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Trends in cost and outcomes among adult and pediatric patients with asthma: 2000–2009

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ABSTRACT

Background: Few studies have examined recent trends in medical expenditures and outcomes in patients with asthma.

Objective: To examine the level and changes in medical expenditures, health status, and functional outcomes in adults, adolescents, and children with asthma and to provide nationally representative estimates of asthma medical costs from 2000 through 2009.

Methods: Medical Expenditure Panel Surveys from 2000 through 2009 were used to estimate the trends of medical expenditures (adjusted for medical price inflation), number of workdays lost or schooldays lost, and/or the physical component summary and the mental component summary from the revised 12-Item Short-Form Health Survey, adjusting for sociodemographic variables and comorbidities.

Results: The averaged physical component summary decreased 0.09 units annually (95% confidence interval 0.02–0.16, $P < .01$) in adults, but there were no significant changes to the averaged mental component summary. There was no significant change in the number of workdays lost and a marginal decrease of 1.8% per annum in the number of schooldays lost (95% confidence interval –0.1 to 3.5, $P = .06$). The medical expenditure means increased 2.5% annually in adolescents (95% confidence interval 0.0–4.9, $P = .049$), but there were no significant changes for adults and children. The total incremental medical expenditures of asthma in the United States were estimated to be \$62.8 billion in 2009.

Conclusion: This study found that, although medical costs for patients with asthma increased or remained stable across all age groups over a 10-year period, outcomes did not improve. Considering the economic burden of asthma and the previous 10-year performance, continued attention should be focused on asthma management in the United States.

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Introduction

Asthma, a chronic respiratory disease characterized by episodic airway obstruction, hyper-responsiveness, and inflammation, is one of the most prevalent and burdensome chronic diseases in the United States.¹ In 2009, asthma affected 24.6 million Americans, with 12.8 million having had at least 1 asthma attack in the previous year.²

During the past decade, the importance of monitoring asthma control, patient education, and decreasing environmental triggers has been stressed locally and internationally in an effort to disseminate evidence-based asthma guidelines, including recent

guidelines for patients 5 years and younger.^{3–5} Previous studies have identified the negative impact of asthma on health care expenditures in adult and pediatric patients over a short period,^{6–9} whereas few long-term studies are available.^{10–12} For outcome measurements for performance, few studies have examined the change in school or work absenteeism between temporal periods. The change of more critical indicators, such as health status outcomes, hospital admissions, and emergency department (ED) visits, has not yet been studied in the United States. Considering the economic burden of asthma and the tremendous efforts aimed at improving asthma outcomes in the past decade, it will be important to identify outcomes and cost trends together to further guide asthma management efforts in the United States.

The objectives of this study were to examine the level and changes in medical expenditures, use, health status, and functional outcomes in patients with asthma and estimates of total health care expenditures attributable to asthma during the 10-year period from 2000 through 2009. An examination of the most recent

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10-year population trends in asthma expenditures and outcomes may provide an indicator of the performance in asthma management in the United States.

Methods

Data Source

Data from the 2000 through 2009 Medical Expenditure Panel Survey Household Component (MEPS-HC; a set of large-scale nationally representative surveys for the US civilian noninstitutionalized population) were used.¹³ The MEPS-HC provides data from responding families and individuals regarding a wide range of information, such as basic demographics, socioeconomic status, health status, insurance coverage and expenditures, and use of health care. For the present analysis, the full-year consolidated data files and medical condition files from 2000 through 2009 were used. The full sample from 2000 through 2009 varied from 25,096 to 36,855 and the overall response rate ranged from 56.9% to 66.3%. The MEPS national data are exempted from institutional review board review at the University of Washington.

