED visits, hospitalizations, outpatient visits, and prescriptions. Expenditures included total, medical, ED, inpatient, outpatient, and pharmacy

expenditures. The definition of expenditures in MEPS is the sum of direct payments for care during the year, including out-of-pocket payments and payments by Medicaid, private insurance, Medicare, and any other sources.

Statistical Analysis

Statistical analyses used regression methods that differed by the type of outcome variable (described below). Regression specifications were similar across methods: the outcome variable was regressed on asthma (yes or no), controlling for age, sex, race, ethnicity, insurance type, region, family income category, NCC (for child excluding asthma), educational level of reference person, health state of reference person (MCS-12 and PCS-12), all family members' mean NCC, and presence of a current smoking family member. The reference category for the main independent variable was no asthma. The 95% confidence intervals (CIs) were presented, and *P* values indicate statistical significance at the *P* < .05 level. The regressions were also conducted separately for children (aged 6–11 years) and adolescents (aged 12–17 years) as a sensitivity analysis to determine whether there were significant differences within each age category.

Negative binomial regression was used for each of the HCRU outcome variables using the specification delineated above. To address the skewness of expenditure data and clustering of several observations at zero, we conducted a Heckman selection model with logarithmic transformation of expenditures and smearing retransformation similar to previous asthma cost studies in adults.⁶ STATA software, version 13 (StataCorp, College Station, Texas) used for all analyses. The annual health care inflation index from the medical care component of the Consumer Price Index was used to express all expenditures in 2015 US dollars. To provide a national estimate of the total expenditures attributable to asthma, the regression coefficient from the main analysis of total expenditures was multiplied by the weighted total number of school-aged children with asthma in the 2013 MEPS data. The 2013 data were used to derive the most recent annual total population with asthma. All analyses (unadjusted and multivariate) incorporated MEPS person-level weights and variance adjustment weights (strata and primary sampling unit) and are thus nationally representative.

Results

There were 44,670 school-aged children aged 6 to 17 years with positive person-level weights in the MEPS 2007–2013 data. Of these, 5,890 (13.3%) reported current asthma (350 were excluded because of ambiguous asthma status). The final analytic sample included 22,529 children aged 6 to 11 years (3,118, 13.8% of whom had current asthma) and 21,791 adolescents aged 12 to 17 years (2,772, 12.7% of whom had current asthma) for a total sample of 44,320 school-aged children.

Unadjusted Descriptive Statistics

Descriptive characteristics of the sample are presented in Table 1. The mean age of the full cohort was 11.5 years. School-aged children with asthma were first diagnosed with asthma at the age of 4 years and had had asthma for a mean of 7 years. School-aged children with asthma were more likely to be male, black or multiple races, non-Hispanic, insured by public insurance, and poorer than those without asthma. Regionally, they were more likely to be from the Northeast or the South. They were more likely to have a smoking family member and to have more nonasthma comorbidities. Their parents or caregivers were more likely to have a higher comorbidity burden and lower health status (lower PCS-12 and MCS-12 scores) than the parents of school-aged children without asthma.

Table 2 presents the unadjusted mean and median all-cause and asthma-specific annual HCRU and HCEs for all school-aged children

Table 2
Unadjusted Annual HCRU and HCEs for School-aged Children (Aged 6–17 Years)^a

