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ORIGINAL ARTICLE

Incremental Direct Expenditure of Treating Asthma in the United States

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Objective. There is a wide range in the estimates of cost of asthma that are available in the literature. Given the growing prevalence of asthma and its associated healthcare resource use in the United States (U.S.), it is important to obtain current and precise cost estimates attributable to asthma treatment. The objectives of this study were to estimate the incremental direct expenditures associated with asthma in the U.S. **Methods.** Retrospective analysis was conducted using the 2004 Medical Expenditure Panel Survey (MEPS) data that are representative of the civilian non-institutionalized population of the U.S. Asthma respondents were identified as those with *International Classification of Diseases-9-Clinical Modification (ICD-9-CM)* diagnosis codes for asthma in 2004 or those who had a self-report of having asthma in 2004. Incremental total expenditures and expenditures for various categories of resource use including physician office visits, emergency room visits, outpatient visits, inpatient visits, medications, and other medical visits associated with asthma were estimated separately in children (age <18 years) and in adults (age ≥18 years) using generalized linear regression models. The models were adjusted for covariates including age, gender, race, ethnicity, education, marital status (for age group ≥18 years), geographic region, insurance status, and comorbidities. **Results.** The prevalence of asthma among children and adults in 2004 was estimated at 8.7% (6.4 million persons) and 6.72% (14.8 million persons), respectively. The annual adjusted mean incremental total expenditure associated with asthma was \$1,004.6 (SE: \$326.1; $p = 0.002$) per person among children and was \$2,077.5 (SE: \$544.5; $p < 0.0001$) per person among adults, after adjusting for covariates. Prescription medications and physician office visits were the major drivers of total expenditures and constituted approximately 38% and 49% of the total incremental expenditures for asthma in children and adults, respectively. Inpatient visit expenditures were high in both age groups but were not significantly different from zero. **Conclusion.** Given the prevalence of asthma among U.S. children and adults and its associated incremental expenditures, the annual direct medical expenditure attributable to asthma treatment is estimated at approximately \$37.2 billion in 2007 U.S. dollars representing a significant portion of healthcare resource use in the U.S.

Keywords asthma, expenditures, cost, generalized linear model, MEPS, adults, children

INTRODUCTION

Asthma, a chronic respiratory disease with episodic symptoms, is one of the most commonly diagnosed diseases in the United States (U.S.) (1–8). Asthma is characterized by airway obstruction, and the main clinical manifestations of asthma include wheezing (caused by spasmodic contraction of the bronchi), coughing, chest tightness, and shortness of breath (1). Given its prevalence and bothersome symptoms, asthma imposes a growing burden on society in terms of morbidity, quality of life, and healthcare costs. The 2002 data from the National Health Interview Survey (NHIS) from the National Centers for Health Statistics has indicated that approximately 20 million people were affected by current asthma, nearly 6.1 million of whom were under 18 years of age (7, 8). According to the National Surveillance for Asthma in U.S. (1980–2004) report from Centers for Disease Control (CDC), the current asthma prevalence was 8.5% in children and 6.7% in adults during 2001–2003 (1). In a U.S. national probability sample survey conducted among individuals with current asthma in 1998, 10.7% of adults had mild intermittent disease and 77.3% of adults had moderate to severe persistent disease (2).

The treatment of asthma through disease management approach is vital in prevention of the disease and has immense public health implications (9). Although the appropriate use of medical therapy allows many asthmatics to control their

asthma, treatment of asthma is costly. Accurately estimating the cost of asthma treatment is important to evaluate potential cost-benefit arguments and treatment policies surrounding disease management for asthma.

Current literature suggests that the total healthcare costs of treating asthma are quite significant. However, there is a wide range in the estimates of cost of asthma that are available from the literature ranging from \$3.6 billion to \$30.8 billion, depending on the study methodology (6, 10–16). The type of methodology used to evaluate the cost of a disease can have a major impact on the findings, particularly in case of medical conditions with significant comorbidities. The incremental cost approach, that has become popular since the late 1990s (16–22), estimates the excess expenditures associated with a disease, by obtaining the difference between the expenditures associated with the treatment of patients diagnosed with the disease versus *similar* patients not diagnosed with the disease. Thus, the incremental expenditure methodology measures expenditures solely attributable to that particular disease, as it adjusts for differences in variables considered to have an impact on expenditures (17).

