Trends in Cost, Health Status and Functional Outcomes Among Adult and Pediatric Patients with Asthma: 2000-2009

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Abstract

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Background: Asthma, a chronic inflammatory disease of the respiratory tract, has a high prevalence and substantial deleterious effects on health care costs in the U.S. Very few studies have examined recent trends in medical expenditures, health status, and functional outcomes among patients with asthma.

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

Methods: Data from the 2000-2009 Medical Expenditure Panel Survey (MEPS) were used. Patients with asthma were identified by self-reported lifetime asthma diagnosis or medical condition based on International Classification of Disease, Ninth Revision, Clinical Modification. We studied the trends among three age groups: adults age 18 and above, adolescents ages 6-17, and children ages 0-5. Generalized linear models were used to examine the change in health care costs (adjusted for medical price inflation) and functional outcomes (number of work days lost (WDL) in adults and number of school days lost (SDL) in adolescents), while ordinary least square regression (OLS) was used for health status outcome (Physical

Component Summary (PCS) and Mental Component Summary (MCS) from SF-12v2 Health Survey), adjusting for clinical and demographic characteristics, socioeconomic status and comorbidity. Two part models were used to estimate the medical costs of asthma.

Results: Among adults, the mean PCS decreased 0.09 units annually (p<.01) and the trends of mean MCS was not significant. There was no significant change in the number of WDLs and marginal decrease in SDLs with 1.8% annually (p=.06). The trends of medical costs in adults and children with asthma were not significant. However the medical expenditures increased 2.5% annually during the ten year period in adolescents (p=.049). For the most recent year available (2009), the total incremental health care costs of asthma in the United States were $53 billion, $7 billion and $3 billion in adults, adolescents and children, respectively.

Conclusion: This study finds that over a 10-year period, medical costs in asthma patients have increased or remained similar in all age groups, while outcomes have not improved. These data reflect a period of time in the US where increasing attention has been paid to asthma disease management. The lack of improvement in outcomes suggests that approaches to asthma management in the U.S. should be reexamined and modified.

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1. Introduction

Asthma, a chronic respiratory disease with the characteristics of episodic airway obstruction, hyper-responsiveness, and inflammation is one of the most prevalent and burdensome chronic diseases in the U.S. Common clinical symptoms include wheezing, coughing (notably at night and early in the morning), shortness of breath, and chest tightness.[1] In 2009, asthma affected 24.6 million Americans, of those 12.8 million had at least one asthma attack in the previous year.[2] One in 10 children and one in 12 adults reported having asthma in 2009 with an average annual increase of 1.2% in prevalence from 2001 to 2009.

Previous studies have identified the substantial negative impact of asthma on health care expenditures among adult and pediatric patients.[3-8] However, few studies have examined the expenditure trends among asthma patients over a period of at least 5 years.[9,10] Furthermore, there is no study that has reported on the long-term trends in health status and functional outcomes among asthma patients in the U.S.

The objectives of this study are to examine the level and changes in medical expenditures, health status and functional outcomes in persons with asthma. We estimated the trajectory of expenditures and outcomes amongst adults and pediatrics with asthma over the 10-year period 2000 to 2009. Specifically, we set out to describe the trends in health status and functional outcomes of adults and/or pediatrics with asthma and to estimate the mean health care expenditures in asthma patients compared to a control group of patients without asthma. We believe that an examination of the most recent 10-year population trends in asthma expenditures and outcomes may provide an indicator of the potential impact increased attention toward asthma management has had in the U.S.

2. Methods

2.1 Data source

We used data from the Medical Expenditure Panel Survey Household Component (MEPS-HC) from 2000 to 2009.[11] The MEPS-HC provides data from responding family and individuals regarding a wide range of information such as basic demographic, socioeconomic status (SES; employment, income and education), health status, insurance coverage and expenditures and use of health care supplemented by the Medical Provider Component as an imputation source. The MEPS, initiated in 1996, is a set of large-scale nationally representative surveys for the U.S civilian non-institutionalized population.

During each calendar year data are collected simultaneously for two MEPS panels. One panel is in its first year of interviews (e.g. Rounds 1, 2 and 3), while the prior year's panel is in its second year of data collection (e.g. Round 3, 4 and 5). The round 3 for each MEPS panel overlaps two calendar years. Each panel of the MEPS-HC is drawn from a subsample of respondents from the previous year's National Health Interview Survey (NHIS), a nationally representative sample reflecting an oversampling of blacks, Hispanics and beginning in 2006, Asians. The MEPS additionally oversamples certain policy relevant subgroups, including family income level less than 200% of federal poverty level to meet the targeted level of precision in estimates.[12] All panels are followed for 2 years with data collected from 5 rounds of computer-assisted personal interviews over 30 months. For our analysis, the full year consolidated data file and the medical condition file from 2000 to 2009 were used. The full sample during 2000 to 2009 varied from 25,096 to 36,855 and the overall response rate ranged from 56.9% to 66.3%.[13-22] The MEPS national data are exempted from Institutional Review Board review at the University of Washington.[23]

2.2 Sample and identification of asthma patients

The MEPS-HC full year consolidated files from 2000 to 2009 consisted of 335,426 individuals. Since asthma is a chronic condition (although it sometimes recurs infrequently or remains latent), asthma patients are identified on the basis of a life time diagnosis using two 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. The ICD-9-CM codes (3-digit code categories) were collapsed from the fully-specified codes prepared by professional coders from the verbatim text of recording of respondents' self-reporting health problems. Individuals whose asthma status was not ascertained, 1.15% of the whole sample, were excluded from study population.

2.3 Stratification

Many studies have shown that asthma affects pediatrics and adults differently.[2,8,24] For example, adolescents have the highest prevalence of asthma, while younger children with asthma have the highest rates of hospitalization and expenditures.[1,4,25] As a consequence and to make age-specific estimates, we stratified the sample into 3 categories: those ≥ 18 years of age, adolescents ages 6 to 17 and children ages 0 to 5.

2.4 Outcomes

2.4.1 Health status and functional outcomes

The MEPS collects household-level data on health status and functional outcomes. We extracted data on the 12-Item Short Form Health Survey (SF-12) Physical Component Summary (PCS) and Mental Component Summary (MCS) score from 2000 to 2009 for the adult asthma population.[26] Because the version of the SF-12 changed during the study period, we modified the 2000 to 2002 scores to be equivalent to the 2003 to 2009 using the methods provided by Ware et al.[27] The annual number of work days lost (WDL) for adults and the annual number of school days lost (SDL) for adolescents came from a physical illness or injury, or mental or emotional problem were examined from 2000 to 2009. All days lost from work or school were treated as a full day, consistent with previous studies using MEPS.[9,28]

The WDL and SDL were calculated by adding up the lost days from 3 consecutive rounds in each calendar year. Adults who did not work and adolescents who did not attend school during any 3 consecutive rounds in a calendar year were excluded from the annual WDL and SDL calculations (approximately 20% of adults responding in each round and 14% of adolescents responding in each round). Since, the WDL and SDL reported in round 3 pertained to the following year prior to 2003, we prorated those from round 3 in panel 4 to 6 by each person's reference period in the calendar year. For the WDL and SDL in round 3 of panel 7, (reference period approximately started from October, 2002 and ended March, 2003), the lost days of round 3 in 2002 were calculated by subtracting the 2003 values from the values of round 3 in 2002 since the lost days reported in 2003 were true values.

2.4.2 Health care expenditures

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. The total expenditures variable is comprised of the sum of the following component variables: office based visits, hospital outpatient visits, inpatient visits, emergency room visits, prescription medications, dental visit, home health care, vision aids and other medical equipment and services. We combined office based visits and hospital outpatient visits into outpatient visits. Dental visits, home health care, vision aids and other medical equipment and services were aggregated to a new variable called “Other Visits”. To adjust for medical price inflation, expenditures from 2000 to 2008 were adjusted to match the 2009 equivalents using the Consumer Price Index for Medical Care provided by the US Bureau of Labor Statistics.[29]

2.5 Covariates

Sex, age, race (White, Black, Others) recoded from 6 self-reported categories in MEPS, ethnicity (Hispanic, non-Hispanic), type of insurance (any private insurance, public only coverage, or uninsured), U.S census region (Northeast, Midwest, South, West) were included as covariates in analysis for all age categories.

In the MEPS defined race categories, American Indian/Alaska Native, Asian, Native Hawaiian/Pacific Islander and Multiple race reported were aggregated into others for analysis. We also included poverty status categorized from federal poverty level as negative or poor (less than100%), near poor (100% to less than 125%), low income (125% to less than 200%), middle income (200% to less than 400%), and high income (greater than or equal to 400%) as a covariate.