Study Population and Stratification

The 2000 through 2009 MEPS-HC full-year consolidated files consisted of 335,426 individuals. Patients with asthma were identified based on a lifetime diagnosis using 2 methods: (1) respondents who had ever been diagnosed with asthma and (2) respondents having an *International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM)* code of 493.x in any of the medical condition files. Studies have shown that asthma affects pediatric and adult patients differently.^{2,9,14} For example, adolescents have the highest prevalence of asthma, whereas younger children with asthma have the highest rates of hospitalization and expenditures.^{1,4} Furthermore, national and international guidelines for asthma management have published different treatment recommendations across age categories (0–4, 5–11, and ≥ 12 years or 0–5 and ≥ 6 years) because of the changing course of the disease over time, varied levels of scientific evidence for different ages, and availability of reliable measurements for asthma diagnosis.^{3–5} To make age-specific estimates, the sample was stratified into 3 categories: adults (≥ 18 years of age), adolescents (6–17 years), and children (0–5 years).

Analytic Models

A series of regression analyses (ordinary least square regression, generalized linear model, or 2-part model) was used to model outcomes (dependent variables) as a function of the independent variables and covariates. These models provided a way of estimating yearly adjusted means for each outcome while accounting for age, sex, race, and other covariates to be listed.

Dependent Variables

The dependent variables were health status, functional outcomes, use, and medical expenditures. Health status outcomes were assessed by the physical component summary and mental component summary scores extracted from the 12-Item Short-Form Health Survey for the adult population with asthma.¹⁵ Because the version of the 12-Item Short-Form Health Survey changed during the study period, the 2000 through 2002 scores were modified to be equivalent to the 2003 through 2009 scores using the methods provided by Ware et al.¹⁶ Functional outcomes were examined by annual number of workdays lost for adults and annual number of schooldays lost for adolescents. Each day lost came from at least a half-day absence from school or work because of physical illness or injury or mental or emotional problems. Use

variables included inpatient visit and ED visit, which were widely used as the main measurements of asthma control.

Expenditure variables included total expenditures, outpatient visit expenditures, inpatient visit expenditures, ED visit expenditures, prescription medication expenditures, and other visit expenditures. The total expenditures variable was comprised of the sum of 5 component variables. Outpatient visit expenditures included expenditures for office-based visits and hospital outpatient visits. Other visit expenditures were aggregated from dental visits, home health care, vision aids, and other medical equipment and services. Expenditures in the MEPS are the sum of direct payments for medical care provided each year, including out-of-pocket payments and payments by private insurance, Medicaid, Medicare, and other third-party sources. Payments for over-the-counter drugs are not included. To adjust for medical price inflation, expenditures from 2000 through 2008 were adjusted to match the 2009 equivalents using the Consumer Price Index for Medical Care provided by the US Bureau of Labor Statistics.¹⁷

Independent Variables and Covariates

For analysis of outcomes and expenditures in individuals with asthma, the independent variable of interest was year, a continuous variable, with the range of calendar years 2000 to 2009 being converted to 0 to 9. In estimating expenditures attributable to asthma, asthma (yes or no), a binary variable, was an independent variable. Sex, age, race, type of insurance, US Census region, and poverty status categorized from the federal poverty level were included as covariates in the analysis for all age categories. In the adult group, marital status, educational levels, and the adaptation by D'Hoore et al¹⁸ of the Charlson Comorbidity Index¹⁹ were included. The D'Hoore version consists of 17 comorbidities, with weights from 1 to 6, and provides a convenience in matching ICD-9-CM codes in MEPS to related comorbidities because of its categorization of 3-digit ICD-9 codes. Although its predictive validity was established for predicting mortality,^{20,21} it has been widely used for adjustment purposes in previous studies estimating health care expenditures of asthma.^{9,10,12,22} In pediatrics, the applicability of comorbidity adjustment used in adults has important limitations: (1) very few individuals have a positive comorbidity score, and (2) the predictability of the adult ICD-9-CM-based comorbidity instrument is low in pediatric patients. To create a comorbidity adjustment for pediatric patients, the number of ICD-9-CM codes matched with 26 chronic conditions drawn from commonly used drugs for pediatric patients in ambulatory settings was computed to predict use and cost in pediatric patients.²³ Because asthma was of interest in this study, ICD-9-CM codes for asthma were excluded from the comorbidity index computations.