Healthcare expenditure data pose multiple challenges for multivariate modeling because of its peculiar distribution that includes restricted range (non-negative observations), occasionally excessive zero values and skewness (a few individuals with very high expenditures) (23). This creates a challenge for selecting an appropriate multivariate model specification to assess the incremental expenditure associated with a disease. In previous studies of asthma and other respiratory disorders that have used an incremental

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expenditure methodology, an ordinary least square (OLS) regression technique with log-transformation for the cost variables or a two-part model proposed by Duan and colleagues has been used (16, 23, 24). There is much discussion in the literature about the limitations of the log-transformed OLS technique due to the retransformation of cost from the log-scale to the original scale, which is required for the interpretation of results (24). This retransformation results in a potential under- or over-estimation of the predicted costs, even if the Duan smearing estimators are factored in (24). Recently, generalized linear models (GLM) have been proposed as efficient methods to model expenditure data (24). The GLM method directly models both the mean and variance functions on the original scale of the dependent variable, and the results can be interpreted directly without retransforming the dependent variable from the log to the original scale, providing efficient models for estimating incremental expenditures of diseases (24).

Estimation of the precise national expenditures for asthma treatment can provide useful information to guide clinicians and policymakers to implement improved asthma treatments, cost-effectiveness analysis, and cost-benefit studies. The specific study objectives were to (1) estimate the prevalence of asthma in the U.S. in 2004 and; (2) estimate incremental direct expenditures associated with asthma treatment. The prevalence of asthma and incremental direct expenditure was estimated for two subpopulations; children (age < 18 years) and adults (age $\geq$ 18 years).

STUDY DATA AND METHODS

Data Source

The 2004 Medical Expenditure Panel Survey (MEPS), a nationally representative sample of ambulatory population in the U.S. was used as the data source for the analyses. The MEPS is conducted annually since 1996 and is co-sponsored by the Agency for Healthcare Research and Quality (AHRQ) and the National Center for Health Statistics (NCHS). It provides nationally representative estimates of healthcare use, spending, sources of payment, and insurance coverage for the U.S. civilian non-institutionalized population. The 2004 MEPS includes 34,403 persons who responded to the core MEPS, representing a final response rate of 63.1 percent (25, 26). The survey is comprised of three components (25): the Household Component (HC), the Medical Provider Component (MPC) linked to the household survey, and the Insurance Component (IC). The HC provides data from individual households and their members, which is supplemented by data from their medical providers. For these analyses, the 2004 full year consolidated data file and the medical condition file was used. Variables used in the analyses included demographic variables (age, gender, race, ethnicity, insurance, region, education, marital status), medical conditions reported in 2004, prescription medications reported in 2004, and cost variables by category of service (total expenditures, prescribed medicines [RX] expenditures, emergency room [ER] visits expenditures, office-based medical provider visits [OBV] expenditures, inpatient visits [IP] expenditures, outpatient visits [OP] expenditures, and other medical [OM] expenditures). The MEPS-HC survey does not collect information on over-the-counter medications and therefore, only

the cost of prescribed medicines was included in this study (27–30).

Identification of Asthma Patients

Respondents with ICD-9-CM codes 493.xx in the medical conditions file were classified as asthma patients. The ICD-9-CM codes 493.xx include extrinsic asthma (unspecified, with status asthmaticus, or with acute exacerbation), intrinsic asthma (unspecified, with status asthmaticus, or with acute exacerbation), chronic obstructive asthma (unspecified, with status asthmaticus, or with acute exacerbation), exercise-induced bronchospasm, cough variant asthma, and asthma (unspecified, unspecified type with status asthmaticus, or unspecified with acute exacerbation). Respondents self-reporting asthma in 2004 full-year consolidated file were also considered as asthma patients. Remaining respondents were classified as non-asthma patients.

Stratification

Previous studies have demonstrated that the prevalence of asthma and the magnitude of healthcare expenditures associated with asthma treatment are different for adults versus children (1, 6, 10–16). In addition, differences exist in the comorbidities in asthmatic children versus asthmatic adults, which may impact the costs and resources use (1, 31). Thus, all analyses were conducted for two age strata: children age < 18 years and adults age $\geq$ 18 years.

Outcomes

All expenditures were defined as sum of all the direct payments for care provided during the year, including out-of-pocket payments and payments by private insurance, Medicare, Medicaid, and other sources (25). While MEPS provides variables reflecting charges for services received, charges include uncollected liability, bad debt, and charitable care and are not typically counted as expenditures. Seven dependent variables included for the analyses were total direct medical expenditures, RX expenditures, ER visit expenditures, OBV expenditures, IP visit expenditures, OP visit expenditures, and OM expenditures. Other medical expenditures included the portion of the total expenditures not classified in other six categories of services (such as home healthcare, dental care). All dollar amounts were adjusted to 2007 U.S. dollars using the medical care component of the Consumer Price Index (CPI) for 2007 (32).

