

ECONOMICS

The relationship between asthma, asthma control and economic outcomes in the United StatesPatrick W. Sullivan, PhD¹, Julia F. Slejko, PhD², Vahram H. Ghushchyan, PhD³, Brandon Sucher, PharmD¹, Denise R. Globe, PhD^{4†}, Shao-Lee Lin, MD, PhD^{4‡}, and Gary Globe, PhD, MBA⁴¹Regis University School of Pharmacy, Denver, CO, ²University of Washington, Seattle, WA, ³University of Colorado Denver, Denver, CO, and⁴Amgen, Inc., Thousand Oaks, CA**Abstract**

Objective: Asthma, a serious chronic lung disease affecting approximately 26 million Americans, remains clinical and economic burdens on the healthcare system. Although associations between uncontrolled asthma and poor health outcomes is known, the extent of this impact of uncontrolled asthma on economic outcomes in the United States (US) is unknown. We sought to determine the relationship between asthma, asthma control and economic outcomes in the US. **Methods:** The 2008–2010 Medical Expenditure Panel Surveys were used to estimate the impact of uncontrolled asthma (asthma-related emergency department [ED] visit, use of >3 canisters of quick-relief inhaler in past 3 months or asthma attack in past 12 months) on medical expenditures, utilization and productivity. Estimates were generated using multivariate regression controlling for sociodemographics and comorbidity. **Results:** Medical expenditures attributable to asthma were up to \$4423 greater for those with markers of uncontrolled asthma compared with those who did not have asthma. Frequency of hospital discharges were up to 4.6-fold greater for those with uncontrolled asthma than those without asthma ($p < 0.01$), while all others with asthma did not have significantly more discharges. ED visits were up to 1.8-fold greater for those with uncontrolled asthma compared with those without asthma ($p < 0.01$). Productivity was significantly ($p < 0.01$) decreased (more likely to be unemployed, more days absent from work and more activity limitations) for those with uncontrolled asthma. **Conclusions:** In recent national data, individuals with asthma and markers of uncontrolled asthma had higher medical expenditures, greater utilization and decreased productivity.

Keywords

Cost analyses, economic burden, medical expenditures, productivity, uncontrolled asthma, utilization outcomes

History

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Introduction

The burden of asthma is high with 8.4% of the United States (US) population affected by the disease and \$18 billion in additional adult health expenditures due to the disease [1,2]. The extent of the burden of asthma is associated with the level of severity and control as classified in the Expert Panel Report 3: Guidelines for the Diagnosis and Treatment of Asthma (EPR-3) [3]. Asthma control, defined by EPR-3 as the extent to which asthma therapy minimizes asthma symptoms and meets therapy goals, comprises two domains: impairment (asthma-related symptoms and limitations experienced by the patient) and risk (likelihood of future exacerbations) [3].

One of several accepted methods of measuring asthma control is the administration of patient- and physician-completed questionnaires such as the Asthma Control

Questionnaire (ACQ), the Asthma Therapy Assessment Questionnaire (ATAQ) or the Asthma Control Test [4]. Studies assessing outcomes associated with asthma control with these instruments found that uncontrolled asthma significantly impacts patients' healthcare expenditures, utilization and productivity. The The Epidemiology and Natural History of Asthma: Outcomes and Treatment Regimens (TENOR) study showed that individuals with poorly controlled asthma, as assessed by the ATAQ, were more likely to have hospitalizations, emergency room visits and corticosteroid burst treatments [5]. Another US study, using ATAQ-assessed control measures and associated utilization in a HMO population, found that routine and acute asthma care utilization increased with worse asthma control [6]. The 2006 US National Health and Wellness Survey (NHWS) found that individuals with uncontrolled asthma had significantly higher healthcare utilization (emergency department [ED], hospital and provider) and a significantly greater loss of work productivity [7]. However, these studies may not reflect the current general asthma population; the TENOR study was based on a cohort of severe or difficult-to-treat asthma patients, the Vollmer et al. study was collected over 10 years

†Currently with Allergan Inc., Irvine, CA

‡Currently with Gilead Sciences, Inc., Foster City, CA

Correspondence: Patrick W. Sullivan, PhD, Regis University School of Pharmacy, 3333 Regis Blvd., H-28, Denver, CO 80221, USA. Tel: (303) 625-1298. Fax: (303) 625-1298. E-mail: psullivan@regis.edu

ago and was based on a managed care organization sample and the Williams et al. study was based on an internet panel survey. Furthermore, granular sociodemographic and medication data were not collected for the sample, and medical expenditures were not estimated. Therefore, corroboration of these results in a more established panel survey with more granular data would be useful.

Several methods exist for estimating asthma control using such retrospective data, including the use of the Healthcare Effectiveness Data and Information Set to measure asthma quality-of-care, which is based on the proportion of patients who have prescriptions for long-term control medication [8]. Both the ratio of controller-to-total asthma medication ratio (weighted and unweighted) and the quantity of short-acting beta₂-agonist (SABA) inhalers have been used as measures of asthma control [9–11] and can be used to assess two domains of asthma control: symptom control reflected by SABA canister dispensing and exacerbations reflected by hospitalizations, ED visits and/or oral steroid use [9]. Asthma control based on SABA use was defined by a four-level scale in which the use of >12 canisters in a one-year period was associated with poorest control. It was concluded that the number of SABA prescriptions filled in a one-year period is an indicator of long-term asthma control. Furthermore, when the four aforementioned surrogate markers were compared for their ability to predict asthma exacerbations, the largest effect size for predicting reduced emergency hospital care was the number of SABA canisters dispensed [11]. Providing further support for the use of claims data for surrogates for asthma control, Firoozi et al. validated two database indexes using dispensed asthma medications and medical services obtained measuring asthma control and asthma severity against pulmonary function test results of patients with asthma. They demonstrated that these indexes of asthma control correlated well with lung function measures such as FEV₁, which is a reliable index reflecting asthma control not readily available in healthcare databases [12]. Although the level of asthma control in these studies of small populations was assessed using well-established instruments, the use of these instruments in a large nationally representative population sample has not been done to date. The use of data from very broad populations is needed to assess outcomes at a societal level.