In the adult group, marital status, educational levels, and the D'Hoore adaptation[30] of the Charlson comorbidity index[31] (DCCI) were included. The DCCI consists of 17 comorbidities with weights from 1 to 6 and provided a convenience in matching ICD-9-CM codes in MEPS to related comorbidities due to its categorization of 3 digit ICD-9 codes. Despite its simplicity, its predictive validity has been comparable to other comorbidity index measures for administrative databases.[32-34]

In pediatrics, applicability of comorbidity adjustment used in adults has important limitations: (1) very few individuals have a positive value of the DCCI, and (2) predictability of adult ICD-9-CM based comorbidity instrument is low in pediatrics. To create a comorbidity adjustment for pediatrics, named pediatric chronic diseases score (PCDS) we computed the number of ICD-9-CM codes matched with 26 chronic conditions drawn from commonly used drugs for pediatrics in ambulatory settings.[35] Because asthma was of interest in our study, ICD-9-CM codes for asthma were excluded in the comorbidity index computations.

2.6 Analytic approach

PCS and MCS scores were approximately normally distributed. Multiple linear regression was used to estimate the 10-year change in mean PCS and MCS.

Furthermore, we predicted the annual mean PCS and MCS with year as a dummy variable, using the Kleinman and Norton direct substitution method.[36]

To examine the 10-year WDL and SDL outcomes over a decade, we used generalized linear models (GLMs) with a log-link and a gamma distribution. This approach was selected after considering the positive skewness of the WDL and SDL estimates and information obtained from the Akaike information criterion (AIC) and Bayesian information criterion (BIC) scores. As before, we predicted annual mean WDL and SDL outcomes using the year as a dummy variable and applying the Kleinman and Norton direct substitution method.[36] The SDL was not analyzed in the children ages 0 to 5.

To evaluate the 10-year expenditure trends, we estimated the level of adjusted mean total expenditures by age category. Then, we selected a cohort of individuals from MEPS who did not have asthma and estimated the difference in mean expenditures between the asthma and no-asthma groups over the 10-year period, by age category. This method, referred to as the incremental method, is widely used in population-based studies of disease burden as it measures expenditures that are exclusively attributable to the disease of interest while adjusting for covariates.[8,9,37-40]

In order to address the positive skewness of the expenditure variable, we used GLMs with a gamma distribution and a log link function rather than log transformed ordinary least square regression, which has the limitation of difficulty in interpretation due to retransformation.[41] We considered the lower value of AIC and BIC for choosing the appropriate link function and distribution.[42] In addition, to handle a high concentration of zero ($0.00) observations in the expenditure variable, we used a two-part model.[43,44] The first part of the model represents the probability of positive expenditures using a logistic regression in the presence of asthma. The second part of the model is a GLM with a gamma distribution and a log link function to estimate expenditures conditional on having an expenditure of greater than $0.00. The estimated expenditures for each individual are gained from the multiplication of predictions from each part of the model. To compute the difference of mean expenditures between subjects with asthma and without asthma from the two-part model, we used the Kleinman and Norton direct substitution method.[9,36]

The final analytic step was to compute the total and category-specific expenditures for asthma in the U.S. To determine total expenditures, we multiplied the difference in expenditures derived from the incremental method by the estimated U.S. asthma population in each year. We calculated confidence intervals using the bootstrap method.[45] Then, we determined category-specific expenditures using the same 2-part model and bootstrap procedure. To identify a shift in the composition of asthma expenditures, we compared the two consecutive 5-year periods: 2000-2004 and 2005-2009. Since the total U.S expenditures for asthma were not equal to the numeric sum of the estimated categories, we used the later value 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 the STATA 12 software (College Station, TX).[46,47] For the PCS and MCS outcome variables, Self-Administered Questionnaire weights were used rather than a personal-level weight following the recommendation of the

MEPS analysts.[13] To appropriately pool data from 2000 to 2009, we used the combined variance stratum and primary sampling unit variables with an adjustment for a change in the method in 2002.[48]

3. Results

We identified a total of 330,942 MEPS respondents with complete data on age and asthma status covering the period 2000 to 2009. From this, we selected all patients with asthma and identified 21,946 adults age 18 and above, 8,386 adolescents, and 3,096 children.

3.1 Prevalence

Because MEPS is nationally representative of the US population, it can be used to make estimates of disease prevalence. The prevalence of lifetime diagnosis of asthma in the U.S changed from 9.7% in 2000 to 10.3% in 2009. Among adults, asthma prevalence increased from 9.3% to 9.8%, in adolescents, 12.1% to 13.5% and among children, 8.3% to 9.0%. In general, the lifetime prevalence of asthma in each age group matched estimates from the Behavioral Risk Factor Surveillance System and National Health Interview Survey.[49,50]

3.2 Demographic characteristics

We compared the characteristics of asthma patients in 2000 to those in 2009. In the adult group, individuals with asthma in 2009 were more likely to be covered by public insurance, uninsured, poorer, and had a higher mean comorbidity score (Table 1). In adolescents, the respondents in 2009 had higher coverage rates by public insurance, and were more likely to belong to others race categories than those in 2000 (Table 2). In addition the mean PCDS was higher in 2009 than in 2000. Children in 2009 were more likely to be covered by public insurance than those in 2000 (Table 3). The changes in insurance status may reflect the impact of the 2008-2009 economic downturn and subsequent unemployment in the US economy.

Tables 1-3 also compared individuals with and without asthma in 2009 to examine factors that may influence the difference in expenditures between the 2 groups. Adults with asthma were on average 1.2 years younger, more likely to be female, poorer, less likely to be Hispanic, less likely to be presently married, have lower education, and less likely to reside in the Southern region of the U.S. In addition, individuals with asthma had a higher average comorbidity score than those without asthma.

Compared to adolescents without asthma, adolescents having asthma were more likely to be male, black, and covered by public insurance, and were less likely to be Hispanic. Furthermore, those with asthma were more likely to reside in the Northeastern and Southern region of the U.S. and had a higher average PCDS. In children, the group with asthma was slightly older, poorer, more likely to be male, black, covered by public insurance and to reside in the Northeastern region of the U.S. Respondents with asthma were also more likely to have a higher mean PCDS.

3.3 Outcomes and expenditures by age

3.3.1 Health status & functional outcomes

The results from the adjusted multivariable analysis of PCS and MCS for adults with asthma during 2000 to 2009 are shown in Figure 1. Over a ten year period, the linear trend showed statistically significant decrease in the mean PCS with 0.09 for every one year increase ($p<.01$). The mean MCSs were consistent, but slightly increased since 2007. However, the linear trend of the mean MCSs over the decade was not significant ($p=0.67$).

Findings from the adjusted multivariable analysis of WDL in adults from 2000 to 2009 are shown in Figure 2. No statistically significant trend was detected in WDLs over the 10 year period ($p=.924$). The finding from the SDL analysis in adolescents is depicted in Figure 3. The mean SDL was not statistically significant ($p=0.06$).

The results from these analyses suggest that health status and functional outcomes in patients with asthma have declined or remained unchanged over the 10-year period 2000-2009.

3.3.2 Heath care expenditures

3.3.2.1 Trend of expenditures in asthma patients

Figure 4, panels A, B and C, show the inflation and covariate adjusted mean medical expenditures for each of the three asthma age groups. In adults and children, the trends of medical expenditures were not statistically significant ($p=.23$, $p=.22$). In contrast, in the adolescent group, the mean health care expenditures increased approximately 2.5% per year during the 10-year study period ($p=0.049$).

3.3.2.2 Incremental direct expenditure of asthma

Inflation-adjusted asthma-attributable expenditures are presented in Tables 4-6 for all age groups. These estimates were computed by multiplying the incremental direct expenditures between individuals with and without asthma by the estimated U.S asthma population in each year.

After full statistical adjustment, the mean medical expenditures for adults with asthma was $6,080 (95% CI: $5,257-$7,010), compared with $4,123 (95% CI: $3,854-$4,468) for those without asthma in 2000 (inflation adjusted to 2009 dollars). For the adolescent group, we estimated mean expenditures of $1,414 (95% CI: $1,205-$1,718) in asthma patients compared with $1,201 (95% CI: $1,053-$1,359) in those without asthma. For children with asthma, mean expenditures were $3,474 (95% CI: $1,656-$6,051) compared with $1,114 (95% CI: $902-$1,386) in those without asthma.