Variable	No asthma		Asthma		P value
	Mean (SE)	Median	Mean (SE)	Median	
All-cause HCRU, annual mean numbers of events					
ED visits	0.11 (0.00)	0.00	0.21 (0.01)	0	<.001
Hospitalizations	0.02 (0.00)	0.00	0.03 (0.00)	0	<.001
Outpatient visits	2.90 (0.09)	1.00	5.13 (0.24)	2	<.001
Prescriptions	1.98 (0.05)	0.00	6.97 (0.24)	3	<.001
Asthma-specific HCRU, annual mean numbers of events					
ED visits	NA	NA	0.03 (0.00)	0	NA
Hospitalizations	NA	NA	0.00 (0.00)	0	NA
Outpatient visits	NA	NA	0.60 (0.04)	0	NA
Prescriptions	NA	NA	1.43 (0.05)	1	NA
All-cause HCEs, \$US (2015)					
Total	1,628 (47)	414	3,076 (205)	1144	<.001
Medical	890 (31)	137	1,561 (120)	329	<.001
ED	84 (4)	0	152 (12)	0	<.001
Inpatient	204 (17)	0	337 (53)	0	<.001
Outpatient	592 (22)	119	1,049 (86)	257	<.001
Prescription	257 (28)	0	1,027 (153)	126	<.001
Asthma-specific HCEs, \$US (2015)					
Total	NA	NA	507 (28)	30	NA
Medical	NA	NA	130 (14)	0	NA
ED	NA	NA	20 (3)	0	NA
Inpatient	NA	NA	25 (6)	0	NA
Outpatient	NA	NA	85 (10)	0	NA
Prescription	NA	NA	377 (21)	4	NA

Abbreviations: ED, emergency department; HCE, health care expenditure; HCRU, health care resource use; NA, not applicable.

^aMedical expenditures include ED, inpatient, and outpatient expenditures. Expenditure data may not total because some other categories are not listed (eg, vision).

(aged 6–17 years) with asthma compared with those without. School-aged children with asthma appeared to have higher all-cause HCRU and HCEs for all categories. This association was consistent for both children and adolescent cohorts: expenditures were greater for school-aged children with asthma among both groups (Fig 1). Adolescents with asthma appeared to have higher expenditures than children with asthma for all categories except pharmacy. Figure 2 shows the type of expenditures as a percentage of total unadjusted HCE by age category. Children with asthma tended to spend a substantially larger proportion on pharmacy and a relatively smaller percentage on outpatient services. Other expenditures (including dental and vision) represented a smaller portion of total expenditures for children with asthma than those without asthma. Adolescents with asthma also spent a relatively larger percentage on pharmacy services. A smaller proportion of total expenditures went toward pharmacy for adolescents with asthma compared with children with asthma.

The source of insurance payments from 2007 to 2013 is displayed in Figure 3 by age cohort. Medicaid paid a substantial amount of HCEs for children with asthma (41%) compared with those without asthma (32%). Private insurance and self-pay constituted a smaller portion of total HCEs for children with asthma. For adolescents with asthma, a larger percentage of HCEs was paid by Medicaid. However, compared with younger children with asthma, adolescents with asthma had a smaller percentage of total HCEs paid by Medicaid (31%), and a larger percentage was self-paid (26%).

Table 3 and Table 4 give the results of regression analyses of all-cause annual HCRU and HCEs for the entire age cohort (aged 6–17 years). School-aged children with asthma had more annual all-cause ED visits (IRR, 1.5), inpatient visits (IRR, 1.4), outpatient

visits (IRR, 1.4) and prescription drugs (IRR, 3.2) than school-aged children without asthma. School-aged children with asthma also had higher annual all-cause total health care expenditures (\$847 total), medical expenditures (\$275), ED expenditures (\$132), outpatient expenditures (\$125), and pharmacy expenditures (\$360) than school-aged children without asthma. Results of the separate regression analyses for children and adolescents are presented in eTables 1–4. Results were consistent with the results of the full cohort (aged 6–17 years) analyses. Adjusted HCRU and HCEs were higher for adolescents than children with asthma for all categories except pharmacy, which was higher for children.

The weighted total number of school-aged children with asthma in the United States in 2013 was 6,991,373. Multiplying this by the coefficient of total expenditures in Table 4 (\$847) results in the national burden: the total annual HCEs attributable to asthma for school-aged children (aged 6–17 years) in the United States in 2013 was \$5.92 billion.

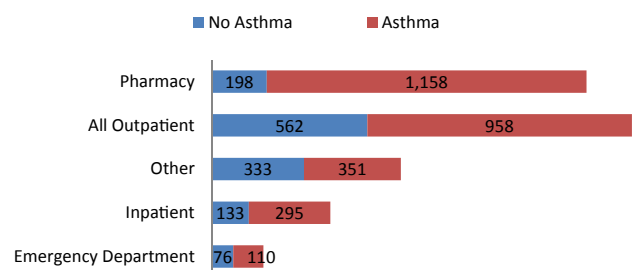
Discussion

This nationally representative study provides important information about the burden of asthma among school-aged children in the United States. The results document a significant association between childhood asthma and increased HCRU and HCEs. They indicate that asthma continues to be a significant public health concern among children and adolescents and represents a substantial economic burden.