The current evidence suggests that identifying individuals with poorly controlled asthma may be an important step in ameliorating skyrocketing medical expenditures. Recent research provides feasible methods for identifying individuals with poorly controlled asthma. Many studies have examined the economic burden of asthma generally [13–18] and some have studied asthma severity or control and costs in European or limited US populations [19–22], but no studies have described this particular issue in the general US population of individuals with asthma. It is not clear to what degree utilization, expenditures and productivity are affected by asthma and asthma control on a national level, rather than in just privately insured or specialty clinic populations. It would be useful to examine asthma at the broader societal level, such that the full spectrum of the population and disease severity is represented. It may also be useful to understand the characteristics and general burden of those with uncontrolled asthma in the US population.

To date, no existing data set has administered a validated asthma control instrument, such as the ACQ or ATAQ, to a nationally representative sample; however, markers of control can be used to assess patient data in these samples. While a wealth of evidence exists describing asthma outcomes in a clinical setting, an observational, real-world study to examine asthma control and outcomes important to patients and policy researchers, such as healthcare utilization, expenditures and productivity, is needed. Understanding the outcomes associated with control, as well as understanding the characteristics of patients with uncontrolled asthma are both important steps in the analysis of asthma burden in the US.

The objective of this study is to use established surrogate markers of asthma control to explore the relationship between asthma, asthma control and economic outcomes (utilization, direct costs and productivity loss) in a nationally representative sample.

Methods

Data source

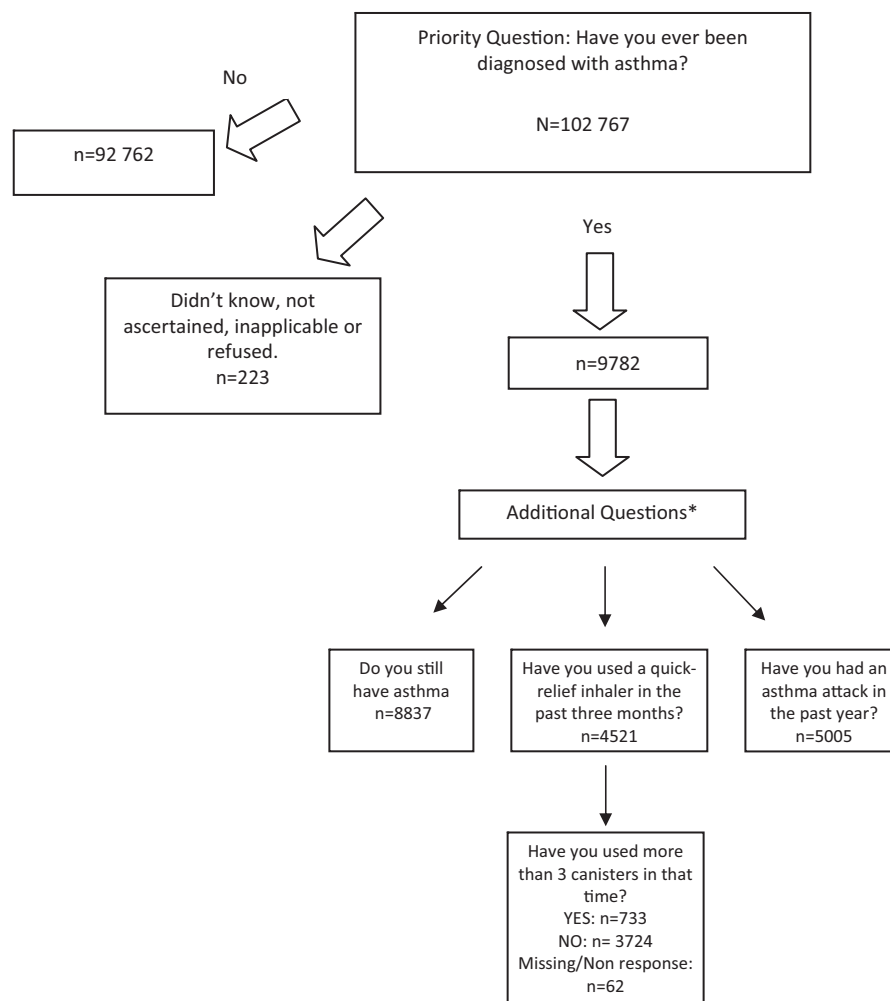
The Medical Expenditure Panel Survey (MEPS) is a nationally representative survey of the US civilian non-institutionalized population and includes a self-reported Household Component (HC) and a provider-reported Medical Provider Component (MPC) [23–25]. In each of three rounds per year for two years in an overlapping panel design, respondents completed a battery of questions for the HC on demographic and socioeconomic characteristics, health conditions, insurance status, smoking status, utilization and cost of healthcare services, employment, missed work days and more detailed questions on certain “priority conditions”. Data on utilization and expenditures of office- and hospital-based care, home health care, dental services, vision aids and prescribed medicines were obtained by a follow-back survey that collects detailed information from a sample of pharmacies and healthcare providers used by MEPS respondents. The MPC supplements and validates information on medical utilization, pharmacy events and expenditures. Medical conditions reported by individuals or the MPC were mapped to 693 three-digit International Classification of Diseases, Ninth Revision (ICD-9) codes by professional coders. Further details on MEPS are available at www.meps.ahrq.gov.