Analyzing 2009 separately and with the same adjustments, the mean medical expenditure among adults with asthma was $7,536 (95% CI: $6,788-$8,483), compared to $5,185 (95% CI: $4,920-$5,528) for those without asthma. For adolescents, the mean expenditures were $2,413 (95% CI: $1,911-$3,057) for those with asthma compared to $1,349 (95% CI: $1,225-$1,492) those without asthma. In the children group, mean expenditures were $2,911 (95% CI, $1,821 to $4,479) for asthmatics compared to $1,628 (95% CI, $1,167 to $2,165) for non-asthmatics.

Over the 10-year period, the inflation-adjusted incremental expenditures attributable to asthma in adults increased approximately 20% from $1,958 (95% CI: $1,122-$2,846) to 2,351 (95% CI: $1,559-$3,308). For adolescents, there was a 401% increase from $213 (95% CI: $-35-$532) to $1,064 (95% CI: $564-$1,719) and for children, asthma expenditures decreased an estimated 46% from $2,360 (95% CI: $559-$4,841) to $1,283 (95% CI: $446-$2,554).

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 and a change in the intensity of medical services for asthma.

3.3.2.3 National estimates of asthma expenditures

We now report national estimates of the change in expenditure burden associated with asthma in the U.S. using the population sampling weights from MEPS applied to our findings. The total national asthma expenditures for adults increased 43% with a 19% increase in the population with asthma (Table 4). The five year average difference we observed in the total expenditures between adults with and without asthma in 2005-2009 was accounted for by outpatient visits (20%), inpatient visits (29%), prescription medications (40%), emergency room visits (3%) and other visits (7%). Amongst the component expenditures, the percentage of 5-year average expenditures for prescription medications increased 4% from 2000-2004 to 2005-2009. However, the percentage of five year mean outpatient expenditures and inpatient expenditures decreased 3% from 2000-2004 to 2005-2009 (Figure 5).

The total national asthma expenditures for adolescents increased 466% with a 13% increase in the population with asthma (Table 5). The five year mean total national burden attributable to asthma among adolescents in 2005-2009 was explained by outpatient visits (12%), inpatient visits (5%), prescription medications

(79%), emergency room visits (3%) and other visits (2%) (Figure 5).

The total national asthma expenditures for children with asthma decreased 37% with 16% increase of the population with asthma (Table 6). The five year average total burden attributable to asthma among children in 2005-2009 was explained by outpatient visits (10%), inpatient visits (49%), prescription medications (31%), emergency room visits (5%) and other visits (4%) (Figure 6).

4. Discussion

Our aims were to quantify and describe changes in 10 year trends in health status, functional outcomes, and expenditures in both adults and pediatrics with asthma. We found that in general there were no changes in health status and functional outcomes in individuals with asthma over the decade, 2000-2009. We evaluated the change in hospitalization and emergency room visits over the same period The number of inpatient admissions for asthma declined by 2.3% (p=.01), 6.8% (p=.12), 5.8% (p=.03) per annum in the adult, adolescent and child age groups, respectively. For emergency room visits, there was no statistically significant change. When examining expenditure trends, we found no significant changes 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 2.4%.

Modest, but positive, changes in hospitalization rates and no difference in population outcomes, emergency room visits and increasing expenditures in the adolescent age group may indicate that our medical treatments and public health measures need to be reconsidered. The period 2000-2009 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. Yet none of these taken together, seemed to have changed population outcomes or expenditures.

Very few novel asthma medications were introduced between 2000-2009. Only one, omalizumab, approved in 2003, had a new mechanism of action (anti-IgE), and was indicated as adjunctive therapy for severe persistent allergic asthma. Three additional agents were approved, but they contained ingredients that had been approved previously.[51]

Over the 10-year period, the overall composition of expenditures has changed. Inpatient expenditures have declined during the same period that prescription expenditures have increased. This is particularly notable in the adolescent age group. Prescription medications comprised the largest proportion of expenditures in adults and adolescents. Some might suggest that our data support the hypothesis that increased medication use leads to lower hospitalizations. We would argue that a more targeted comparative study is needed to evaluate this claim.

Our study represents the most recent and largest effort to evaluate asthma expenditures in the United States. Barnett et al used comparable data and methods. We used a larger dataset and a broader definition (lifetime prevalence) of asthma. They found that although the trend of expenditures over the same period over 2000 to 2007 seemed similar, the absolute expenditures in each year were higher in our study. For example, $64.2 billion combined from estimates of all ages in 2007 (adults $60.2 billion, adolescents $2.5 billion, children $1.5 billion) was greater than $50.1 billion estimated by Barnett et al (Table 7). Several explanations are possible. First, our asthma group was based on the lifetime prevalence, while the Barnett et al study defined their asthma population as someone having 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 et al used the DCCI adjusting for comorbidities in all ages. However, in the pediatric groups, the adaptation of DCCI to pediatrics has several limitations (as stated in the methods section). Therefore, their estimate for the pediatrics may be overestimated due to minimal adjustments for medical comorbidities. Lastly, it did not examine expenditures by age groups (pediatrics and adults). Thus, they did not capture the differing trends in adults and pediatrics.

Our findings provide some evidence that the U.S. needs to redouble its efforts to improve asthma outcomes. First, we need to encourage asthma patients and their families to be informed and educated about self-management, which is one of the main recommendations from National Asthma Education and Prevention Program Expert Panel Report 3.[52] The NHIS reported that among individuals with current asthma or parents of pediatrics with current asthma, most responded having being taught how to use an inhaler. However, 44.3%, 29.9% responded having been given an asthma management plan, 53.2%, 50.0% reported having been advised to change things at home, school, or work to improve asthma and 72.1%, 54.8% said having taught how to recognize early signs or symptoms of an asthma episode in pediatrics and adults, respectively.[53] Considering that most cases of asthma symptoms can be well controlled by the correct use of prescribed medicines and asthma attacks can be prevented by avoiding asthma triggers, health professionals and public campaigns should focus on self-management to increase the adherence to existing medications. Second, there has been emerging evidence that poor health literacy in individuals with asthma and their families might be an important key barrier to asthma knowledge.[54] This implies that health care providers should take into account a patient's level of health literacy when providing asthma education. Lastly, the development of novel and cost-effective treatments for asthma is needed.

Several limitations of this study are worth noting. First, since the MEPS data is based on self-report, it is susceptible to the misclassification bias. That is, our sample of patients with asthma may be underrepresented. However, our asthma definition was mostly based on response about the lifetime asthma prevalence, reducing the possibility of misclassification. Second, we did not adjust for the severity of asthma in comparing the trends of expenditure, health status and functional outcomes in asthma patients because it was not available in the MEPS. Third, among adults, we compared the WDLs as a functional outcome measure. However, it only represents someone has worked during the reference periods of the survey. Therefore, it did not capture the number of days lost due to illness among a group not working. Although a non-working group would lose more days than the working group due to illness, there would be no strong reason to believe that the trends of number of days lost due to illness would be different between working group and non-working group. Fourth, in the children group we do not have any useful functional outcome measures in the MEPS data. We used the regression based model for estimating the U.S. total expenditure attributable to asthma with adjusting for many covariates. Although our estimates from the two part model may approximate the true value, it is still not the true value. As the previous studies have found, our estimates includes not only asthma specific expenditures but also expenditures of asthma-related other diseases.[9,55] Our estimates would be more valuable, if we want to estimate the overall asthma expenditures. However, if we want to examine the expenditures only attributable to asthma specifically, our estimates might be overestimated. However, in pediatrics, our adjustment for comorbidity including asthma-related disease such as allergic rhinitis, eczema, and steroid-dependent diseases would increase the precision in our estimates for the expenditures only attributable to asthma specifically, compared to the adults group in which only chronic pulmonary disease was adjusted for using the DCCI.