Independent Variable and Covariates

The main independent variable of interest was asthma (yes/no), no asthma being a referent category. Covariates in the analyses included respondent's age, gender, race, ethnicity, education, insurance status, and geographic region. Marital status and the D'Hoore et al. adaptation of the Charlson comorbidity index (33) were additionally included in the regression models for the adult subpopulation. The 17 comorbidities considered in the D'Hoore adaptation of Charlson comorbidity index (33) were myocardial infarction, congestive heart failure, peripheral vascular disease, dementia, cerebrovascular disease, chronic pulmonary disease, connective tissue disease, ulcer disease, mild liver disease, diabetes, hemiplegia, moderate or severe renal disease, any

TABLE 1.—Comparison of demographic characteristics between asthma and non-asthma children.

Characteristics	Children (unweighted n = 10,320)				p value
	Asthma [†] (unweighted n = 997)		No asthma [†] (unweighted n = 9,323)		
	95% CI [‡]		95% CI [‡]		
Age in yrs [mean (SE)]	9.09 (0.23)	8.63–9.54	8.69 (0.08)	8.53–8.85	0.0949
Gender %					<0.0001
Male	60.91	56.42–65.22	50.06	48.77–51.35	
Female	39.09	34.78–43.58	49.94	48.65–51.23	
Race %					<0.0001
White	68.27	64.17–72.1	78.04	76.17–79.81	
Black	24.01	20.40–28.03	14.46	12.89–16.18	
Other	7.72	5.85–10.12	7.50	6.51–8.62	
Ethnicity %					0.0684
Hispanic	20.05	16.77–23.79	19.61	17.68–21.70	
non-Hispanic	79.95	76.21–83.23	80.39	78.30–82.32	
Education in yrs [mean (SE)]	3.10 (0.14)	2.81–3.38	3.04 (0.05)	2.95–3.14	0.7114
Insurance %					<0.0001
Uninsured	4.88	3.02–7.78	7.52	6.64–8.49	
Private	55.96	51.49–60.33	64.32	62.22–66.37	
Public	39.16	34.93–43.55	28.16	26.20–30.22	
Region %					0.1678
Northeast	19.25	15.55–23.58	17.57	15.86–19.43	
Midwest	19.24	15.33–23.87	22.21	20.12–24.45	
South	39.86	34.96–44.97	36.14	33.34–39.04	
West	21.65	17.70–26.22	24.08	21.39–26.99	
Number of medications (other than for asthma) [mean (SE)]	4.26 (0.38)	3.52–5.01	1.86 (0.07)	1.73–1.99	<0.0001

[‡]CI = Confidence Interval; SE = Standard Error.

[†]Stratified sample estimates projected to a population of 6,364,118 children (age <18 years) with asthma and 66,760,347 children with no asthma. The n's for independent variables varied from 9,121 to 9,809 due to missing values and excluding observations with zero weights.

tumor, leukemia, lymphoma, moderate or severe liver disease, and metastatic tumor. For the children subpopulation, number of medications (including refills) was used as a proxy for comorbidities (34), as previous studies have shown that number of distinct medication is a valid index for comorbidity adjustment (35). Since asthma was the condition of interest and the goal of the comorbidity index was to assess comorbidities, diagnoses codes for asthma and medications related to asthma were excluded from the computation of respective indexes. For the models of adult subpopulation, ICD-9-CM codes for asthma (493.xx) were excluded in the Charlson comorbidity index computation. In the models of children subpopulation, any medications related to asthma were excluded from the index. Medications related to asthma were identified using Multum Lexicon therapeutic classification of respiratory agents (36, 37).

Statistical Analysis

The demographic and clinical characteristics of asthma versus non-asthma patients were compared using the Chi-squared test and Student's *t* test.

To assess the incremental expenditures associated with asthma, within each age strata, separate multivariate regression models were developed for the total expenditures and for expenditures for each service category. To select the appropriate model specifications within generalized linear models (GLM), models with different variance function, i.e., GLM with Gaussian variance function, GLM with Poisson variance function, GLM with negative binomial variance function, and GLM with gamma variance function were evaluated. Based on the assessment of model fit using a modified Park's test (24, 38, 39) and comparison of the squared correlation coefficient between the predicted cost (obtained from each model) and the observed cost, a log-link GLM with Poisson variance function was selected for all the models as it resulted in the

best-fitting model to estimate the incremental expenditure of asthma.