The analytic sample combined MEPS 2008, 2009 and 2010 annual data. These survey years were chosen because they were the most recently available data at the time of analysis and ensured an adequate sample size. Medical condition-level data were merged to the individual data to form an individual-level analytic sample. The MEPS sample design includes stratification, clustering, multiple stages of selection and disproportionate sampling. MEPS sampling weights incorporate adjustment for the complex sample design and reflect survey non-response and population totals from the Current Population Survey.

Asthma-specific questions in MEPS

Asthma is considered a “priority condition” in MEPS, which results in more detailed questions (Priority conditions are identified by Agency for Healthcare Research and Quality as

Figure 1. Results of asthma priority questions in MEPS.



*Responses of "didn't know, not ascertained, inapplicable or refused" are not shown.

medical conditions that have a significant impact on the health of the country either in prevalence or individual burden). As such, there are several asthma-specific questions given to respondents that were used in this research. All persons surveyed were asked if they had ever been diagnosed with asthma (Figure 1). Those responding affirmatively were asked additional follow-up questions: (1) "do you still have asthma?"; (2) "have you had an episode of asthma or asthma attack in the past 12 months?"; and (3) "have you used the kind of prescription inhaler that you breathe in through your mouth that gives quick relief from asthma symptoms?" Those who answered affirmatively were subsequently asked whether they had used more than three canisters of this type of inhaler in the past 3 months.

Sociodemographic characteristics

A number of sociodemographic characteristics were used in the analysis as independent variables to control for confounding based on and assumed theoretical relationship with the dependent variable. Education was measured as high school not completed, high school completed, other degree, Bachelor's degree and Master's or PhD. Family income was categorized based on the federal poverty level as poor (<100%), near poor (100%–124%), low income (125%–199%), middle income (200%–399%) or high income

(≥400%) based on the survey year, federal poverty threshold. Race was classified as white, black, American Indian/Alaska native, Asian, native Hawaiian/Pacific islander or multiple races reported. Ethnicity was categorized as Hispanic or non-Hispanic. Current smoking status (yes/no) and physical activity (yes/no) was measured as whether or not the respondent spent a half hour or more in moderate to vigorous activity at least three times a week. Finally, a variable was constructed from all reported ICD-9 codes to capture chronic comorbidity burden. The total number of reported chronic conditions minus asthma were added together to create a summary variable representing the number of chronic conditions [2].

Independent variables

Individuals were classified based on markers of uncontrolled asthma: asthma attacks in the last year, use of quick-relief inhalers (>3 canisters), ED visits over the previous year and combinations thereof. In total, three markers of asthma control ((1) asthma-related ED visit, (2) asthma attack and (3) use of >3 canisters of quick-relief inhaler in past 3 months) were established and explored. These independent variables were included in the regressions as dichotomous variables with the reference group being individuals who do not have asthma. For example, the following three variables

were created for asthma attack: (1) did have an asthma attack in the previous 12 months and has been diagnosed with asthma; (2) did not have an asthma attack in the previous 12 months and has been diagnosed with asthma; and (3) has not been diagnosed with asthma (reference group).

Outcomes (dependent) variables

Dependent variables included the following: (1) annual medical expenditures (sum of direct payments for care provided during the year, including out-of-pocket payments and payments by private insurance, Medicaid, Medicare and other sources), (2) annual utilization (office-based visits, hospital visits and prescriptions reported on an annual basis) and (3) productivity (employment, annual wages, missed work days, days spent sick in bed and activity limitations and inability). For productivity measurements, individuals were classified as employed if they were employed at any time during the year. Annual wages included all self-reported income from salary and wages. Wages were adjusted to be expressed in \$US 2011 using the Bureau of Labor Statistics annual increase.

Statistical analysis

All analyses (unadjusted summary statistics and multivariate regressions) incorporated MEPS person-level weights and variance adjustment variables (strata and probability sampling unit) and are thus nationally representative and statistically robust. Descriptive statistics were used to explore associations of asthma subgroups (controlled and uncontrolled) with all outcomes and potential confounding factors, including education, poverty category, insurance coverage, race, ethnicity, age, gender, smoking status and physical activity. Multivariable analyses adjusting for potential confounders used the methods described below. All analyses were performed using STATA 12 (StataCorp LP; College Station, TX).

Medical expenditures

Medical expenditure analysis used the Generalized Linear Models (GLM) regression method. The logarithm of the expected value of annual all-cause and asthma-specific annual total healthcare, medical and pharmacy expenditures were regressed on asthma control markers controlling for age, sex, region, race, ethnicity, education, poverty category, smoking status, insurance status and chronic comorbidity burden. The dependent variable was assumed to follow a Gamma distribution. Expenditure data were inflated to \$US 2011 as a common year using the Medical Care component of the Consumer Price Index [26].

Utilization

Healthcare utilization was estimated using negative binomial regression. Annual all-cause and asthma-specific office-based visits, outpatient visits, ED visits, hospital discharges and number of prescriptions were regressed on asthma control markers, controlling for age, sex, region, race, ethnicity, education, poverty category, smoking status, insurance status and chronic comorbidity burden.