5. Conclusions

Our objectives are to examine the 10-year trends in health status, functional outcomes and expenditures in adults and pediatrics with asthma. We found that there were no significant improvements observed in health status (PCS and MCS), functional outcome (WDL) and medical expenditures in adults with asthma. In adolescents with asthma, health care expenditures have been increasing and functional outcome (SCL) has improved marginally. In conclusion, considering the economic burden of asthma and the past 10-year performance, asthma management in the U.S should be re-evaluated and refined

Table 1. Characteristics of Adults With and Without Asthma, MEPS 2000 and 2009[a]

Characteristics	Mean or %				p Value for Difference Between Respondents[b]	
	2000		2009			
	Asthma	No Asthma	Asthma	No Asthma	With and Without Asthma, 2009	With Asthma, 2000 vs 2009
No. sampled (respondents)	1,529	15,928	2,484	23,472		
Estimated No. of adults in US population, millions	18.8	183.7	22.5	206.8		
Age, mean	44.0	45.1	45.2	46.4	0.02	0.18
Female, %	61.5	51.2	62.9	50.4	<0.001	0.47
Race, %[c]					0.12	0.05
White	83.2	83.7	80.6	81.3		
Black	13.0	11.9	12.9	11.6		
Others	3.8	4.4	6.5	7.1		
Hispanic, %	8.8	10.9	10.6	14.2	<0.001	0.16
Insurance coverage, %					<0.001	<0.01
Any private	71.6	74.5	64.3	68.0		
Public only	18.0	12.7	22.7	15.8		
Uninsured	10.4	12.7	13.0	16.2		
Marital status, %[d]					<0.001	0.91
Presently married	47.4	56.6	47.2	54.3		
Presently not married	52.6	43.4	52.8	45.7		
Poverty status, %[c]					<0.001	<0.01
Negative or poor	11.6	9.3	16.5	11.6		
Near poor	4.0	3.9	5.3	4.1		
Low	14.3	12.3	14.4	13.4		
Middle	30.2	32.2	28.7	30.8		
High	39.9	42.2	35.1	40.1		

(Continued)

Table 1. *(Continued)*

Characteristics	Mean or %				p Value for Difference Between Respondents[b]	
	2000		2009			
	Asthma	No Asthma	Asthma	No Asthma	With and Without Asthma, 2009	With Asthma, 2000 vs 2009
Education, %						
No degree	19.9	18.4	17.1	15.8	0.04	0.18
GED	6.0	4.2	5.1	3.8		
High school diploma	45.9	47.1	44.1	45.3		
Bachelor's degree	13.4	16.0	15.9	17.6		
Master's degree	6.6	5.9	7.1	7.0		
Doctorate degree	1.4	1.6	1.4	2.1		
Other degree	6.7	6.4	8.9	7.8		
Missing	0.3	0.4	0.4	0.5		
Region, %[d]						
Northeast	19.1	19.1	19.5	18.4	0.03	0.74
Midwest	23.4	23.0	22.3	21.8		
South	35.1	35.5	33.0	37.0		
West	22.4	22.5	25.2	22.9		
Charlson Comorbidity Index Score, mean	0.39	0.27	0.78	0.45	<0.001	<0.001

Abbreviation: MEPS, Medical Expenditure Panel Survey; GED, Graduation Equivalency Degree.
[a] All percentages are estimated from weighted sample using complex survey design methods.[47,48]
[b] Chi-squared test used to test difference in proportions; t test used in mean comparisons.
[C] See “Methods” for definitions.
[d] 1 missing observation for marital status and region in no asthma group in 2000 not reported.

Table 2. Characteristics of Adolescents Ages 6-17 With and Without Asthma, MEPS 2000 and 2009[a]

	Mean or %				p Value for Difference Between Respondents[b]	
	2000		2009			
Characteristics	**Asthma**	**No Asthma**	**Asthma**	**No Asthma**	**With and Without Asthma, 2009**	**With Asthma, 2000 vs 2009**
No. sampled (Respondents)	575	4,355	965	5,999		
Estimated No. of adolescents in US population, millions	5.9	42.4	6.6	42.3		
Age, mean	11.3	11.5	11.6	11.5	0.73	0.19
Women, %	40.9	49.4	38.0	50.8	<0.001	0.38
Race, %[c]					<0.001	<0.01
White	73.7	79.0	68.8	77.3		
Black	23.2	16.1	22.6	13.7		
Others	3.1	4.8	8.5	9.0		
Hispanic, %	14.8	15.7	18.3	21.9	0.03	0.19
Insurance coverage, %					<0.01	0.01
Any private	66.3	72.4	61.8	62.6		
Public only	26.1	17.7	34.0	29.7		
Uninsured	7.6	9.9	4.2	7.7		
Poverty status, %[c]					0.23	0.83
Negative or poor	19.9	14.9	21.8	18.5		
Near poor	5.1	5.0	5.8	5.5		
Low	14.0	14.3	14.5	16.2		
Middle	37.0	33.8	33.1	32.4		
High	23.9	32.0	24.8	27.5		
Region, %					0.02	0.54
Northeast	21.1	17.9	18.2	17.1		
Midwest	20.9	23.8	19.1	21.5		
South	36.5	33.6	42.5	36.7		
West	21.4	24.7	20.2	24.7		
Pediatric Chronic Diseases Score, mean	0.53	0.28	0.67	0.37	<0.001	<0.01

Abbreviation: MEPS, Medical Expenditure Panel Survey
[a] All percentages are estimated from weighted sample using complex survey design methods.[47,48]
[b] Chi-squared test used to test difference in proportions; t test used in mean comparisons.
[C] See "Methods" for definitions.

Table 3. Characteristics of Children Ages 0-5 With and Without Asthma, MEPS 2000 and 2009[a]

Characteristic	Mean or %				P Value for Difference Between Respondents[b]	
	2000		2009			
	Asthma	No Asthma	Asthma	No Asthma	With and Without Asthma, 2009	With Asthma, 2000 vs 2009
No. sampled (Respondents)	208	2,176	352	3,246		
Estimated No. of children in US population, millions	2.0	22.1	2.3	23.5		
Age, mean	3.0	2.5	3.2	2.4	<0.001	0.23
Women, %	37.2	50.3	38.1	49.6	<0.01	0.88
Race, % [c]						
White	73.4	79.7	67.0	76.0	<0.001	0.08
Black	23.6	15.0	23.1	13.5		
Others	2.9	5.3	9.9	10.5		
Hispanic, %	18.3	18.2	25.3	25.5	0.96	0.18
Insurance coverage, %						
Any private	63.5	64.9	49.7	57.9	<0.01	0.03
Public only	32.1	26.6	48.0	37.7		
Uninsured	4.5	8.6	2.4	4.5		
Poverty status, % [c]						
Negative or poor	21.0	18.7	34.8	23.4	0.04	0.08
Near poor	3.9	6.1	4.2	5.6		
Low	18.1	17.0	14.3	16.1		
Middle	35.2	32.7	22.8	29.8		
High	21.7	25.4	23.9	25.1		
Region, %						
Northeast	17.1	18.0	25.5	14.0	<0.01	0.48
Midwest	23.0	24.2	22.8	22.5		
South	44.1	32.2	37.1	37.8		
West	15.8	25.6	14.6	25.7		
Pediatric Chronic Diseases Score, mean	0.31	0.15	0.38	0.23	<0.001	0.28

Abbreviation: MEPS, Medical Expenditure Panel Survey
[a] All percentages are estimated from weighted sample using complex survey design methods.[47,48]
[b] Chi-squared test used to test difference in proportions; t test used in mean comparisons.
[C] See “Methods” for definitions.

Table 4. Estimated Incremental Expenditures of asthma Among US Adults, MEPS 2000-2009[a]

Year	Total (95% CI)[b]	Expenditure (95% CI)[b]				
		Inpatient	Outpatient	ER	Pharmacy	Others
2000	36.9 (21.1-53.6)	22.2 (5.7-40.9)	9.1 (5.3-13.5)	1.6 (0.8-2.5)	10.1 (7.9-12.7)	3.0 (-0.2-6.1)
2001	27.0 (18.5-36.5)	7.8 (-1.8-19.7)	8.7 (5.1-12.7)	2.0 (1.0-3.1)	14.4 (12.2-16.8)	1.1 (-0.6-2.8)
2002	54.0 (42.2-66.5)	26.9 (14.3-40.8)	14.7 (10.5-19.2)	2.7 (1.6-3.8)	20.3 (16.9-23.9)	1.5 (-0.1-3.5)
2003	40.6 (28.6-58.0)	6.1 (-7.7-23.6)	13.3 (8.9-18.0)	1.2 (0.5-2.1)	26.3 (20.5-31.5)	0.7 (-0.8-2.1)
2004	58.8 (35.0-84.5)	18.0 (0.6-34.6)	11.2 (6.4-16.7)	1.6 (0.7-2.6)	20 (16.6-24.3)	7.3 (0.9-13.6)
2005	57.6 (29.7-91.9)	6.7 (-5.9-20.4)	9.7 (5.1-14.3)	2.0 (1.1-3.1)	25.2 (18.8-33.0)	11.9 (0.1-27.6)
2006	46.0 (33.5-59.8)	13.5 (1.7-25.6)	12.2 (7.4-16.7)	2.7 (1.5-3.9)	24.3 (19.2-30.1)	1.9 (0.2-3.9)
2007	60.2 (43.7-79.2)	40.3 (19.1-66.2)	12.5 (6.6-19.0)	1.7 (0.8-2.7)	27.2 (21.7-33.7)	2.7 (0.6-5.0)
2008	37.4 (25.3-51.6)	8.7 (-4.1-21.9)	10.3 (5.5-15.8)	1.5 (0.3-2.8)	22.9 (18.4-28.2)	1.9 (-0.3-4.5)
2009	52.8 (35.0-74.3)	18.2 (0.1-33.5)	15.5 (9.6-21.5)	2.1 (0.8-3.6)	20.7 (15.7-25.8)	2.5 (0.4-5.0)

Abbreviation: ER, emergency room; MEPS, Medical Expenditure Panel Survey

[a] All estimates based on weighted sample using complex survey design methods.[47,48] All amounts are expressed in billions of US dollars and are inflation-adjusted to 2009. The incremental costs of asthma are estimated from the 2-step model (step1, logit; step2 GLM with gamma distribution and log link). Covariates; age, sex, race, ethnicity, insurance coverage, poverty status, education, marital status, residence area and Charlson Comorbidity Index Score.