In all the analyses, the results were projected to the U.S. civilian non-institutionalized population using the sampling weights provided by MEPS. All analyses were conducted using SAS version 9.1.3 (SAS Institute, Cary, NC) (40), and STATA version 10.0 (STATA Corporation, College Station, TX) (41). An *a priori* alpha value of 0.05 was used for all statistical tests. Because of the complex sample design of the MEPS, Taylor series variance estimation method was used to calculate sampling errors of estimates and 95% confidence intervals (CI).

RESULTS

Among the total respondents (n = 34,403), there were 10,320 children (age <18 years) and 24,083 adults (age ≥18 years). Of the total respondents, only 31,934 respondents with 9,121 children and 22,813 adults had non-missing values and positive weights on all of the independent variables and thus included in the final analyses.

Asthma Prevalence

The prevalence of asthma in the U.S. in 2004 among children was estimated to be 8.7%, i.e., 6,364,118 persons, (95% CI: 7.97% to 9.5%) and among adults was estimated to be 6.72%, i.e., 14,815,251 persons, (95% CI: 6.32% to 7.15%). The remaining 91.3% (66,646,755) children and 93.28% (205,587,286) adults were considered to have no asthma.

Characteristics of the Study Sample

Tables 1 and Table 2 compares the demographic characteristics of study patients with and without asthma for the children and adult subpopulations, respectively. Among children with asthma, the mean ± standard error (SE) age was

TABLE 2.—Comparison of demographic characteristics between asthma and non-asthma adults.

Characteristics	Adults (unweighted n = 24,083)				p value
	Asthma [†] (unweighted n = 1,616)		No Asthma [†] (unweighted n = 22,467)		
	95% CI [‡]		95% CI [‡]		
Age in yrs [mean (SE)]	45.85 (0.57)	44.73–46.96	45.75 (0.22)	45.31–46.19	0.8623
Gender %					<0.0001
Male	33.63	30.94–36.42	49.41	48.82–50.01	
Female	66.37	63.58–69.06	50.59	49.99–51.18	
Race %					0.5794
White	81.10	78.54–83.41	81.69	80.30–83.01	
Black	12.39	10.58–14.47	11.45	10.39–12.59	
Other	6.51	5.13–8.22	6.86	6.11–7.70	
Ethnicity %					0.0001
Hispanic	9.16	7.57–11.04	12.88	11.74–14.12	
non-Hispanic	90.84	88.96–92.43	87.12	85.88–88.26	
Education %					0.0026
No Degree	18.22	16.37–20.22	17.65	16.78–18.56	
GED [#]	6.67	5.32–8.35	3.91	3.59–4.25	
High School diploma	43.8	40.87–46.78	46.58	45.57–47.60	
Bachelor's degree	17.15	14.26–20.49	16.36	15.44–17.32	
Master's degree	5.95	4.57–7.72	6.31	5.82–6.83	
Doctorate degree	1.79	1.14–2.81	1.81	1.55–2.11	
Other degree	6.41	5.20–7.88	7.38	6.85–7.96	
Insurance %					<0.0001
Uninsured	9.50	7.93–11.34	14.34	13.53–15.18	
Private	70.36	67.50–73.07	71.75	70.59–72.89	
Public	20.14	17.92–22.56	13.91	13.19–14.66	
Region %					0.0349
Northeast	22.13	19.27–25.28	18.78	17.36–20.29	
Midwest	22.79	19.54–26.40	22.30	20.60–24.09	
South	32.09	28.90–35.45	36.14	34.02–38.32	
West	22.99	19.97–26.32	22.78	20.95–24.72	
Marital Status %					<0.0001
Presently married	48.15	44.91–51.40	55.52	54.42–56.61	
Presently not married	51.85	48.60–55.09	44.48	43.39–45.58	
Charlson Comorbidity Index Score [mean (SE)]	0.55 (0.03)	0.48–0.61	0.33 (0.01)	0.31–0.34	<0.0001
Charlson Comorbidity Index Score %					<0.0001
Zero comorbidity	76.06	73.38–78.54	85.15	84.47–85.79	
One comorbidity	7.21	5.84–8.88	3.34	3.07–3.63	
Two comorbidities	10.43	8.86–12.24	8.64	8.18–9.13	
Three or more comorbidities	6.30	5.07–7.80	2.87	2.57–3.21	

[‡]CI = Confidence Interval; SE = Standard Error; [#]GED = Graduation Equivalency Degree;

[†]Stratified sample estimates projected to a population of 14,815,251 adults (age ≥ 18 years) with asthma and 205,587,286 adults with no asthma.

The n's for independent variables varied from 22,815 to 22,928 due to missing values and excluding observations with zero weights.