The study provides novel information because of the separate assessment of children and adolescents, the national generalizability of the results, the incorporation of the national burden to different payers (such as Medicaid), and the inclusion of the influence of parental health status and educational level.

Results underscore the burden of asthma on HCEs. School-aged children with asthma had higher annual all-cause HCRU and HCEs

All-Cause Expenditures Children (Aged 6-11 Years)



All-Cause Expenditures Adolescents (Aged 12-17 Years)

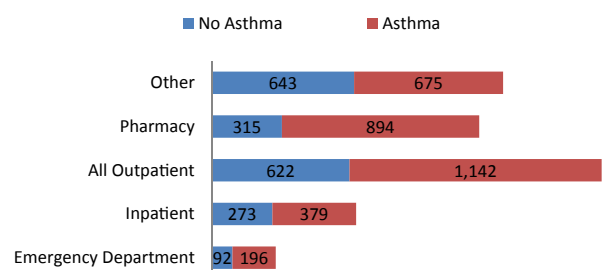


Figure 1. Unadjusted all-cause annual health care expenditures by age category and asthma status in 2015 US dollars.

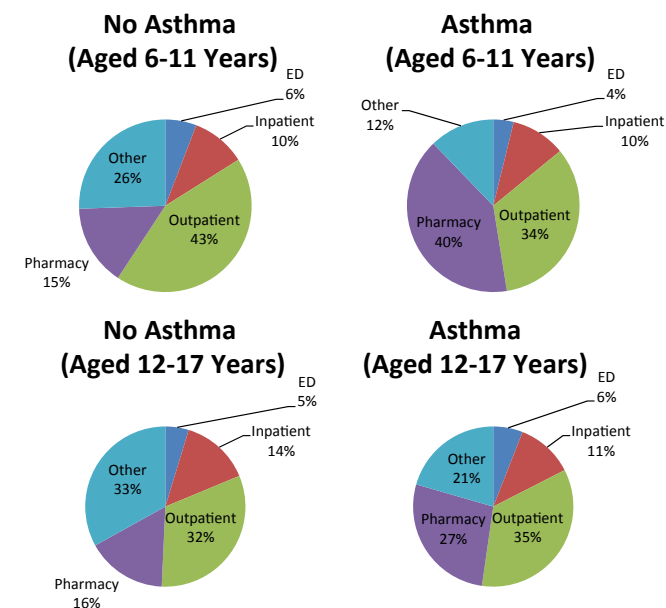


Figure 2. Source of unadjusted all-cause annual health care expenditures for school-aged children in the United States by age category and asthma status. ED, emergency department.

attributable to asthma. These results provide up-to-date estimates of the burden of asthma and document total national HCEs of \$5.92 billion attributable to asthma. Other trends were also evident. School-aged children spent more on pharmacy and outpatient visits. Most expenditures for children were paid by Medicaid, whereas most expenditures for adolescents were paid by private insurance.

A substantial proportion of HCEs in the United States is paid by the families of children with asthma. The families of children with asthma paid between 19% and 26% of their own HCEs. This finding has significant clinical and policy ramifications. High cost sharing may influence a child's adherence to asthma treatment and follow-up. These national estimates of the proportion of out-of-pocket expenditures paid by the families of children with asthma may help inform national policy discussions about health care insurance and coverage.