[b] 95% percentile bootstrap confidence intervals are presented in parentheses.

Table 5. Estimated Incremental Expenditures of asthma Among US Children Ages 6-17, MEPS 2000-2009[a]

Year	Total (95% CI)[b]	Expenditure (95% CI)[b]				
		Inpatient	Outpatient	ER	Pharmacy	Others
2000	1.2 (-0.2-3.1)	-1.1 (-3.9-1.3)	0.2 (-0.2-0.8)	0.1 (-0.1-0.3)	1.4 (1.0-2.0)	0.7 (-0.4-2.0)
2001	4.0 (1.1-7.3)	1.4 (-2.1-6.4)	0.7 (0.2-1.3)	0.4 (0.0-1.0)	2.1 (1.5-3.0)	0.8 (-0.7-2.2)
2002	4.9 (3.0-7.1)	2.4 (0.5-5.2)	0.9 (0.4-1.6)	0.1 (0.0-0.3)	1.7 (1.3-2.6)	1.7 (0.4-3.0)
2003	4.5 (3.1-6.1)	1.5 (0.3-4.0)	1.2 (0.5-2.0)	0.1 (0.0-0.3)	2.7 (2.1-3.4)	0.4 (-0.2-1.1)
2004	2.9 (1.8-4.5)	-0.2 (-1.2-1.6)	1.0 (0.4-1.7)	0.1 (-0.1-0.3)	2.5 (1.9-3.4)	0.6 (-0.1-1.4)
2005	2.4 (0.4-5.0)	-2.3 (-8.8-2.9)	1.0 (0.3-1.9)	0.3 (0.1-0.5)	3.2 (2.2-5.9)	-0.1 (-0.6-0.4)
2006	4.2 (2.6-6.2)	-0.1 (-1.7-2.1)	0.4 (-0.1-1.1)	0.3 (0.1-0.5)	6.1 (4.0-9.1)	0.7 (0.0-1.5)
2007	2.5 (1.2-4.3)	-0.2 (-1.8-1.2)	0.2 (-0.3-0.8)	0.1 (0.0-0.4)	5.5 (3.8-9.0)	0.1 (-0.6-1.2)
2008	4.4 (2.6-6.6)	2.3 (-1.4-9.0)	1.9 (0.9-2.9)	0.3 (0.1-0.6)	6.6 (4.6-10.9)	-0.4 (-1.2-0.7)
2009	7.0 (3.7-11.4)	2.4 (-0.8-8.7)	1.3 (0.5-2.1)	0.2 (0.0-0.5)	10.7 (5.1-17.4)	0.3 (-0.4-1.3)

Abbreviation: ER, emergency room; MEPS, Medical Expenditure Panel Survey

[a] All estimates based on weighted sample using complex survey design methods.[47,48] All amounts are expressed in billions of US dollars and are inflation-adjusted to 2009. The incremental expenditures of asthma are estimated from the 2-step model (step1, logit; step2 GLM with gamma distribution and log link). Covariates; age, sex, race, ethnicity, insurance coverage, poverty status, residence area and Pediatric Chronic Diseases Score.

[b] 95% percentile bootstrap confidence intervals are presented in parentheses.

Table 6. Estimated Incremental Expenditures of asthma Among US Children Ages 0-5, MEPS 2000-2009[a]

Year	Total (95% CI)[b]	Expenditure (95% CI)[b]				
		Inpatient	Outpatient	ER	Pharmacy	Others
2000	4.7 (1.1-9.7)	0.1 (-2.0-2.8)	0.7 (0.3-1.2)	0.2 (0.0-0.4)	0.4 (0.3-0.5)	1.9 (0-6.3.0)
2001	2.3 (1.4-3.5)	2.7 (0.1-7.0)	0.6 (0.3-1.0)	0.2 (0.1-0.3)	0.6 (0.4-0.8)	-0.2 (-0.4-0.0)
2002	2.3 (1.2-3.8)	3.2 (0.0-10.1)	0.4 (0.2-0.7)	0.2 (0.1-0.3)	0.5 (0.4-0.7)	0.0 (-0.1-0.2)
2003	2.6 (1.4-4.2)	1.6 (-0.7-4.7)	0.7 (0.3-1.1)	0.2 (0.1-0.3)	0.8 (0.6-1.1)	0.2 (0.0-0.5)
2004	3.3 (2.0-5.0)	3.5 (0.1-11.2)	0.7 (0.2-1.4)	0.2 (0.1-0.3)	0.9 (0.6-1.2)	0.1 (0.0-0.3)
2005	1.8 (0.5-3.4)	0.7 (-4.7-9.9)	0.2 (-0.1-0.7)	0.2 (0.0-0.5)	0.7 (0.4-1.0)	0.2 (-0.1-0.6)
2006	1.5 (0.3-3.0)	0.6 (-1.5-4.1)	0.3 (0.0-0.8)	0.1 (-0.1-0.2)	0.7 (0.5-1.0)	0.1 (-0.1-0.3)
2007	1.5 (0.4-3.2)	1.4 (-1.7-8.3)	0.1 (-0.1-0.4)	0.1 (-0.1-0.2)	1.0 (0.6-1.6)	0.3 (-0.2-0.8)
2008	1.1 (0.0-2.6)	0.5 (-4.2-10.4)	0.1 (-0.1-0.4)	0.1 (0.0-0.2)	0.7 (0.4-1.0)	0.0 (-0.3-0.4)
2009	3.0 (1.0-5.9)	2.9 (-5.5-28.7)	0.5 (0.1-1.1)	0.2 (0.0-0.5)	0.8 (0.6-1.2)	0.0 (-0.1-0.2)

Abbreviation: ER, emergency room; MEPS, Medical Expenditure Panel Survey

[a] All estimates based on weighted sample using complex survey design methods.[47,48] All amounts are expressed in billions of US dollars and are inflation-adjusted to 2009. The incremental expenditures of asthma are estimated from the 2-step model (step1, logit; step2 GLM with gamma distribution and log link). Covariates; age, sex, race, ethnicity, insurance coverage, poverty status, residence area and Pediatric Chronic Diseases Score.

[b] 95% percentile bootstrap confidence intervals are presented in parentheses.

Table 7. Estimated Incremental Expenditures of asthma Among US Population, MEPS 2000-2009[a]

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Estimated U.S asthma population[b] (Millions)	26.7	27.7	28.7	28.9	28.6	29.3	30.8	30.4	31.1	31.4
National estimates of asthma expenditure[c]										
All ages	42.8	33.3	61.2	47.7	65.0	61.8	51.7	64.2	42.9	62.8
Adults	36.9	27.0	54.0	40.6	58.8	57.6	46.0	60.2	37.4	52.8
Adolescents	1.2	4.0	4.9	4.5	2.9	2.4	4.2	2.5	4.4	7.0
Children	4.7	2.3	2.3	2.6	3.3	1.8	1.5	1.5	1.1	3.0

Abbreviation: MEPS, Medical Expenditure Panel Survey

[a] All estimates based on weighted sample using complex survey design methods.[47,48]

[b] Population with lifetime diagnosis of asthma

[c] All amounts are expressed in billions of US dollars and are inflation-adjusted to 2009. The incremental expenditures of asthma are estimated from the 2-step model (step1, logit; step2 GLM with gamma distribution and log link) in age category, respectively.