Analytic Approach

Physical component summary and mental component summary scores were approximately normally distributed. Multiple linear regressions were used to estimate the change in mean physical component summary and mental component summary scores. Generalized linear models with a log link and a binomial distribution were chosen for use variables, inpatient visit, and ED visit, and generalized linear models with a log link and a γ distribution were selected for the number of workdays lost, the number of schooldays lost, and total expenditures in estimating the level of adjusted mean change in individuals with asthma by age category. The lower value of the Akaike information criterion and Bayesian information criterion was considered for choosing the appropriate link function and distribution in all analyses.²⁴ To examine the expenditures attributable to asthma in each year from 2000 through 2009, a cohort of individuals from MEPS who did not have asthma was selected and the difference in mean expenditures

Table 1Characteristics of age groups with and without asthma, Medical Expenditure Panel Survey, 2009^a

Characteristic	Mean or percentage ^b					
	Adults		Adolescents		Children	
	Asthma	No asthma	Asthma	No asthma	Asthma	No asthma
Sampled (respondents), n	2,484	23,472	965	5,999	352	3,246
Estimated persons in US population, millions	22.5	206.8	6.6	42.3	2.3	23.5
Age, mean	45.2 ^f	46.4	11.6	11.5	3.2 ^h	2.4
Female, %	62.9 ^h	50.4	38.0 ^h	50.8	38.1 ^g	49.6
Race, %						
White	80.6	81.3	68.8 ^h	77.3	67.0 ^h	76.0
Black	12.9	11.6	22.6 ^h	13.7	23.1 ^h	13.5
Others ^c	6.5	7.1	8.5 ^h	9.0	9.9 ^h	10.5
Hispanic, %	10.6 ^h	14.2	18.3 ^f	21.9	25.3	25.5
Insurance coverage, %						
Any private	64.3 ^h	68.0	61.8 ^g	62.6	49.7 ^g	57.9
Public only	22.7 ^h	15.8	34.0 ^g	29.7	48.0 ^g	37.7
Uninsured	13.0 ^h	16.2	4.2 ^g	7.7	2.4 ^g	4.5
Poverty status, % ^d						
Negative or poor	16.5 ^h	11.6	21.8	18.5	34.8 ^f	23.4
Near poor	5.3 ^h	4.1	5.8	5.5	4.2 ^f	5.6
Low	14.4 ^h	13.4	14.5	16.2	14.3 ^f	16.1
Middle	28.7 ^h	30.8	33.1	32.4	22.8 ^f	29.8
High	35.1 ^h	40.1	24.8	27.5	23.9 ^f	25.1
Region, %						
Northeast	19.5 ^f	18.4	18.2 ^f	17.1	25.5 ^g	14.0
Midwest	22.3 ^f	21.8	19.1 ^f	21.5	22.8 ^g	22.5
South	33.0 ^f	37.0	42.5 ^f	36.7	37.1 ^g	37.8
West	25.2 ^f	22.9	20.2 ^f	24.7	14.6 ^g	25.7
Comorbidity index score, mean ^e	0.78 ^h	0.45	0.67 ^h	0.37	0.38 ^h	0.23
Marital status, %						
Currently married	47.2 ^h	54.3				
Currently not married	52.8 ^h	45.7				
Education, %						
No degree	17.1	15.8				
GED or high school diploma	49.2	49.1				
Bachelor's degree	15.9	17.6				
Graduate degree	8.5	9.1				
Other degree	8.9	7.8				
Missing	0.4	0.5				

Abbreviation: GED, Graduation Equivalency Degree.