These research findings have significant clinical implications. Asthma represents a significant financial burden to school-aged

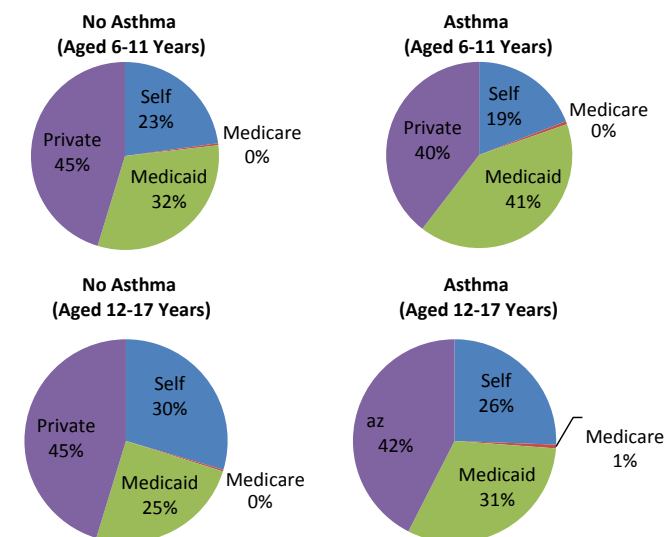


Figure 3. Payer contribution as a percentage of health care expenditures by age category and asthma status.

Table 3

Adjusted Annual HCRU for School-aged Children (Aged 6–17 Years)^a

Cause	Coefficient (95% CI)	SE	P value
Emergency department	1.502 (1.339–1.685)	0.088	<.001
Inpatient	1.394 (1.050–1.851)	0.201	.02
All outpatient	1.354 (1.255–1.460)	0.052	<.001
Prescriptions	3.246 (3.003–3.510)	0.129	<.001

Abbreviations: CI, confidence interval; HCRU, health care resource use.

^aAll results from negative binomial regressions controlling for sex, race, ethnicity, insurance type, region, family income category, number of comorbid conditions (for child), educational level of reference person, health state of reference person, family members' mean number of comorbid conditions, and smoking family member.

children in the United States,⁹ and previous studies have found that poor asthma control is prevalent.¹⁰ This finding is supported by the current analysis revealing significantly higher HCRU, particularly ED visits, among school-aged children with asthma. Uncontrolled asthma results in significantly higher HCEs.^{11,12} Results from this study suggest that ED, pharmacy, and outpatient expenditures are significant. Targeted interventions, such as disease management programs aimed to optimize treatment and promote adherence to pharmacotherapy consistent with asthma guidelines, may help improve control and reduce acute care hospitalizations and ED visits and the associated financial burden. Optimal preventive management should result in a shift of use from higher-cost acute care to lower-cost pharmacy and/or outpatient use. There is also the potential for sub-optimal pharmacy and outpatient use, resulting in unnecessary costs. However, these costs are much lower than high-cost acute care that could be avoided through better asthma management. The scope of this study is too broad to ascertain whether outpatient and pharmacy costs result from optimal asthma management consistent with national guidelines. Future studies characterizing these aspects and how they have changed over time would be beneficial.

A benefit of this study design is the data source. In contrast to many other valuable studies that focused on clinical populations (often with more severe asthma), the current study is based on a general population survey. Consequently, the estimates provided herein are nationally representative and reflect the entire spectrum of school-aged children (across all race/ethnicity groups, poverty statuses, and geographic regions) with asthma in the United States.

Although the methods are different, these results suggest that the burden of asthma in school-aged children has increased since 1996. Using 1996 MEPS data, Wang et al⁷ estimated that the national direct costs of asthma in school-aged children was US\$1.009 billion (expressed in 2003 dollars). Using the Consumer Price Index inflation for medical care, US\$1.009 billion would be US\$1.52

Table 4

Adjusted Annual Medical Expenditures for School-aged Children (Aged 6–17 Years)

Cause	Coefficient (95% CI), \$US (2015) ^a	P value
Total	847 (742 to 952)	<.01
Medical	275 (197 to 353)	<.01
Emergency department	132 (38 to 227)	<.01
Inpatient	554 (–3,346 to 4,454)	.78
All outpatient	125 (76–174)	<.01
Pharmacy	360 (278–442)	<.01

Abbreviation: CI, confidence interval.