9.09 ± 0.23 years and the mean ± SE education 3.10 ± 0.14 years. Compared to non-asthmatics, children with asthma were less likely to be white (68.27% versus 78.04%; $p < 0.0001$), more likely to be male (60.91% versus 50.06%; $p < 0.0001$), more likely to be insured (95.12% versus 92.48%; $p < 0.0001$), and use higher numbers of prescription drugs, including refills (4.26 versus 1.86; $p < 0.0001$). The proportion of Hispanics among children with asthma (20.05%) were comparable to children without asthma (19.61%; $p = 0.0684$). Approximately 40% of asthmatic children resided in the southern region of the U.S. versus 36.14% of children without asthma ($p = 0.1678$).

Among adults with asthma, 81.10% were whites with mean ± SE age of 45.85 ± 0.57 years. Compared to non-asthmatics, adults with asthma were more likely to be female (66.37% versus 50.59%; $p < 0.0001$), less likely to be Hispanics (9.16% versus 12.88%; $p = 0.0001$), less likely to have an education higher than graduation equivalency degree (75.10% versus 78.44%; $p = 0.0026$), more likely to be insured (90.50% versus 85.66%; $p < 0.0001$), less likely to reside in the southern region of the U.S. (32.3% versus 36.2%; $p = 0.0349$), and less likely to be presently married (48.15% versus 55.52%; $p < 0.0001$). In addition, adults with asthma were more likely to have two or more comor-

bidity compared to adults without asthma (16.73% versus 11.51%; $p < 0.0001$). The mean ± SE Charlson comorbidity index score for adults with asthma was significantly higher at 0.55 ± 0.03 compared to adults without asthma at 0.33 ± 0.01. Among the 17 comorbidities used in the D'Hoore et al. adaptation of Charlson comorbidity index (33), adults with asthma were more likely to have diabetes (11.48% versus 7.01%; $p < 0.0001$), chronic pulmonary disease (3.89% versus 0.70%; $p < 0.0001$), connective tissue disease (2.61% versus 0.79%; $p < 0.0001$), congestive heart failure (2.34% versus 0.90%; $p < 0.0001$), myocardial infarction (1.56% versus 0.78%; $p = 0.0451$), and mild liver disease (0.94% versus 0.46%; $p = 0.0289$) compared with non-asthmatics (Table 3).

Incremental Total Direct Medical Expenditure Associated with Asthma

After adjusting for age, gender, race, ethnicity, education, insurance, region, and number of medications, children with asthma had 92% higher total expenditures than those without asthma (parameter estimate: 1.92; $p < 0.0001$) (Table 4). Likewise, after adjusting for age, gender, race, ethnicity, education, marital status, insurance, region, and Charlson comorbidity index, adults with asthma had 66% higher total

TABLE 3.—Comparison of Charlson Comorbidity Index clinical conditions between asthma and non-asthma adults.

Comorbidities	Adults (unweighted n = 24,083)				p value
	Asthma [†] % (unweighted n = 1,616)		No asthma [†] % (unweighted n = 22,467)		
	95% CI [‡]		95% CI [‡]		
Myocardial infarction	1.55	0.97–2.48	0.80	0.67–0.95	0.0108
Congestive heart failure	2.34	1.71–3.19	0.90	0.75–1.08	<0.0001
Peripheral vascular disease	1.95	1.28–2.97	1.26	1.07–1.48	0.0518
Dementia	0.24	0.08–0.68	0.27	0.20–0.36	0.8601
Cerebrovascular disease	0.80	0.44–1.45	0.52	0.40–0.69	0.1835
Chronic pulmonary disease (excluding asthma)	3.89	2.90–5.19	0.70	0.59–0.85	<0.0001
Connective tissue disease	2.61	1.85–3.66	0.79	0.65–0.94	<0.0001
Ulcer disease	0.69	0.37–1.28	0.52	0.42–0.66	0.4053
Mild liver disease	0.94	0.51–1.73	0.46	0.36–0.58	0.0289
Hemiplegia	0.92	0.46–1.84	0.91	0.78–1.07	0.9660
Moderate or severe renal disease	0.82	0.35–1.90	0.35	0.25–0.50	0.0707
Diabetes	11.48	9.71–13.53	7.01	6.59–7.45	<0.0001
Any tumor	3.53	2.65–4.69	3.22	2.90–3.58	0.5339
Leukemia	0.21	0.07–0.69	0.08	0.04–0.14	0.1423
Lymphoma	0.11	0.03–0.42	0.09	0.06–0.15	0.7878
Moderate or severe liver disease	0.29	0.11–0.72	0.22	0.16–0.32	0.6200
Metastatic solid tumor	0.75	0.42–1.36	0.39	0.30–0.51	0.0516

[‡]CI = Confidence Interval; [†]Stratified sample estimates projected to a population of 14,815,251 adults (age ≥ 18 years) with asthma and 205,587,286 adults with no asthma.

expenditure than those without asthma (parameter estimate: 1.66; $p < 0.0001$).