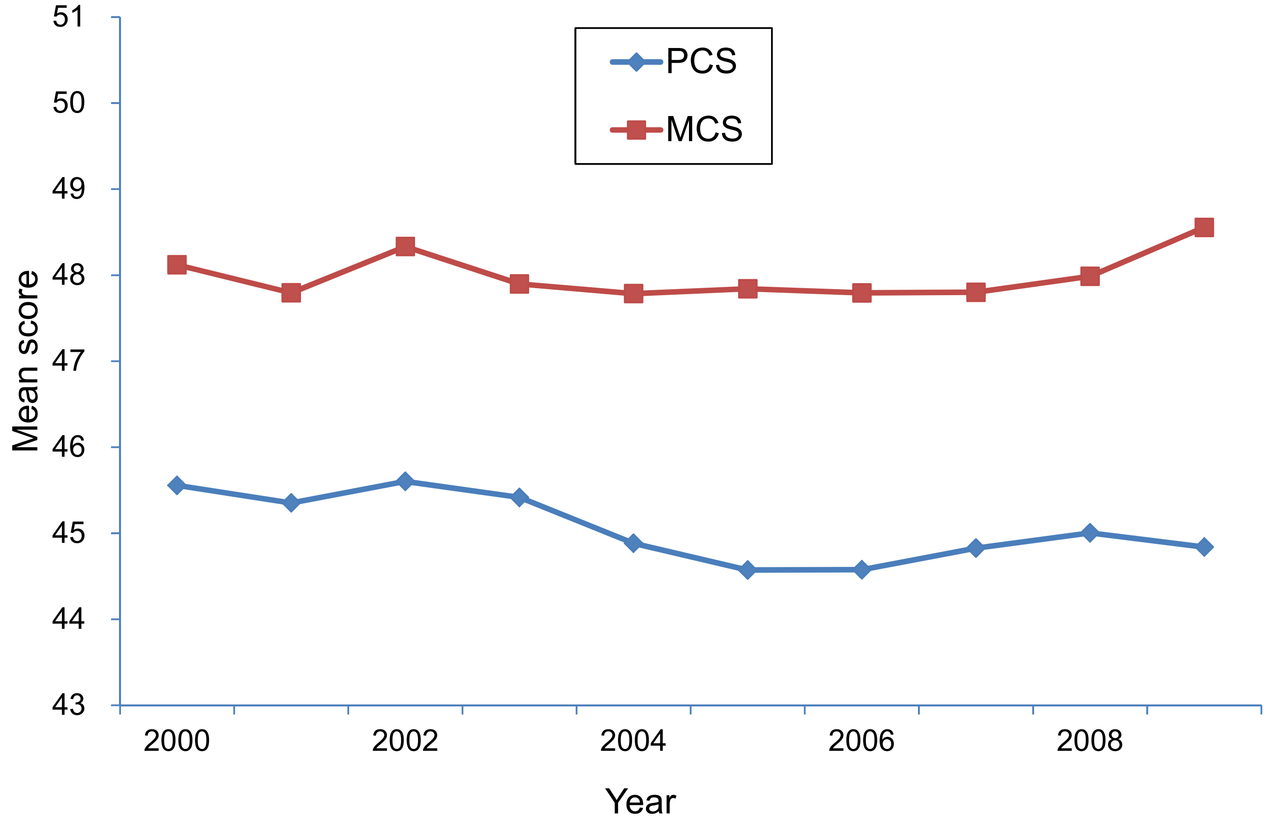


Figure 1. The Mean PCS and MCS Scores in Adults with Asthma Adjusting for Covariates, MEPS 2000-2009

The predicted annual mean scores estimated by using the Kleinman and Norton's direct substitution method[36] in linear regression model. Covariates; age, sex, race, ethnicity, insurance coverage, poverty status, education, marital status, residence area and Charlson Comorbidity Index Score.

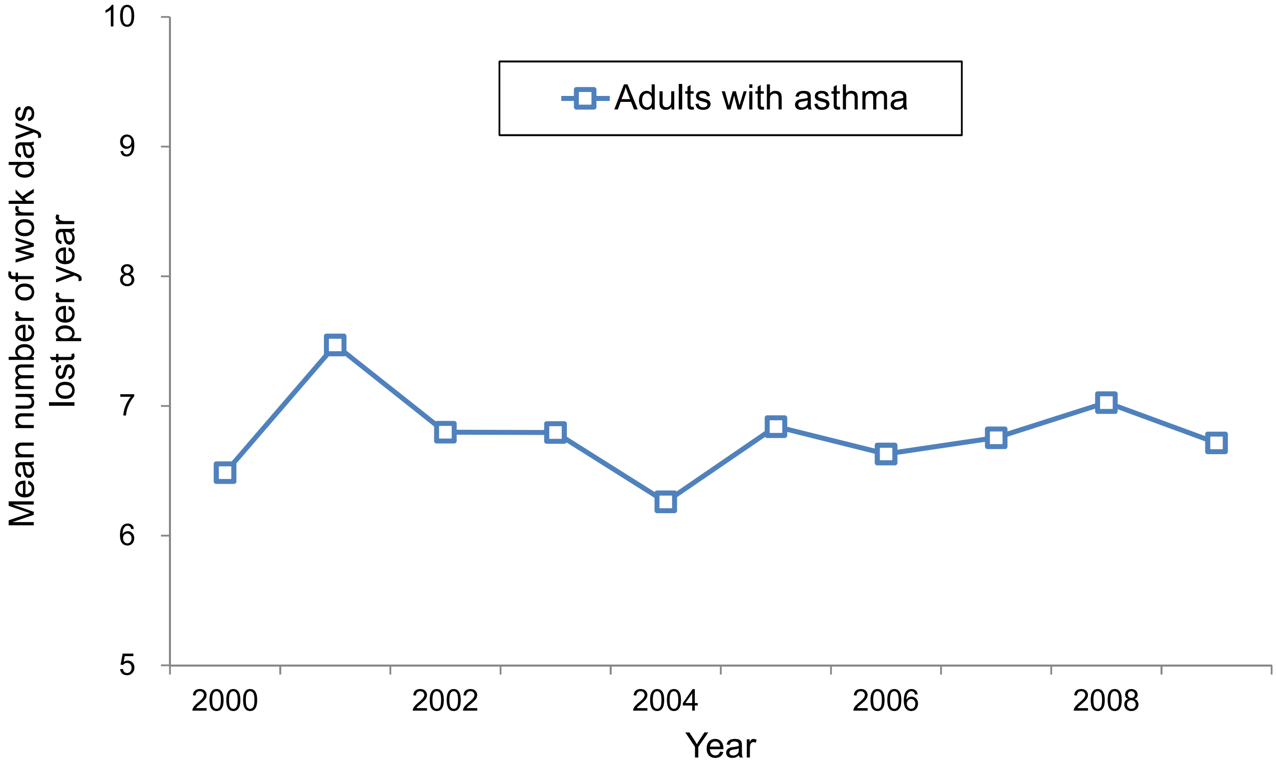


Figure 2. The Mean Number of Work Days Lost per Year in Adults with Asthma Adjusting for Covariates, MEPS 2000-2009

The predicted annual mean number of work days lost estimated by using the Kleinman and Norton's direct substitution method[36] in GLM model with gamma distribution and log link. Covariates; age, sex, race, ethnicity, insurance coverage, poverty status, education, marital status, residence area and Charlson Comorbidity Index Score.