^aAll percentages were estimated from a weighted sample using complex survey design methods.^bThe χ^2 test was used to test difference in proportions; *t* test was used in mean comparisons.^cIncludes American Indian/Alaska Native, Asian, Native Hawaiian/Pacific Islander, and multiple races.^dPoverty status was categorized from the federal poverty level as negative or poor (<100%), near poor (100% to <125%), low income (125% to <200%), middle income (200% to <400%), and high income ($\geq$ 400%).^eAdaptation by D'Hoore et al¹⁸ of the Charlson Comorbidity Index score used for adults. Pediatric chronic diseases score was used for adolescents and children.^f*P* < .05.^g*P* < .01.^h*P* < .001.

between the asthma and no-asthma groups was estimated. This method, referred to as the incremental method, is widely used in population-based studies of disease burden because it measures expenditures that are exclusively attributable to the disease of interest while adjusting for covariates.^{9,10,25,26} To address the positive skewness of the expenditure variable, a generalized linear model with a γ distribution and a log-link function was used rather than log-transformed ordinary least square regression, which has the limitation of difficulty in interpretation owing to retransformation.²⁷ In addition, to handle a high concentration of 0 (\$0.00) observation in the expenditure variable (no-asthma group [16.1%] vs asthma group [6.4%] with all age groups combined), a 2-part model was used.^{28,29} To compute the difference of mean expenditures between patients with asthma and those without asthma from the 2-part model, the direct substitution method of Kleinman and Norton was used.^{10,30}

To determine total expenditures, the difference in expenditures derived from the incremental method was multiplied by the estimated US asthma population in each year. The bootstrap method was used to calculate confidence intervals.³¹ Then, category-specific expenditures using the same 2-part model was determined. To

identify a shift in the composition of asthma expenditures, the 2 consecutive 5-year periods, 2000 through 2004 and 2005 through 2009, were compared. Because the total US expenditures for asthma were not equal to the numeric sum of the estimated categories, the latter value was used in calculating the percentages. In all analyses, the complex survey design of MEPS was taken into account by using the person-level weight, sampling strata, primary sampling unit, and survey command within STATA 12 (StataCorp, College Station, Texas).^{32–34}

Results

The authors identified 330,942 MEPS respondents with complete data on age and asthma status from 2000 through 2009. Of those, patients with asthma (21,946 adults, 8,386 adolescents, and 3,096 children) were approximately evenly distributed across the years.

Demographic Characteristics

The characteristics of patients with asthma in 2000 were compared with those in 2009. Although adults and adolescents

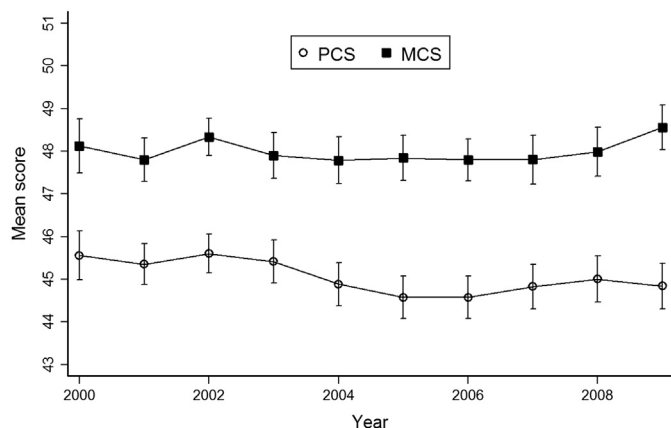


Figure 1. Mean physical component summary (PCS) and mental component summary (MCS) scores in adults with asthma, adjusting for covariates from the Medical Expenditure Panel Survey from 2000 through 2009. The predicted annual mean scores were estimated using the direct substitution method of Kleinman and Norton³⁰ in the linear regression model. Covariates were age, sex, race, ethnicity, insurance coverage, poverty status, education, marital status, residence area, and the adaption of the Charlson Comorbidity Index score by D'Hoore et al.¹⁸ The 95% confidence intervals were calculated using the bootstrap method.

with asthma in 2009 were more likely to be covered by public insurance (22.7% vs 18.0%, $P < .01$; 34.0% vs 26.1%, $P = .01$, respectively) and had a higher mean comorbidity score (0.78 vs 0.39, $P < .001$; 0.67 vs 0.53, $P < .01$, respectively) than those in 2000, only children with asthma in 2009 were more likely to be covered by public insurance (48.0% vs 32.1%, $P = .03$) than those in 2000.