Table 5 describes the results from individual regression models of incremental expenditure associated with asthma for overall total and each category of service. For the children subpopulation, the adjusted annual mean incremental total expenditure associated with asthma was \$1,004.6 (SE: \$326.1; $p = 0.002$) per person. Physician office visits accounted for the largest proportion of the total expenditures estimated at \$205.2 (SE: \$73.5; $p = 0.005$), followed by

medications at \$180.6 (SE: \$30.1; $p < 0.0001$). Inpatient visit expenditures were high but were not significantly different from zero (\$326.0, SE: \$204.2; $p = 0.110$). Prescription medications and physician office visits constituted approximately 38% of the total incremental medical expenditure associated with asthma among children.

For the adult subpopulation, the adjusted annual mean incremental total expenditure associated with asthma was \$2,077.5 (SE: \$544.5; $p < 0.0001$) per person. Medications accounted for the largest proportion of the total expenditures

TABLE 4.—Results of regression analysis to estimate the incremental direct total expenditure of treating asthma.

Parameter [§]	Adults (unweighted n = 22,813) [†]			Children (unweighted n = 9,121) [†]		
	Parameter Estimate	95% CI ^{##}	p value	Parameter Estimate	95% CI ^{##}	p value
Asthma	1.66	1.35–2.03**	<0.0001	1.92	1.41–2.61**	<0.0001
No Asthma [‡]	1.0	1.0	—	1.0	1.0	—
Age	1.02	1.02–1.02	<0.0001	0.91	0.86–0.96**	0.001
Male	0.82	0.75–0.90**	<0.0001	0.95	0.80–1.14	0.586
Female [‡]	1.0	1.0	—	1.0	1.0	—
Black	0.87	0.77–0.97**	0.023	0.59	0.46–0.75**	<0.0001
Other	0.65	0.56–0.76**	<0.0001	0.64	0.50–0.82**	<0.0001
White [‡]	1.0	1.0	—	1.0	1.0	—
Hispanic	0.69	0.60–0.79**	<0.0001	0.76	0.56–1.04	0.091
Non-hispanic [‡]	1.0	1.0	—	1.0	1.0	—
Education (in yrs)	NA	NA	—	1.14	1.06–1.23**	<0.0001
GED [#]	1.06	0.89–1.28	0.500	NA	NA	—
High School Diploma	1.09	0.98–1.22	0.100	NA	NA	—
Bachelor's Degree	1.08	0.88–1.31	0.461	NA	NA	—
Master's Degree	1.13	0.93–1.37	0.207	NA	NA	—
Doctorate Degree	0.82	0.67–1.01	0.064	NA	NA	—
Other Degree	1.07	0.93–1.24	0.345	NA	NA	—
No Degree [‡]	1.0	1.0	—	NA	NA	—
Uninsured	0.34	0.27–0.41**	<0.0001	0.67	0.46–0.99**	0.042
Private	0.96	0.86–1.07	0.426	1.32	1.08–1.60**	0.006
Public [‡]	1.0	1.0	—	1.0	1.0	—
Midwest	1.01	0.85–1.19	0.918	1.02	0.76–1.37s	0.870
South	0.88	0.75–1.02	0.095	0.82	0.60–1.11s	0.201
West	1.01	0.82–1.25	0.918	0.89	0.63–1.25s	0.490
Northeast [‡]	1.0	1.0	—	1.0	1.0	—
Presently Married	1.02	0.94–1.12	0.606	NA	NA	—
Presently Not Married [‡]	1.0	1.0	—	NA	NA	—
Charlson Comorbidity Index Score	1.33	1.29–1.37**	<.0001	NA	NA	—
Number of medications (other than for asthma)	NA	NA	—	1.04	1.03–1.05**	<0.0001

[#]GED = graduation equivalency degree; ^{##}95%CI = 95% confidence interval; **significant at $\alpha = 0.05$; NA = not applicable; [‡]referent category.

[§]Results based on generalized linear model with loglink and Poisson distribution.

[†]Stratified sample estimates projected to a population of 219,540,350 adults and 68,079,585 children.

TABLE 5.—Results of regression analysis to estimate the incremental expenditure of asthma by service categories.