Productivity

Several variables were developed to understand the association of asthma and asthma control with productivity. The number of missed work days and the number of days spent sick in bed per year were used to measure absenteeism. These outcomes were treated as count variables. Negative binomial regression was used to regress the number of missed work days and sick days on asthma control markers, controlling for age, sex, region, race, ethnicity, education and chronic comorbidity burden. Logistic regression was used to regress the dichotomous variables (unemployed for the full year, activity limitation and activity inability) on asthma control markers controlling for age, sex, region, race, ethnicity, education and chronic comorbidity burden. Annual wage was used as a monetary measure of lost productivity. A GLM model with logarithmic transformation of annual wages and Gamma distribution was developed. Wage data were inflated to \$US 2011. In this analysis, a GLM was used to model the association between asthma control and annual wage controlling for age, sex, region, race, ethnicity, education and chronic comorbidity burden. To avoid potential endogeneity bias, smoking, income level and type of insurance were not used as control variables in the productivity models.

Results

Markers of asthma control

Of the 102 767 adults in MEPS (2008–2010), 9782 individuals (10%) had a diagnosis for asthma (Table 1). Of those individuals who reported having been diagnosed with asthma, 5005 individuals (51%) had an asthma attack in the previous 12-month period, 733 individuals (15%) used >3 canisters of quick relief inhaler in the previous 3 months and 271 individuals (6%) had an asthma-related ED visit.

Of the individuals who used >3 canisters of quick-relief inhaler in the previous 3 months, 11% (82/733 individuals) had an ED visit related to asthma, compared with 5% (189/3724) of those who used ≤3 canisters (Table 2). Likewise, 77% (558/729 individuals) of those who used >3 canisters of quick-relief inhaler in the past 3 months had an asthma attack, compared with 69% (2548/3716) of those who used ≤3 canisters (Table 2). This suggests that those subjects with a high use of quick-relief inhaler (>3 canisters in the previous 3 months), a marker for uncontrolled asthma, were slightly more likely to have asthma-related ED visit or asthma attacks, which are direct markers of uncontrolled asthma.

All unadjusted measures of cost, utilization and productivity were worse for subjects with markers of uncontrolled asthma (>3 canisters of quick relief inhaler in past 3 months; asthma attack in the previous year) than those with asthma without a marker of uncontrolled asthma (>3 canisters of quick relief inhaler in past 3 months; asthma attack in the previous year; Tables 3–5). Subjects with markers of uncontrolled asthma (>3 canisters of quick relief inhaler in past 3 months; asthma attack in the previous year) had increased inpatient and outpatient visits, ED visits and prescriptions (Table 3). Likewise, all unadjusted measures of expenditures were higher for subjects with markers of uncontrolled asthma (>3 canisters of quick relief inhaler in past 3 months; asthma

Table 1. Demographics and baseline characteristics for individuals with asthma (MEPS 2008–2010).

	Asthma diagnosis				<i>p</i> Value
	No		Yes		
	<i>N</i>	Mean (SE) or % (SE)	<i>N</i>	Mean (SE) or % (SE)	
Sample, %	92 762	90.5 (0.2)	9782	9.5 (0.2)	
Number of years with asthma, mean (SE)	—	—	6360	16.3 (0.3)	
Number of chronic comorbidities, mean (SE)	92 762	1.4 (0.0)	9782	2.3 (0.1)	0.00
Sex (male), % (SE)	44 859	49.7 (0.2)	4258	43.5 (0.8)	0.00
Age (years), mean (SE)	92 762	37.4 (0.2)	9782	35.5 (0.4)	0.00
Age ≤17	26 056	24.0 (0.3)	3302	27.6 (0.7)	0.00
Age 18–34	21 951	22.9 (0.4)	2172	23.4 (0.7)	0.49
Age 35–49	18 761	20.4 (0.2)	1745	19.2 (0.6)	0.08
Age 50–64	15 697	19.3 (0.3)	1612	18.6 (0.6)	0.27
Age 65–79	7484	9.5 (0.2)	730	8.5 (0.5)	0.03
Age ≥80	2813	3.9 (0.2)	221	2.8 (0.3)	0.00
Region, % (SE)					
Northeast	13 535	17.8 (0.6)	1744	19.8 (1.0)	0.01
Midwest	18 478	21.7 (0.6)	2128	22.1 (0.9)	0.63
South	35 253	37.0 (0.8)	3606	35.6 (1.2)	0.14
West	25 496	23.5 (0.7)	2304	22.5 (1.0)	0.22
Insurance, % (SE)					
Private insurance	50 733	66.0 (0.6)	4928	62.2 (1.1)	0.00
Public insurance	25 408	20.3 (0.4)	3723	27.4 (0.9)	0.00
Uninsured	16 621	13.7 (0.4)	1131	10.4 (0.5)	0.00
Race, %					
White	64 862	80.3 (0.7)	6193	76.8 (1.0)	0.00
Black	18 333	12.1 (0.6)	2706	16.1 (0.8)	0.00
American Indian	978	0.8 (0.2)	134	1.3 (0.4)	0.00
Asian	6312	4.7 (0.4)	376	2.6 (0.3)	0.00
Hawaiian	343	0.3 (0.1)	34	0.3 (0.1)	0.79
Other	1934	1.8 (0.1)	339	2.9 (0.3)	0.00
Hispanic	26 949	16.4 (0.8)	2 044	12.7 (0.9)	0.00
Non-Hispanic	65 813	83.6 (0.8)	7738	87.4 (0.9)	0.00
Education, %					
No degree	16 327	13.0 (0.3)	1679	14.0 (0.5)	0.05
High school	31 991	37.4 (0.4)	3131	34.9 (0.8)	0.00
BA or other	14 187	19.6 (0.3)	1377	18.5 (0.7)	0.09
MA or PhD	4598	6.9 (0.3)	395	6.5 (0.5)	0.35
Income, %					
Poor	19 543	13.8 (0.4)	2778	19.4 (0.8)	0.00
Near poor	6062	4.6 (0.1)	674	5.1 (0.4)	0.13
Low income	15 669	13.9 (0.3)	1606	14.1 (0.5)	0.72
Mid income	27 469	30.8 (0.4)	2631	29.3 (0.8)	0.04
High income	24 019	36.9 (0.6)	2093	32.1 (1.0)	0.00
Physical activity	36 758	59.5 (0.5)	3241	53.2 (1.0)	0.00
Smoking (yes), %	10 427	13.0 (0.3)	1376	15.9 (0.6)	0.00

Table 2. Quick-relief inhaler use, asthma-related ED visits and asthma attacks.