Table 1 presents a comparison of individuals with and without asthma in 2009 to examine factors that can influence the difference in expenditures between the 2 groups. In all ages, respondents with asthma were more likely to be covered by public insurance and had a higher mean comorbidity score than those without asthma. Although adults with asthma were more likely to be women, the opposite was true in pediatric patients. In addition, pediatric patients with asthma were more likely to be Black.

Health Status, Functional Outcomes, and Use

The results from the adjusted multivariable analysis of the physical component summary and mental component summary for adults with asthma from 2000 through 2009 are shown in Figure 1. The linear trend showed a statistically significant decrease in the mean physical component summary, with 0.09 for every 1-year increase (95% confidence interval -0.16 to -0.03 , $P < .01$). However, the linear trend of the mean mental component summary was not significant. Findings from the adjusted multivariable analysis of the number of workdays lost for adults and the number of schooldays lost for adolescents from 2000 through 2009 are shown in Figure 2. No statistically significant trend was detected in either measurement ($P = .924$, $P = .06$). Inpatient visits for asthma decreased by 2.3% ($P = .01$), 6.8% ($P = .12$), and 5.8% ($P = .03$) per annum in the adult, adolescent, and child age groups, respectively. For ED visits, there was no statistically significant trend of change in children, adolescents, or adults.

Health Care Expenditures

Without inflation adjustments, the covariate-adjusted medical expenditure means increased by an average of 5.1% ($P < .001$) and 6.8% ($P < .001$) per annum, respectively, during the 10-year study period in the adults and adolescents. However, with inflation adjustments, the means for medical expenditures showed no significant decreasing or increasing trend across time in adults

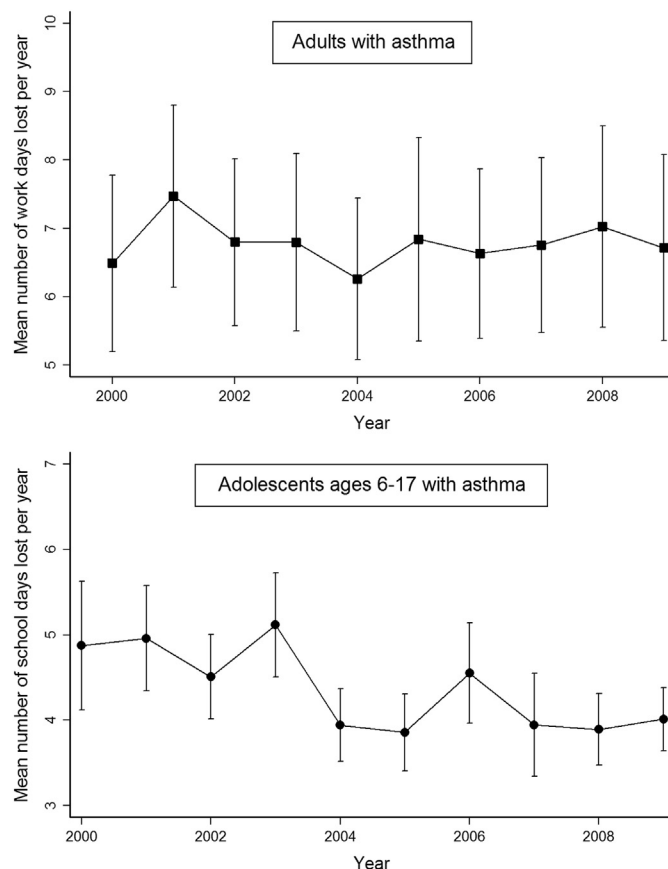


Figure 2. Mean number of days lost per year in adults and adolescents with asthma, adjusting for covariates, from the Medical Expenditure Panel Survey from 2000 through 2009. The predicted annual mean number of days lost was estimated using the direct substitution method of Kleinman and Norton³⁰ in the generalized linear model with γ distribution and log link. Covariates were age, sex, race, ethnicity, insurance coverage, poverty status, residence area, comorbidity index score, education (adults only), and marital status (adults only). The 95% confidence intervals were calculated using the bootstrap method.