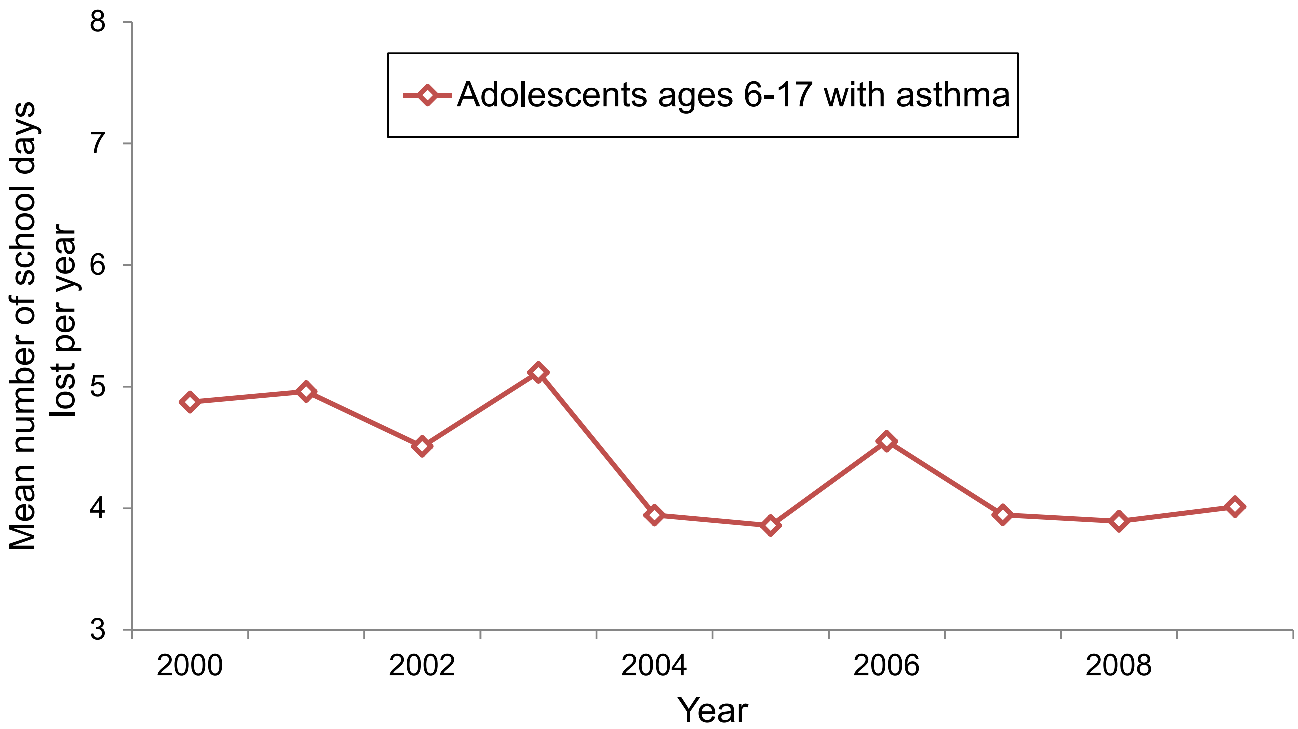
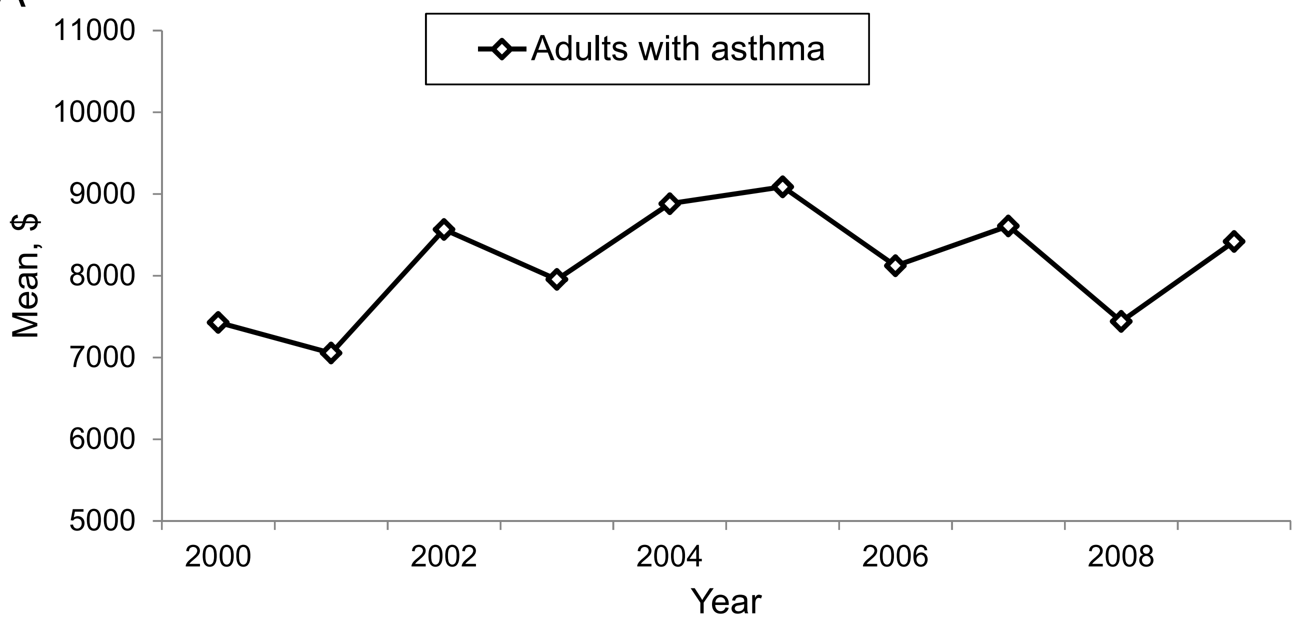


Figure 3. The Mean Number of School Days Lost per Year in Adolescents Ages 6-17 with Asthma, MEPS 2000-2009

The predicted annual mean number of school days lost estimated by using the Kleinman and Norton's direct substitution method[36] in GLM model with gamma distribution and log link. Covariates; age, sex, race, ethnicity, insurance coverage, poverty status, residence area and Pediatric Chronic Diseases Score.

A



B

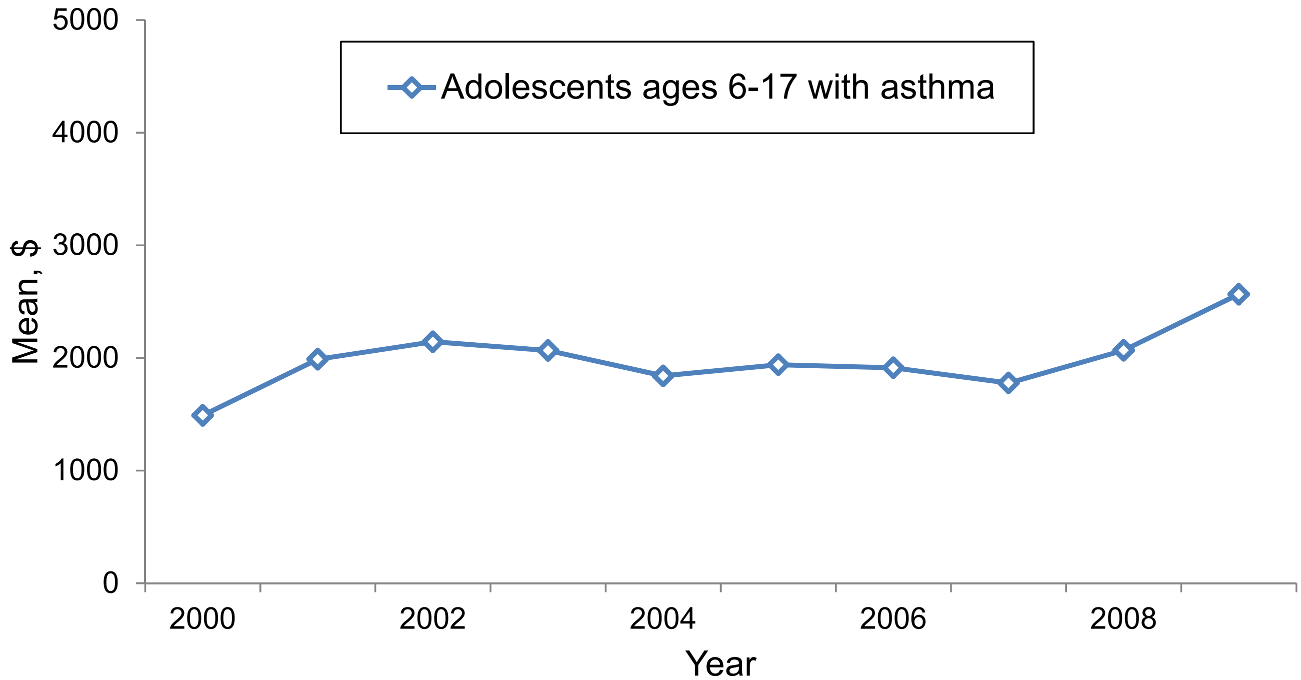


Figure 4. The Annual Average Medical Expenditures in Respondents with Asthma Adjusting for Relevant Covariates, MEPS 2000-2009 (A) Adults; (B) Adolescents Ages 6-17; (C) Children Ages 0-5

(Continued)