	Frequency of quick-relief inhaler		Total <i>n</i> (%)
	≤3 canisters in past 3 months <i>n</i> (%)	>3 canisters in the past 3 months <i>n</i> (%)	
Asthma-related ED visit	<i>N</i> = 3724	<i>N</i> = 733	<i>N</i> = 4457
No	3535 (95%)	651 (89%)	4186 (94%)
Yes	189 (5%)	82 (11%)	271 (6%)
Asthma attack	<i>N</i> = 3716	<i>N</i> = 729	<i>N</i> = 4445
No	1168 (31%)	171 (23%)	1339 (30%)
Yes	2548 (69%)	558 (77%)	3106 (70%)

attack in the previous year; Table 4). Subjects with markers of uncontrolled asthma (>3 canisters of quick relief inhaler in past 3 months; asthma attack in the previous year) were also more likely to be unemployed, missed more work days,

experienced more days sick in bed, have lower wages and were more likely to have activity limitations and inability (Table 5). Similarly, those who still had asthma and those who had previously been diagnosed with asthma exhibited worse outcomes compared to those who have never been diagnosed with asthma.

Multivariable regression results

Table 6 presents the results of several regression analyses. The outcome variables included medical expenditures, utilization, productivity and activity limitations. The independent variables included asthma attack in the previous 12 months, frequency of quick-relief inhaler use and asthma-related ED visits. In each regression, individuals without a diagnosis of asthma were the reference group. For example, medical expenditures were regressed on the two dichotomous variables associated with asthma attack in the previous 12 months

Table 3. Unadjusted annual utilization by asthma status and indicators of asthma control.

	Asthma diagnosis				Frequency of quick-relief inhaler	
	No <i>n</i> = 92 762 Mean (SE)	Yes <i>n</i> = 9782 Mean (SE)	Still asthma <i>n</i> = 8837 Mean (SE)	Asthma attack <i>n</i> = 5005 Mean (SE)	≤3 canisters in past 3 months <i>n</i> = 3724 Mean (SE)	>3 canisters in the past 3 months <i>n</i> = 733 Mean (SE)
<i>All cause</i>						
Number of visits						
Office based	4.8 (0.1)	7.4 (0.2)	7.6 (0.2)	8.0 (0.3)	8.2 (0.3)	10.5 (0.6)
Outpatient	0.4 (0.0)	0.6 (0.1)	0.7 (0.1)	0.7 (0.1)	0.9 (0.1)	1.2 (0.4)
ED	0.2 (0.0)	0.3 (0.0)	0.3 (0.0)	0.4 (0.0)	0.4 (0.0)	0.6 (0.1)
Home health provider	1.5 (0.1)	2.7 (0.3)	2.9 (0.3)	3.6 (0.5)	2.8 (0.5)	8.9 (1.6)
Inpatient visits	0.1 (0.0)	0.2 (0.0)	0.2 (0.0)	0.2 (0.0)	0.2 (0.0)	0.3 (0.0)
Length of inpatient stay	0.5 (0.0)	0.8 (0.1)	0.8 (0.1)	0.9 (0.1)	0.8 (0.1)	1.8 (0.2)
Number of prescribed medications	9.6 (0.2)	18.8 (0.5)	19.8 (0.5)	22.0 (0.8)	22.3 (0.8)	44.3 (2.0)
<i>Asthma-related</i>						
Number of visits						
Office based	–	0.6 (0.0)	0.7 (0.0)	0.9 (0.1)	0.8 (0.1)	1.7 (0.2)
Outpatient visits	–	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.1 (0.0)
ED	–	0.0 (0.0)	0.0 (0.0)	0.1 (0.0)	0.0 (0.0)	0.1 (0.0)
Home health provider	–	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.1 (0.0)
Inpatient	–	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.1 (0.0)
Length of inpatient stay	–	0.0 (0.0)	0.0 (0.0)	0.1 (0.0)	0.0 (0.0)	0.3 (0.1)
Number of prescribed medications	–	1.4 (0.0)	1.5 (0.1)	1.8 (0.1)	2.0 (0.1)	3.7 (0.2)

Table 4. Unadjusted annual medical expenditures by asthma status and indicators of asthma control.