($P = .23$), but in adolescents the increase rate was 2.5% ($P = .049$). In the child group, the 2 trends for medical expenditures were statistically nonsignificant.

Inflation-adjusted asthma-attributable expenditures are presented in Table 2 for all age groups. Because the effect of medical price inflation is removed from the estimates, the observed difference in 10-year expenditures represents the impact of a change in the mix or use of new technology, a change in the intensity of medical services for asthma, and the growth in the population with asthma. The 5-year average total burden attributable to asthma among all age groups in 2005 through 2009 was explained by outpatient visits (19%), inpatient visits (27%), prescription medications (44%), ED visits (3%), and other visits (6%; Figure 3). Comparing the increase in rates of expenditures between the 2 5-year periods showed that prescription medications (49%) were greater than total expenditures (19%), whereas outpatient visits (3%), inpatient visits (0%), and ED visits (8%) were much smaller.

Discussion

In general, there were no changes in health status and functional outcomes in individuals with asthma. Given that at least 2 points' difference in the physical component summary was considered meaningful,³⁵ the significant decrease in the physical component summary with 0.81 point during the past decade does not indicate improvement. Although inpatient visits decreased significantly in

Table 2Estimated incremental expenditures of asthma in US population, Medical Expenditure Panel Survey, 2000–2009^a

Year	Estimated US asthma population ^b (millions)	National estimates of asthma expenditure ^c (95% CI) ^d			
		All ages	Adults	Adolescents	Children
2000	26.7	42.8	36.9 (21.1–53.6)	1.2 (–0.2 to 3.1)	4.7 (1.1–9.7)
2001	27.7	33.3	27.0 (18.5–36.5)	4.0 (1.1–7.3)	2.3 (1.4–3.5)
2002	28.7	61.2	54.0 (42.2–66.5)	4.9 (3.0–7.1)	2.3 (1.2–3.8)
2003	28.9	47.7	40.6 (28.6–58.0)	4.5 (3.1–6.1)	2.6 (1.4–4.2)
2004	28.6	65.0	58.8 (35.0–84.5)	2.9 (1.8–4.5)	3.3 (2.0–5.0)
2005	29.3	61.8	57.6 (29.7–91.9)	2.4 (0.4–5.0)	1.8 (0.5–3.4)
2006	30.8	51.7	46.0 (33.5–59.8)	4.2 (2.6–6.2)	1.5 (0.3–3.0)
2007	30.4	64.2	60.2 (43.7–79.2)	2.5 (1.2–4.3)	1.5 (0.4–3.2)
2008	31.1	42.9	37.4 (25.3–51.6)	4.4 (2.6–6.6)	1.1 (0.0–2.6)
2009	31.4	62.8	52.8 (35.0–74.3)	7.0 (3.7–11.4)	3.0 (1.0–5.9)

Abbreviation: CI, confidence interval.

^aAll estimates were based on a weighted sample using complex survey design methods.^bPopulation with lifetime diagnosis of asthma.^cAll amounts are expressed as billions of US dollars and adjusted for inflation to 2009. The incremental expenditures of asthma in each age category were estimated from the 2-step model (step 1, logit; step 2, generalized linear model with γ distribution and log link), with adjustment for covariates.^dThe 95% percentile bootstrap confidence intervals are presented in parentheses.

adults and children with asthma, no significant time trends were observed in ED visits among children, adolescents, or adults.

When examining expenditure trends, no significant changes were found in inflation-adjusted medical expenditures per capita in adults and children. However, the medical expenditures per person in the adolescent group increased at an annual rate of 2.5%.