Service category [†]	Adults (unweighted n = 22,813) [‡]			Children (unweighted n = 9,121) [‡]		
	Incremental estimate	SE	p value	Incremental estimate	SE	p value
Inpatient visits	\$327.9	215.1	0.128	\$326.5	204.2	0.110
Outpatient visits	\$75.9	41.6	0.068	\$41.9	35.6	0.239
Emergency room visits	\$54.7	18.3	0.003	\$31.7	15.0	0.035
Prescription medications	\$643.6	53.2	<0.0001	\$180.6	30.1	<0.0001
Office-based medical visits	\$383.0	90.2	<0.0001	\$205.2	73.5	0.005
Other medical expenses (including home health visits)	\$604.8	428.6	0.158	\$14.8	39.6	0.708
Total expenditure	\$2,077.5	544.5	<0.0001	\$1,004.6	326.1	0.002

SE = standard error.

[†]Generalized linear model with loglink and Poisson distribution (only asthma estimate is reported); total medical event expenditure = intercept + asthma + age + gender + race + ethnicity + education + insurance + region + marital status (not applicable for children subpopulation) + Charlson comorbidity score (not applicable for children subpopulation) + number of non-asthma medications (not applicable for adult subpopulation) + error.

[‡]Stratified sample estimates projected to a population of 219,540,350 adults and 68,079,585 children.

estimated at \$643.6 (SE: \$53.2; $p < 0.0001$), followed by physician office visits at \$383.0 (SE: \$90.2; $p < 0.0001$). These two categories constituted approximately one half of the total incremental medical expenditure associated with asthma among adults. Although statistically non-significant, other medical expenses and inpatient visits accounted for a high proportion of the total incremental medical expenditure associated with asthma at \$604.8 (SE: \$428.6; $p = 0.158$) and \$327.9 (SE: \$215.1; $p = 0.128$), respectively. For both children and adult subpopulations, emergency room visit expenditures accounted for only a small proportion of the total incremental medical expenditure associated with asthma at \$31.7 (SE: \$15.0; $p = 0.035$) and \$54.7 (SE: \$18.3; $p = 0.003$), respectively.

DISCUSSION

This study estimated the prevalence of asthma in the U.S. in 2004 and provides robust estimates of the national annual incremental direct expenditure associated with asthma treatment for both age strata (age < 18 years and age ≥ 18 years). The prevalence of asthma in the U.S. in 2004 among children and adult was 8.7% and 6.72%, respectively. This estimate is comparable to the current asthma prevalence of 8.5% in children and 6.7% in adults during 2001–2003 reported by the CDC in the National Surveillance for Asthma in U.S. (1980–2004) report (1). Consistent with national findings, this study also found a higher prevalence of asthma in women for age group ≥ 18 years, while the prevalence was higher in men for age group < 18 years (7, 8).

Using estimates from this study, the national annual direct medical expenditure associated with asthma treatment among children in the U.S. is at \$6.39 billion in 2007 US dollars. This was obtained by multiplying the per-person total incremental medical expenditure associated with asthma among children (\$1,004.6) with the prevalence of asthma (6.4 million persons). Similarly, the estimated national annual direct medical expenditure associated with asthma among adults was at \$30.77 billion, obtained by multiplying the per-person total incremental medical expenditure associated with asthma among adults (\$2,077.5) with the prevalence of asthma (14.8 million persons). The total direct annual expenditure associated with asthma is estimated at \$37.17 billion in 2007 U.S. dollars. This estimate is relatively higher than the previously reported cost of asthma estimates that range from \$3.6 billion to \$30.8 billion (6, 10–16). Weiss et al. and Smith

et al. reported that the estimated direct cost of asthma was \$3.6 billion in 1990 and \$5.1 in 1994, respectively, where as Yelin et al. calculated that the direct cost of asthma at \$30.8 billion in 1996 (10, 11, 16).

The differences in the cost of asthma obtained in our study compared to previous studies could possibly be owing to the high, although steady, prevalence of asthma (1, 7, 8, 42) and the methodological approach used to estimate incremental cost associated with asthma. For example, two studies by Weiss et al. (11, 12) may not be comparable to this study because they used charge data as opposed to payment or expenditure data used in current study to derive cost estimates. As previously discussed, the present study uses an incremental expenditure methodology along with a robust statistical technique to model cost data that are typically skewed (24). Further, the analyses are conducted using the MEPS data, which is nationally representative of the ambulatory population in the U.S.