	Asthma diagnosis				Frequency of quick-relief Inhaler	
	No <i>n</i> = 92 762 Mean (SE)	Yes <i>n</i> = 9782 Mean (SE)	Still asthma <i>n</i> = 8837 Mean (SE)	Asthma attack <i>n</i> = 5005 Mean (SE)	≤3 canisters in past 3 months <i>n</i> = 3724 Mean (SE)	>3 canisters in the past 3 months <i>n</i> = 733 Mean (SE)
<i>All cause expenditures (2011 dollars)</i>						
Total health care	\$3961 (69)	\$6354 (237)	\$6550 (242)	\$6898 (323)	\$6877 (332)	\$12 515 (1148)
Prescribed medications	\$799 (17)	\$1700 (55)	\$1791 (61)	\$1934 (84)	\$1990 (82)	\$4293 (286)
Medical, excluding Rx	\$3161 (62)	\$4655 (212)	\$4759 (212)	\$4964 (279)	\$4887 (293)	\$8222 (1003)
Office based	\$956 (18)	\$1342 (46)	\$1384 (51)	\$1439 (63)	\$1476 (78)	\$1873 (171)
Outpatient	\$364 (15)	\$510 (38)	\$527 (41)	\$497 (53)	\$603 (75)	\$709 (182)
ED	\$158 (6)	\$261 (15)	\$269 (16)	\$343 (26)	\$317 (32)	\$547 (72)
Inpatient	\$1179 (43)	\$1863 (163)	\$1876 (153)	\$1955 (189)	\$1801 (200)	\$3780 (767)
Home health care	\$151 (14)	\$258 (33)	\$276 (37)	\$307 (54)	\$223 (51)	\$794 (170)
Other	\$31 (2)	\$54 (5)	\$59 (6)	\$59 (8)	\$67 (9)	\$133 (35)
<i>Asthma-related expenditures (2011 dollars)</i>						
Total health care	–	\$573 (26)	\$634 (28)	\$824 (45)	\$769 (43)	\$1986 (145)
Prescribed medications	–	\$389 (18)	\$431 (19)	\$513 (29)	\$544 (29)	\$1225 (83)
Medical, excluding Rx	–	\$184 (16)	\$203 (18)	\$312 (3)	\$225 (28)	\$761 (114)
Office based	–	\$82 (8)	\$91 (9)	\$124 (13)	\$107 (14)	\$265 (60)
Outpatient	–	\$6 (1)	\$6 (1)	\$10 (2)	\$9 (2)	\$22 (9)
ED	–	\$24 (3)	\$26 (3)	\$46 (6)	\$31 (6)	\$117 (29)
Inpatient	–	\$66 (11)	\$73 (13)	\$124 (22)	\$68 (21)	\$325 (73)
Home health care	–	\$5 (2)	\$6 (2)	\$8 (3)	\$10 (4)	\$31 (19)

(yes or no; reference group - those without a diagnosis of asthma), controlling for age, gender, race, income, ethnicity, education, smoking, insurance coverage and comorbidities. After controlling for covariates, individuals with asthma or markers of uncontrolled asthma had higher medical expenditures, greater utilization and worse productivity than those who have never been diagnosed with asthma (Table 6). After controlling for all sociodemographic characteristics and comorbidity, the per-person annual medical expenditures for individuals who had an asthma attack in the previous year

were \$1399 greater than those who have not been diagnosed with asthma; medical expenditures were \$771 greater for those who have been diagnosed with asthma but did not have an asthma attack compared to those who have not been diagnosed with asthma. Similarly, medical expenditures were \$2862 greater for those who used >3 canisters compared to those without asthma and \$724 greater for those who used ≤3 canisters compared to those who do not have asthma.

Measures of utilization showed similar trends. The rates of hospital discharges for individuals with an asthma attack or

Table 5. Unadjusted productivity by asthma status and indicators of asthma control Subpopulation of individuals 18–65 years old.

	Asthma diagnosis				Frequency of quick-relief inhaler	
	No	Yes	Still asthma	Asthma attack	≤3 canisters in past 3 months	>3 canisters in the past 3 months
Employed respondents						
Days missed work due to illness injury						
N	33 322	2624	2270	1204	975	124
Mean (SE)	3.2 (0.1)	6.7 (0.5)	6.9 (0.5)	8.1 (0.8)	7.8 (0.9)	12.4 (3.1)
Days missed work and stayed in bed due to illness injury						
N	33 249	2615	2262	1199	970	124
Mean (SE)	1.5 (0.0)	3.9 (0.3)	3.8 (0.3)	4.9 (0.5)	4.4 (0.6)	7.8 (2.1)
Wage (2011 dollars)						
N	42 156	3626	3165	1701	1326	190
Mean (SE)	\$33 731 (265)	\$31 759 (569)	\$31 698 (597)	\$31 204 (904)	\$31 855 (853)	\$31 520 (1866)
All respondents						
Unemployed for full year						
N	11 725	1752	1639	1019	728	235
Mean (SE)	0.2 (0.0)	0.3 (0.0)	0.3 (0.0)	0.3 (0.0)	0.3 (0.0)	0.5 (0.0)
Total days stayed in bed due to illness injury						
N	53 236	5139	4585	2567	1964	388
Mean (SE)	3.9 (0.1)	10.0 (0.6)	10.6 (0.6)	14.0 (1.0)	13.19 (1.2)	20.4 (2.5)
Wage (2011 dollars)						
N	56 409	5529	4918	2766	2091	425
Mean (SE)	\$32 623	\$ 27 280 (762)	\$26 331 (774)	\$25 112 (1120)	\$25 768 (1095)	\$19 839 (2359)
Activity Limitations (all ages)						
N	5116	1223	1146	738	520	234
Mean (SE)	0.1 (0.0)	0.1 (0.0)	0.1 (0.0)	0.2 (0.0)	0.2 (0.0)	0.4 (0.0)
Activity inability						
N	3290	787	743	482	333	169
Mean (SE)	0.0 (0.0)	0.1 (0.0)	0.1 (0.0)	0.1 (0.0)	0.1 (0.0)	0.3 (0.0)

Table 6. Medical expenditure, utilization and productivity measures of asthma by asthma control.