Although the change in the mix of expenditures and decrease of hospitalizations in adults and children could be interpreted as an improvement in quality of asthma care, no difference in health status and functional outcomes, ED visits, and increasing expenditures in the adolescent age group may indicate that medical treatments and public health measures still need to be improved. The period from

2000 through 2009 has seen the introduction of new asthma treatments, revised clinical guidelines for asthma management, and large public campaigns to increase awareness of asthma as a public health concern. However, none of these factors seemed to have changed outcomes or expenditures. During the 10-year period, the overall composition of expenditures has changed. Inpatient expenditures have decreased during the same period that prescription expenditures have increased. This is particularly notable in the adolescent group. Prescription medications comprised the largest proportion of expenditures in adults and adolescents. Some might suggest that the present data support the hypothesis that increased medication use leads to lower hospitalizations. The authors would

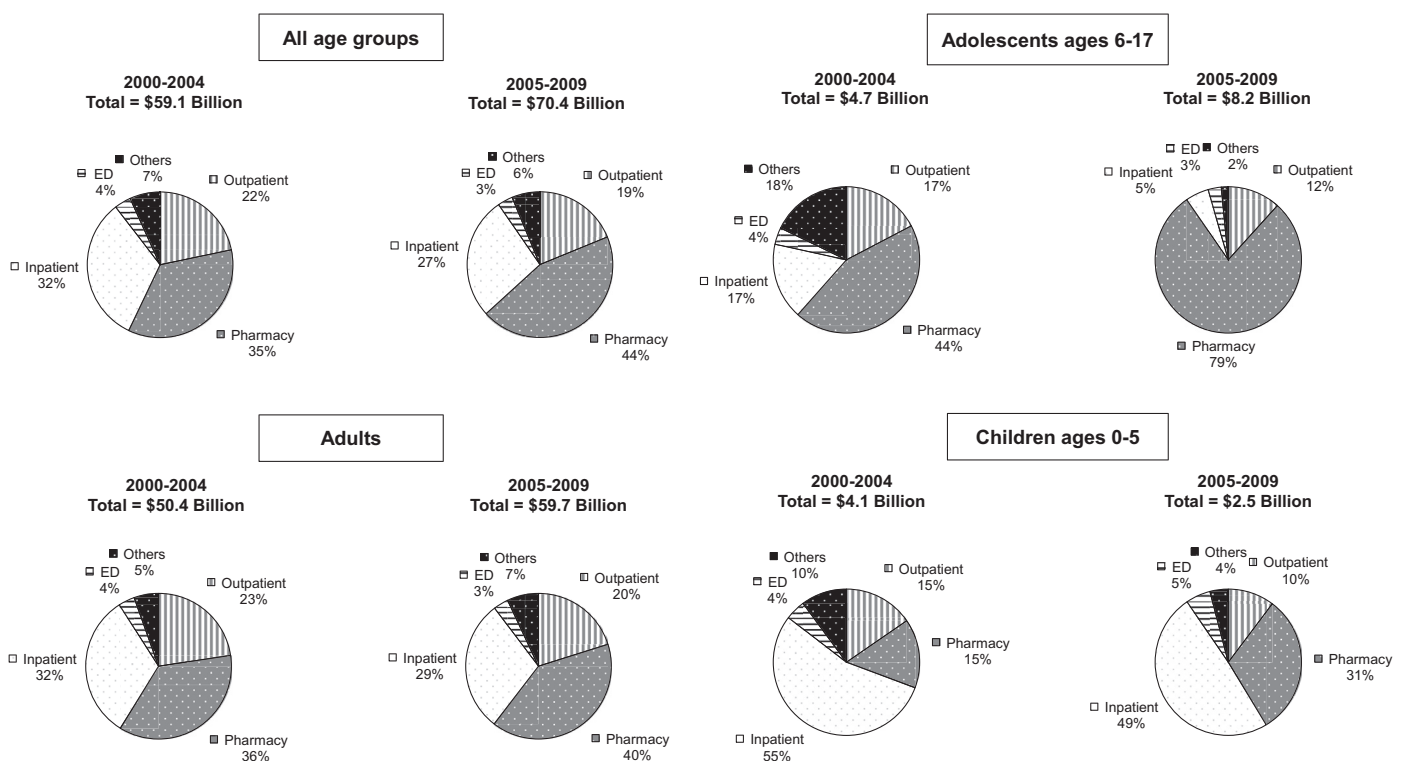


Figure 3. Five-year average expenditures attributable to asthma and its composition by use type in 2000 through 2004 and 2005 through 2009 among all ages (adults; adolescents, 6–17 years old; children, 0–5 years old). Each expenditure category attributable to asthma, estimated from the 2-step model (step 1, logit; step 2, generalized linear model with γ distribution and log link) with adjustment for covariates, was aggregated into 2 5-year average values. Total expenditures were calculated by summing the 5-year average expenditures of each category. ED, emergency department.