^aResults of Heckman selection model controlling for sex, race, ethnicity, insurance type, region, family income category, number of comorbid conditions (for child), educational level of reference person, health state of reference person, family members' mean number of comorbid conditions, and smoking family member. Each coefficient is the result of a separate regression model; hence, values may not total.

billion expressed in 2015 dollars. However, the \$1 billion national total from Wang et al⁷ was unadjusted asthma-related expenditures, whereas the total national expenditures in our study (\$5.92 billion) was estimated after comprehensive adjustment and using cost-specific statistical methods. Wang et al⁷ also estimated the per person excess HCEs attributable to asthma (US\$424 in 2003 dollars). Using the Consumer Price Index inflation for medical care, US\$424 (in 2003 dollars) would be US\$636 in 2015. The adjusted per person expenditures attributable to asthma in our study was US\$847 (in 2015 dollars). Wang et al⁷ controlled for age, sex, race, mother's educational level, poverty status, and health insurance coverage for this per capita estimate of the expenditures attributable to asthma. Our analyses controlled for these covariates and several others. Regardless of the differences in methods, there appears to be a significant increase in HCEs attributable to asthma since 1996 whether per capita or total national burden. It is challenging to compare the relative proportion of expenditures on different categories because the methods of categorizing are different across studies. However, it appears that pharmacy expenditures have increased markedly as a proportion of overall spending. When comparing the 2 studies, pharmacy services account for 40% of medical expenditures in our study (including only those categories included by Wang et al⁷) compared with only 26% in their study from 1996 MEPS data. Results from our study are significantly higher than estimates from a burden-of-illness study conducted in Canada from 1994 to 1998. The authors found that school-aged children with asthma had a higher HCRU and costs more than CAN\$100 (in 2000 dollars) more per child per year than the general population.¹³ However, the results across countries are not comparable.

The study by Wang et al⁷ is the only comparable national study of the direct cost burden of asthma among children in the United States, but it was conducted on data that are more than 20 years old. Other more recent studies have been conducted in adults with asthma. Although it is informative to understand the national burden of asthma among adults, results from adult studies are not comparable to the results of studies in children with asthma: the treatment patterns and costs are substantially different. Nonetheless, studies in adults reveal a significant national burden of asthma. Sullivan et al⁶ estimated the direct cost burden attributable to adult asthma in the 2003–2005 MEPS data. Using methods similar to the current study (but restricted to adults), they found that adults with asthma incurred an additional US\$1,907 (in 2008 dollars) annually per person, resulting in a total national burden of US\$18 billion in HCEs. In addition, they found that adult asthma expenditures were paid by Medicaid (30%), private insurance (28%), Medicare (18%), and self-pay (15%). Although the period studied is slightly different, this highlights the significant proportion of national medical expenditures paid by Medicaid for both adults and school-aged children (Medicaid paid for only 10% of expenditures for adults without asthma in their study). Adults with asthma also appeared to spend more on inpatient visits and less on pharmacy and outpatient visits than school-aged children in our study. However, it is possible that these differences reflect changes in treatment patterns over time rather than differences between adults and school-aged children. Barnett et al⁸ estimated the direct costs associated with asthma for adults and school-aged children combined. Unfortunately, the estimates for school-aged children were not separated from those of adults, precluding any meaningful comparisons to the results for children in the current study. They found that the total annual direct cost of asthma among adults and children in the United States was \$34 billion in 2006, \$3,259 annually per person. The authors used a 2-part generalized linear model with log-link similar to the statistical methods used in our study. The authors also conducted a comparative analysis using alternative methods and found that the total direct cost of asthma

using the bottom-up approach was \$14.8 billion. The authors explain that one of the driving factors resulting in the lower estimates using the bottom-up method is the inclusion of only asthma-specific health care use. These 2 studies do not provide additional insight with respect to the specific burden of childhood asthma but further underscore the total national burden of asthma.

The finding that spending on pharmaceuticals has increased as a proportion of health care spending compared with the 1996 data from Wang et al⁷ is important. The scope of this study is too broad to examine the types of medications and proportions of patients using them. Future research into the sources of this difference would be beneficial.