	Asthma Attack in the last 12 months		Frequency of quick-relief inhaler			Asthma-related ED visits	
	Yes	No	≤3 canisters	>3 canisters	No inhaler	No	Yes
Medical expenditures (total expenditures \$2011) ^{a,b}	1398.91 ^c	770.60 ^c	1186.70 ^c	2861.98 ^c	724.12 ^c	–	–
Utilization (all ages) ^b							
Office-based visits (IRR) ^a	1.3 ^c	1.2 ^c	1.3 ^c	1.5 ^c	1.2 ^c	–	–
Outpatient visits (IRR) ^a	1.3 ^d	1.0	1.4 ^d	1.1	1.0	–	–
ED visits (IRR) ^a	1.7 ^c	1.1	1.6 ^c	1.8 ^c	1.3 ^c	–	–
Hospital discharges (IRR) ^a	4.6 ^c	1.1	3.5 ^c	4.1 ^c	1.8	–	–
Inpatient visits (IRR) ^a	1.3 ^c	1.1	1.2	1.7 ^c	1.1	–	–
Prescriptions (IRR) ^a	2.4 ^c	1.7 ^c	2.4 ^c	3.8 ^c	1.5 ^c	–	–
Productivity ^c (ages 18–64)							
Odds of unemployment ^f	1.4 ^c	1.1	1.3 ^d	2.0 ^c	1.1	1.2 ^c	1.8 ^d
Absent from work (IRR) ^f	1.7 ^c	1.4 ^d	1.6 ^c	2.2 ^c	1.5 ^c	1.5 ^c	2.9 ^c
Absent from work, sick in bed (IRR) ^f	2.0 ^c	1.3 ^d	1.7 ^c	2.7 ^c	1.5 ^c	1.6 ^c	3.9 ^c
Difference in annual wage (\$2011) ^g	–4545 ^c	–1589	–3915 ^d	–8198 ^d	–1915 ^d	–2392 ^c	–6752
Activity limitations (all ages)							
Odds of having activity limitations ^h	1.8 ^c	1.4 ^c	1.5 ^c	2.8 ^c	1.4 ^c	1.6 ^c	2.2 ^c
Odds of having activity inability ^h	1.8 ^c	1.3 ^d	1.5 ^c	2.6 ^c	1.3 ^d	1.6 ^c	1.9 ^d

Reference group is those who have never had asthma.

^aAdjusted for age, gender, race, income, ethnicity, education, smoking, insurance coverage and comorbidities.^bED visits were not included in medical expenditure and utilization regressions because of the strong potential for simultaneity.^cSignificant at $p=0.01$ ^dSignificant at $p=0.05$.^eAnalyses of productivity limited to the subpopulation of individuals 18–65 years old.^fAdjusted for age, gender, income, race, ethnicity, education, smoking and comorbidities.^gAdjusted for age, gender, race, ethnicity, education, smoking, marital status and comorbidities.^hAdjusted for age, gender, income, race, ethnicity, education, physical activity, smoking and comorbidities.

IRR: incidence rate ratio.

use of >3 canisters were over fourfold higher than those without asthma ($p < 0.01$) (Table 6). ED visits were significantly increased, approximately 1.7-fold for asthma attack and 1.6-fold for those who used >3 canisters of quick-relief inhaler compared with those without asthma ($p < 0.01$) (Table 6). Those with asthma but had no asthma attacks or used three or fewer canisters had 1.4 times more ED visits ($p < 0.01$) than those without asthma. Prescriptions were significantly increased by 2.4-fold and 3.8-fold for individuals with asthma attack in the previous 12 months and >3 canisters of quick-relief inhaler, respectively, compared with those without asthma ($p < 0.01$) (Table 6). The number of prescriptions used was also higher for those with asthma without an asthma attack by 1.7-fold and 2.4-fold for those using ≤ 3 canisters compared with those without asthma ($p < 0.01$) (Table 6).

Markers of uncontrolled asthma were also significantly associated with productivity. Individuals with markers of uncontrolled asthma had higher odds of unemployment compared with those without a marker of uncontrolled asthma whether determined by asthma attack in the past 12 months (OR = 1.4; $p < 0.01$), use of >3 canisters of quick-relief inhaler (OR = 2.0; $p < 0.01$) or asthma-related ED visits (OR = 1.8; $p < 0.01$) compared to those without asthma. Those with asthma but without an asthma attack did not experience a statistically significant increase in odds of unemployment (Table 6) compared to those without asthma.

Individuals with markers of uncontrolled asthma experienced significantly more days absent from work and absent from work due to being sick in bed than those without asthma (Table 6). Compared to those without asthma, those with an asthma attack missed 1.7 times more work days, those who used >3 canisters missed 2.2 times more work days and those with an asthma-related ED visit missed 2.9 times more work days. For all others with asthma but without one of the three markers of poor control, days absent from work or absent from work due to being sick in bed were increased 1.3- to 1.7-fold (Table 6). Similarly, annual wages were lower for those with markers of poor asthma control by \$4545 (asthma attack), \$8198 (>3 canisters) and \$6752 (ED visit) compared to those without asthma.

Odds of having activity limitations or activity inability were also increased for individuals with markers of uncontrolled asthma (Table 6). There was a relatively larger impact of use of >3 canisters of quick-relief inhalers (OR = 2.8 and OR = 2.6; $p < 0.01$) than for asthma-related ED visits (OR = 2.2 and OR = 1.9; $p < 0.01$) or recent asthma attack (OR = 1.8 and OR = 1.8; $p < 0.01$), compared to those without asthma. Those who have asthma but did not have a recent asthma attack had 1.4 times the odds ($p < 0.01$) of having activity limitations and 1.3 times the odds ($p > 0.05$) of having activity inability compared to those without asthma. Those who used ≤ 3 canisters of quick-relief inhalers had 1.5 times the odds ($p < 0.01$) of having activity limitations and activity inability compared to those without asthma. Those with asthma who did not have an asthma-related ED had 1.6 times the odds ($p < 0.01$) of having activity limitations and activity inability than those without asthma.