argue that a more targeted comparative study is needed to evaluate this claim.

The recently published Healthy People 2010 final report³⁶ also showed a need for improvement in asthma management, although its objectives, estimated without adjustment, hospitalizations, and school or work absenteeism, except for mortality, have not shown statistically significant differences over the past decade. Furthermore, it showed a need for increasing delivery of appropriate asthma care recommended by National Asthma Education and Prevention Program Expert Panel Report 3. Except for assistance in decreasing exposure to environmental risk factors, the proportion of patients with asthma receiving the other 5 categories of care was similar in the previous 5 years.

Two recent studies conducted by Rank et al¹² and Barnett and Nurmagambetov¹⁰ used the same data source. However, the present study used a larger dataset (longer periods and broader age groups) and a broader definition (lifetime prevalence) of asthma. Although Rank et al¹² found a significant difference in total expenditures for 5- to 56-year-old patients with asthma in 2 time periods (1996–1998 and 2004–2006), the present results showed the opposite in adults and children group. This might be explained mainly by the different periods. Although total expenditure for adults with asthma showed an increasing trend in the first 5 years, it showed a decrease from 2005 to 2008 in the present data. Further confirmatory studies with recent periods would be needed to support this finding. Barnett and Nurmagambetov¹⁰ found that although the trend of expenditures over the same period from 2002 through 2007 seemed similar, the absolute expenditures in each year were higher in the present study. Several explanations are possible. First, the present asthma group was based on lifetime prevalence, whereas Barnett and Nurmagambetov¹⁰ defined their asthma population as patients having an asthma-related medical event or prescription medications during each calendar year. This difference in classification might explain most of the difference found in expenditures. Second, Barnett and Nurmagambetov¹⁰ used the Charlson Comorbidity Index to adjust for comorbidities in all ages. However, in the pediatric groups, the adaptation of the Charlson Comorbidity Index to pediatric patients has several limitations (as stated in the “Methods” section). Therefore, their estimate for pediatric patients may be overestimated owing to minimal adjustments for medical comorbidities. Moreover, it did not examine expenditures by age groups. Thus, they did not capture the differing trends in adults and pediatrics.

Several limitations of this study are worth noting. First, the authors did not adjust for the severity of asthma in these analyses because it was not available in the MEPS. Second, among adults, the authors compared the number of workdays lost as a functional outcome measurement. However, it represents only those who worked during the reference periods of the survey. Therefore, it did not capture the number of days lost owing to illness among those not working. Third, in the child group, the authors do not have any useful functional outcome measurements in the MEPS data. The regression-based model was used for estimating the US total expenditure attributable to asthma with adjustment for many covariates. Although the present estimates from the 2-part model may approximate the true value, it is not the true value. These estimates include not only asthma-specific expenditures but also expenditures of other asthma-related diseases.^{10,37} Thus, these estimates might be overestimated when examining the expenditures attributable to asthma specifically. However, in pediatric patients, the adjustment for comorbidity, including asthma-related diseases such as allergic rhinitis, eczema, and steroid-dependent diseases, would increase the precision in the present estimates for the expenditures that are attributable to asthma specifically compared with the adult group, in which only chronic pulmonary disease was adjusted for using the Charlson Comorbidity Index.

In conclusion, although medical costs for patients with asthma increased or remained stable across all age groups during a 10-year period, outcomes did not improve. Considering the economic burden of asthma and the past 10-year performance, continued attention should be focused on asthma management in the United States.

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