Similar to previously published studies, the results of this study indicate that school-aged children with asthma are more likely to be from underserved or disadvantaged populations (school-aged children with asthma were more likely to be black or multiple races, insured by public insurance, and poor than those without asthma) (Table 1). Their families also appeared to be poorer, to have more chronic comorbidities, and were more likely to include a current smoking member. The finding that a large proportion of national medical expenditures for school-aged children with asthma was paid by Medicaid is consistent with other studies that found that school-aged children with asthma are more likely to be poor and disadvantaged.¹⁴ In addition, the results suggest that a significant proportion of expenditures are paid out of pocket by families of children with asthma. These findings further underscore the important associations among childhood asthma, poverty, race/ethnicity, insurance, and how changes to Medicaid enrollment may disproportionately affect school-aged children with asthma. The relative financial burden on Medicaid and the out-of-pocket expenditures among school-aged children and their families is an important factor for clinicians and policymakers to consider while advancing discussions of national health care financing policies.

This research is not without limitations. Surveys such as MEPS and the National Health Interview Survey are based on self-report and hence may be subject to misclassification bias, which may have affected the accuracy of being diagnosed with current asthma and may be exacerbated by the proxy response of caregivers for some school-aged children. For example, diagnosis of asthma was based on parental proxy response to questions about having been diagnosed with asthma and still having asthma. Previous research has found that self-reported conditions may be underreported and the extent may vary by race and ethnicity. MEPS is also limited in capturing differences in disease severity. It does not include clinical information about asthma severity or direct measures of asthma control. The analysis was cross-sectional and therefore cannot estimate causality. The current study was limited to direct costs attributable to asthma and did not include absenteeism or lost productivity attributable to premature mortality. Despite these limitations, MEPS has the unique advantage of having a nationally representative sample of school-aged children with and without asthma, detailed HCRU and HCEs, and comprehensive sociodemographic characteristics. This study provides an important overview of the burden of asthma in a nationally representative general population sample of school-aged children in the United States.

Supplementary Data

Supplementary data related to this article can be found at <http://dx.doi.org/10.1016/j.anai.2017.07.002>.

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Supplementary Data

eTable 1

Adjusted Results of Annual All-Cause Expenditures for Children Aged 6 to 11 Years

All-cause expenditures	Coefficient (95% CI), \$US (2015)	P value
Total	715 (613 to 817)	<.01
Medical	183 (100 to 266)	<.01
Emergency department	37 (–69 to 144)	.87
Inpatient	4,556 (–4,252 to 13,364)	.48
All outpatient	271 (191 to 350)	<.01
Pharmacy	290 (222 to 358)	<.01

Abbreviation: CI, confidence interval.

eTable 3

Adjusted Results of Annual All-Cause HCRU for Children Aged 6 to 11 Years

All-cause HCRU	IRR Coefficient (95% CI)	SE	P value
Emergency department	1.448 (1.242–1.688)	0.113	<.001
Inpatient	1.321 (0.877–1.988)	0.275	.18
All outpatient	1.260 (1.127–1.409)	0.071	<.001
Prescriptions	3.601 (3.229–4.016)	0.200	<.001

Abbreviations: CI, confidence interval; HCRU, health care resource use; IRR, incidence rate ratio.

eTable 2

Adjusted Results of Annual All-Cause Expenditures for Adolescents Aged 12 to 17 Years

All-cause expenditures	Coefficient (95% CI), \$US 2015	P value
Total	914 (719 to 1,164)	<.01
Medical	371 (232 to 425)	<.01
Emergency department	263 (111 to 165)	<.01
Inpatient	–12,895 (–2,215 to 11,743)	.055
All outpatient	168 (92 to 183)	<.01
Pharmacy	379 (211 to 564)	<.01

Abbreviation: CI, confidence interval.

eTable 4

Adjusted Results of Annual All-Cause HCRU in Children Aged 12 to 17 Years

All-cause HCRU	IRR Coefficient (95% CI)	SE	P value
Emergency department	1.524 (1.290–1.800)	0.129	<.001
Inpatient	1.436 (1.023–2.015)	0.248	.04
All outpatient	1.443 (1.320–1.577)	0.065	<.001
Prescriptions	2.825 (2.524–3.160)	0.161	<.001

Abbreviations: CI, confidence interval; HCRU, health care resource use; IRR, incidence rate ratio.