Prescription medicines and office-based visits comprised approximately 38% of the total expenditure associated with asthma among children; whereas the above two service categories accounted for approximately 49% of the total expenditure of asthma treatment among adults. This finding is comparable to most previous studies in which prescription medications and office-based visits were found to constitute 40% to 68% of the overall treatment expenditure among all persons with asthma (13, 16, 43). According to the National Heart Lung and Blood Institute (NHLBI), prescription medicines and office-based visits accounted for 68% of the total direct cost of asthma treatment, although it is unclear how these estimates were derived (44). However, in an older study conducted by Weiss et al. (11), inpatient services accounted for largest single share of approximately US\$1.6 billion of the total direct expenditures for asthma in 1990. This shift in distribution of asthma expenditures between categories of medical service, i.e., from inpatient services to prescription medications, over the period of about two decades could be due to the availability of more expensive pharmaceuticals that result in better management of the disease, which potentially results in fewer inpatient visits.

There are several limitations to this study. First, some covariates, such as history and severity of asthma among responding individuals, were not included because of the unavailability of these variables in the MEPS data. Second, as the focus of the present study was on estimating the direct incremental expenditures associated with asthma, indirect costs

were not considered. A more detailed analysis capturing direct, as well as indirect expenditures such as, the expenditures associated with lost productivity (missed workdays and/or school days), unpaid care providers, premature death, or pain and suffering would provide a more precise overall economic burden associated with current asthma. Third, we identified asthma patients based on medical conditions reported by respondents in the MEPS. The reported medical conditions were coded by professional coders to fully-specified ICD-9-CM codes. However, it is likely that some individuals who presented with milder or intermittent symptoms of asthma did not receive a diagnosis for asthma. This might have resulted in under-reporting of the prevalence of asthma. These respondents with milder or intermittent symptoms of asthma would then be classified as non-asthmatics resulting in underestimating the incremental expenditures associated with asthma.

Accurate assessment of expenditures associated with a disease is important to establish cost-effectiveness of pharmaceuticals and interventions to manage the disease. For example, results of the national incremental direct expenditure associated with asthma from this study could be included in the cost-benefit analyses to justify expenditures for asthma disease management programs. Further, the study provides information on the distribution of the expenditures across various categories of medical service. Given that the bulk of asthma expenditures are due to prescription expenditures and office-based visits, disease management programs would benefit from targeting interventions to effectively manage these categories of healthcare resource utilization for both children and adults. Past studies on asthma disease management programs have demonstrated their potential to decrease in healthcare resource utilization (45–48). For example, Kelly et al. demonstrated that an asthma self-management education program combined with clinical care lead to significant reduction in emergency room visits and hospitalizations with economic savings of \$476 and \$1,044 per child per year respectively, for intervention versus control group among Medicaid children with asthma in 1995 (46). Similarly, in a recent (2002–2004) prospective, randomized clinical trial among high-morbidity pediatric population, it was found that an emergency department-based follow-up clinic visit resulted in significantly fewer mean unscheduled visits for asthma care during the 6-month follow-up period (1.39 vs. 2.34; RR = 0.60 95% CI: 0.46–0.77) (47). Another randomized controlled trial of an inner-city social worker-based education program also found cost reduction of \$2,509 per child with one or more hospital visits at baseline, \$1,050 per child with two or more unscheduled visits at baseline, and \$220 per child in subgroup with more than 50% of days with asthma symptoms at baseline by using the education program (48).

Given the high expenditures associated with asthma and the evidence from the literature on the potential for cost savings using educational interventions among asthma patients, there are possible avenues for decreasing expenditures on the treatment of asthma. However, to achieve such cost savings, more public health efforts are needed to educate children (including parents) and adults on the disease condition, medications use including compliance and adherence, the need for follow-up care, and the importance of avoiding known disease “triggers.” Thus, collaborative efforts among health

education professionals (including school health professionals) and primary care providers are essential for asthma prevention. Further, effectiveness studies would be needed to ensure that the preventive strategies are cost-effective.

In summary, the present study provides estimates of annual direct incremental expenditures associated with asthma treatment in the U.S. and confirms the substantial economic burden that asthma imposes on the society. The prevalence of asthma in 2004 among children and adults was estimated at 8.7% and 6.72%, respectively. Asthma in both subpopulations, children and adults, is associated with a significant increase in direct medical expenditures, with the overall annual direct medical expenditure associated with asthma estimated at approximately \$37.2 billion in 2007 U.S. dollars. More aggressive asthma management strategies with cost-effective prescription medications might reduce the need for subsequent office-based physician visits and inpatient visits thereby decreasing expenditures associated with asthma. Future research estimating incremental indirect costs associated with asthma, cost savings associated with the control of asthma, and its major comorbidities would be of interest. In addition, disparities in insurance coverage on overall asthma resource use and incremental health care expenditures could be further explored.

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