Discussion

While a number of recent studies have examined asthma control and outcomes within a clinical or managed care setting [5–7,26], little evidence exists exploring associations of markers of control and outcomes in the general asthma population in the US. To shed light on the national burden of uncontrolled asthma, we used established markers of asthma control [9] to determine if the patterns of increased healthcare utilization and decreased productivity seen in smaller samples persist in a broad population composed of those of varying disease severity and not limited to those in a managed care plan. We found that uncontrolled asthma, across a variety of definitions, was prevalent and associated with increased costs, increased healthcare utilization and decreased productivity.

Using the 2003–2005 MEPS, Sullivan et al. estimated the national economic burden of asthma to be \$18 billion [2]. They also found higher medical expenditures and utilization and lower productivity associated with asthma. Other studies in MEPS have corroborated these findings. Barnett and Nurmagambetov found the total cost of asthma to society to be \$56 billion, including all direct and indirect costs in 2002–2007 MEPS [27]. Wu and Erickson used the 2008 MEPS to assess the impact of asthma on absenteeism [28]. They found a significant correlation between asthma and absenteeism, but this significant correlation disappeared after controlling for other comorbidities. This research highlights the importance of appropriate control for comorbidity as well as substantiating the need to examine how asthma control may affect absenteeism. In addition to research that documents the national economic burden of asthma, other research has examined national medication use patterns in MEPS and found that asthma control may be suboptimal due to underuse of long-term control medications, overuse of quick-relief inhalers and a significant number of self-reported asthma exacerbations. Our research expands upon this previous national research by studying the economic outcomes associated with markers of uncontrolled asthma in more recent MEPS data.

While asthma is generally known to be a burdensome disease, uncontrolled asthma contributes a significant additional burden. We found that total annual healthcare expenditures were up to \$2861 higher for those with a marker of uncontrolled asthma compared to those without asthma and up to \$1675 higher than for those with asthma but without a marker of poor control. This is consistent with the results from Sullivan et al., which documented that asthma contributed an additional \$1907 (\$US 2008) to annual per person medical expenditures [2].

In the TENOR study population, the occurrence of asthma exacerbations, as estimated by measuring hospitalizations, ED visits and corticosteroid bursts, increased 6.4-fold in children with very uncontrolled asthma and by 3.2-fold in adults [5]. This is consistent with our finding that those with an asthma attack or high use of quick-relief inhalers experienced higher rates of ED visits. This further supports the use of ED visits as a measure of uncontrolled asthma.

In this analysis, 5% of individuals who used ≤ 3 canisters of quick-relief inhaler in the past 3 months had an asthma-related ED visit, compared with 11% of individuals who used

>3 canisters. This is consistent with the reported increased odds of daily SABA medication use for individuals who had an ED visit (OR = 6.00) [26]. Furthermore, ED visits were associated with younger age, increased medication use and a 62% increased odds of hospital admissions in the previous year [26]. In this study, we found that uncontrolled asthma, which is associated with increased ED visits, was associated with increased healthcare costs and utilization (inpatient, outpatient and office-based visits, hospital discharges and prescriptions). This implies that controlling asthma, and thus ED visits, could help reduce the healthcare and economic burden of asthma.

Data from the NHWS, an internet-based questionnaire, indicated that individuals with controlled asthma had 56% fewer ED visits, 55% fewer hospital days and 24% fewer provider visits over a 6-month period [7]. Our findings over a longer period corroborate theirs, with 20–60% more ED visits for individuals with uncontrolled asthma than those with controlled asthma. Although the earlier NHWS study did not estimate medical expenditures overall and measured absenteeism and productivity with a different method, their findings were of a similar trend; controlled asthma was associated with a 16% reduction in activity impairment and 4% reduction in absenteeism [7]. We found that those with uncontrolled asthma had 70%–432% more missed work days than those with controlled asthma.

Results from this analysis of markers of asthma control and their correlation with economic and clinical outcomes may help to improve asthma management at the population level. Understanding how asthma and markers of asthma control can influence the total cost of care can inform decisions about the need to invest in programs or treatments that improve control. Specifically, this information can be used to inform innovative insurance benefit designs such as Value-Based Insurance Design (VBID). Effective asthma management might improve clinical outcomes to reduce downstream costs. In this case, waiving the patient copayment actually results in greater effectiveness and cost-effectiveness by maximizing patient access to efficacious treatment. This analysis of the MEPS data suggests that poor asthma control is associated with increased cost and utilization. Future research may help to incorporate this information within VBID to improve population health.

This research is not without limitations. This study was a retrospective, cross-sectional analysis and therefore causal relationships cannot be determined. MEPS is based on self-report and hence this research is subject to potential misclassification and recall bias. Analyses were conducted on all patients without stratification by age. It is possible that patterns of outcomes may be different among the pediatric population than the adult population. Productivity measures were restricted to adults: for example, absenteeism from school was not included within this analysis. Patients may not accurately recall being diagnosed with asthma, recent use of beta agonists and asthma attacks. It is also possible that subjects do not properly distinguish between COPD and asthma. Previous research has shown that self-reported conditions may be underreported, and the extent may vary by race and ethnicity. Because it is a self-report, general population survey (as opposed to a clinical study) MEPS does

not contain clinical measures of lung function. Given these limitations, there is some degree of uncertainty in the conclusions: the research is most appropriately interpreted as indicative of potential associations rather than causal certitudes. Prospective research including clinical measures of asthma and asthma control in a nationally representative population is challenging because of its broad scope and expense. Nonetheless, future research in this area using validated instruments or clinical measures would be helpful to corroborate our findings.

Conclusions

Survey and utilization-based measures are helpful in classifying individuals with uncontrolled asthma. In recent national data, individuals with markers of uncontrolled asthma had worse productivity, greater utilization and higher medical expenditures.

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Declaration of interest

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