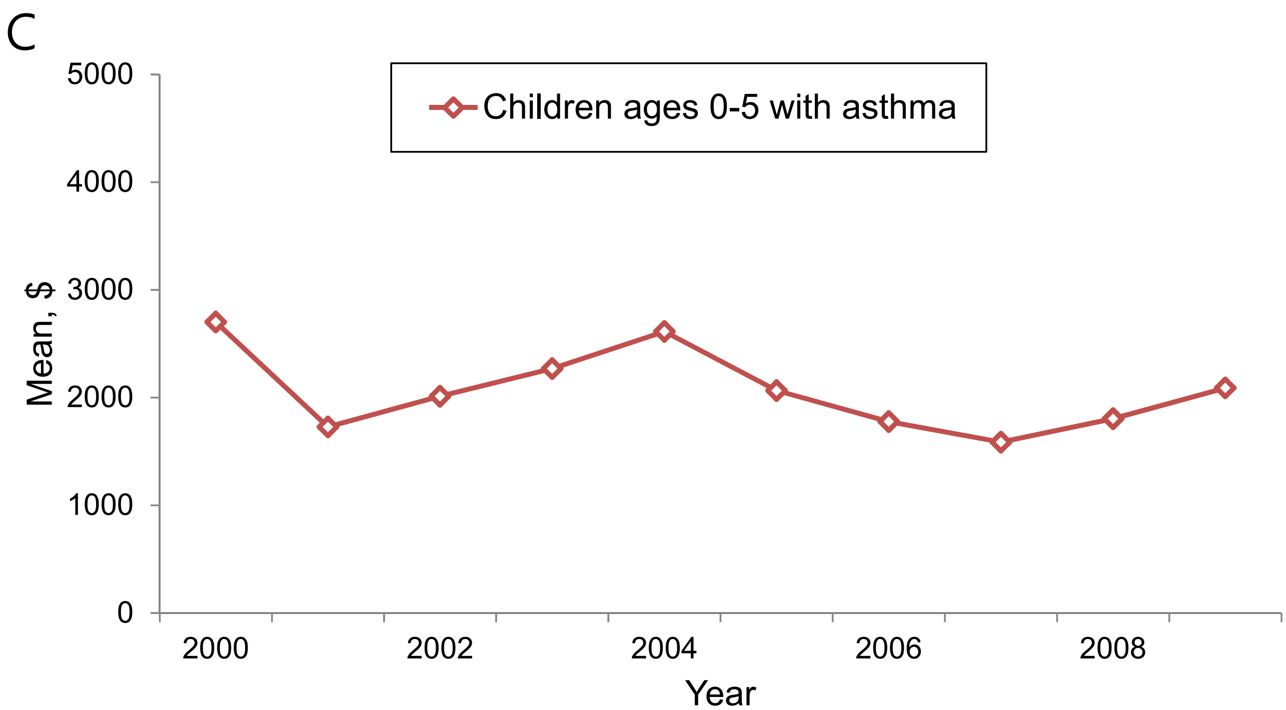
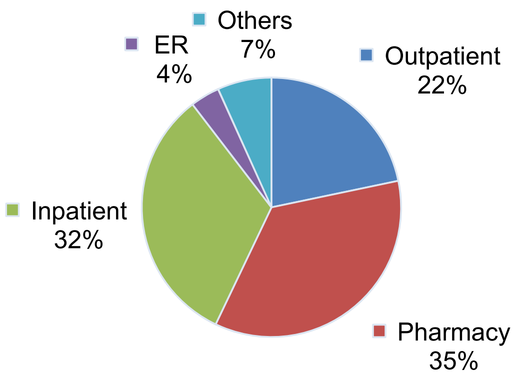


Figure 4. (Continued)

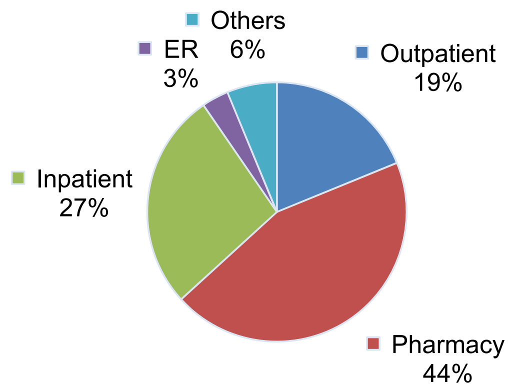
The predicted annual average medical expenditures estimated by using the Kleinman and Norton's direct substitution method[36] in GLM model with gamma distribution and log link. Covariates for adults; age, sex, race, ethnicity, insurance coverage, poverty status, education, marital status, residence area and Charlson Comorbidity Index Score. Covariates for pediatrics; age, sex, race, ethnicity, insurance coverage, poverty status, residence area and Pediatric Chronic Diseases Score.

All age groups

2000-2004
Total = $59.1 Billion

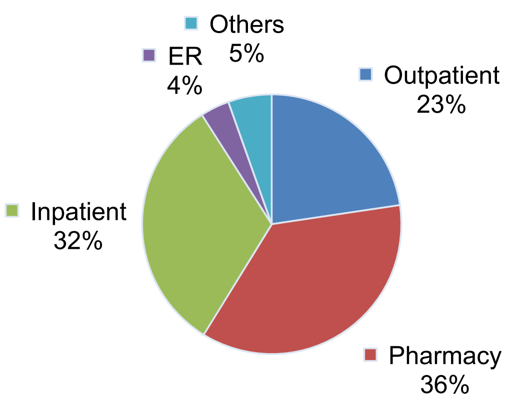


2005-2009
Total = $70.4 Billion



Adults

2000-2004
Total = $50.4 Billion



2005-2009
Total = $59.7 Billion

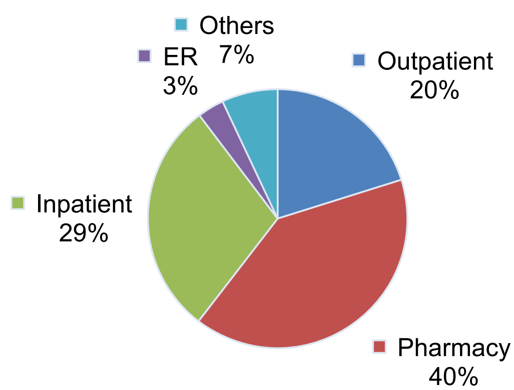
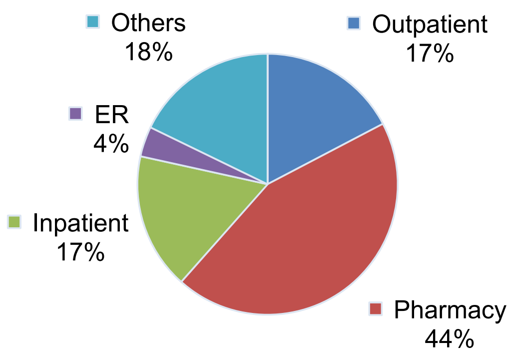


Figure 5. The 5 year average expenditures attributable to asthma and its composition by use type in 2000-2004 and 2005-2009 amongst all ages, adults, Adolescents Ages 6-17, and children Ages 0-5

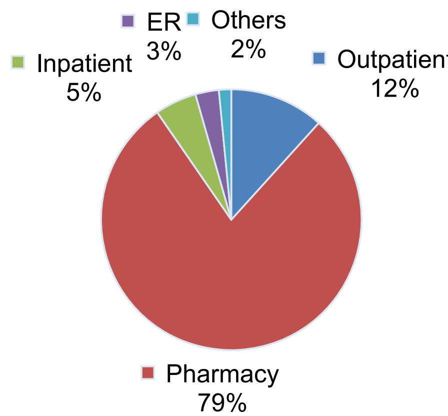
(Continued)

Adolescents ages 6-17

2000-2004
Total = $4.7 Billion

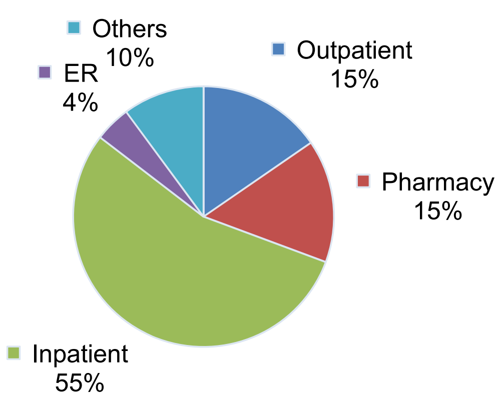


2005-2009
Total = $8.2 Billion



Children ages 0-5

2000-2004
Total = $4.1 Billion



2005-2009
Total = $2.5 Billion

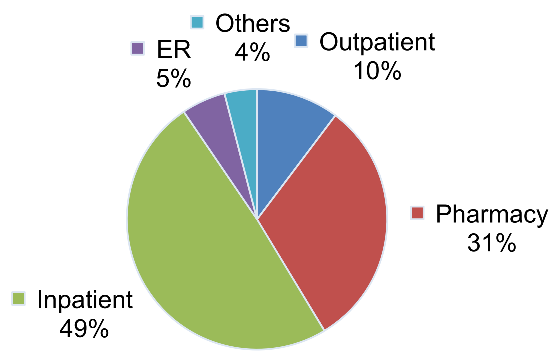


Figure 5. (Continued)
Each expenditure category from table 4-6 was aggregated into two five year average values. Total expenditures were calculated by adding up five year average expenditures of each category.

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