Applied Health Economics and Health Policy (2023) 21:915–924
https://doi.org/10.1007/s40258-023-00814-8

ORIGINAL RESEARCH ARTICLE

Direct Medical Costs of COPD in the USA: An Analysis of the Medical Expenditure Panel Survey 2017–2018

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Accepted: 10 May 2023 / Published online: 3 June 2023

Abstract

Aim In this study, we aimed to provide a nationally representative estimate of the economic burden of chronic obstructive pulmonary disease (COPD) by examining direct medical costs among individuals aged 45 years and older in the USA.

Methods Medical Expenditure Panel Survey (2017–2018) data were used to estimate the direct medical costs associated with COPD. All-cause (unadjusted) cost and COPD-specific (adjusted) cost were determined for the various service categories using a regression-based approach among patients with COPD. We developed a weighted two-part model and adjusted for various demographic, socioeconomic, and clinical characteristics.

Results The study sample consisted of 23,590 patients, of which 1073 had COPD. Patients with COPD had a mean age of 67.4 years (standard error (SE): 0.41), and the total all-cause mean medical cost per patient per year (PPPY) was 2018 US $19,449 (SE: US $865), of which US $6145 (SE: US $295) was for prescription drugs. Using the regression approach, the mean total COPD-specific cost was US $4322 (SE: US $577) PPPY, with prescription drugs contributing US $1887 (SE: 216) PPPY. These results represented an annual total COPD-specific cost of US $24.0 billion, with prescription drugs contributing US $10.5 billion. The mean annual out-of-pocket spending accounted for 7.5% (mean: US $325) of the total COPD-specific cost; for COPD-specific prescription drug cost, 11.3% (mean: US $212) was out-of-pocket cost.

Conclusion COPD poses a significant economic burden on healthcare payers and patients 45 years of age and older in the USA. While prescription drugs accounted for almost half of the total cost, more than 10% of the prescription drug cost was out-of-pocket.

1 Introduction

Chronic obstructive pulmonary disease (COPD) is a progressive respiratory disease. The defining characteristics of COPD are obstructive ventilatory patterns, cough symptoms, production of sputum, dyspnea, and a progressive lung function decline [1–3]. It is an irreversible condition and may result in chronic respiratory failure [1]. According to the Centers for Disease Control and Prevention and the National Center for Health Statistics, 4.6% of adults have ever been diagnosed with COPD in the USA [4]. It is estimated that

Key Points for Decision Makers

Based on data from 2017 to 2018, we found a 72% increase in mean annual COPD-specific medical cost that was driven by an eight-fold rise in the mean COPD-specific prescription drug cost and accompanied by a 27% decrease in inpatient spending, when compared with 2000 data.

Our results are indicative of a shift in the management of COPD toward the use of more effective and costly medications.

While there is more spending toward prescription drugs in recent years, out-of-pocket costs remain high and continue to be a significant challenge for socioeconomically deprived patients.

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more than 50% of individuals with COPD remain undiagnosed [5, 6]. COPD presents a major source of mortality and morbidity and was the fourth leading cause of death in the USA in 2017 [7]. COPD has been shown to have detrimental impacts on both mental and physical health leading to a lower health-related quality-of-life among patients [8].

COPD imposes substantial economic burdens on patients, the healthcare system, and US society. A recent study projected that the annual direct medical costs attributable to COPD would increase from US $46.91 billion to US $57.86 billion over a 20-year period [9]. Similarly, the study estimated that the indirect absenteeism costs, measured by days of work missed, would rise from US $6.82 billion to US $6.97 billion in 20 years [9]. Other studies have estimated the economic burden of COPD from a single payer with substantial emphasis being on the cost of exacerbations in individuals with COPD [10–14]. Moreover, prior research has found that demographic and socioeconomic characteristics of patients, healthcare utilization, and medical costs tend to vary widely between different payers [15–17].

In recent years, significant changes have taken place in the US healthcare system, including the passage of the Patient Protection and Affordable Care Act, introduction of the Hospital Readmissions Reduction Program that penalized excess rehospitalization for conditions including COPD [18], consolidation of Medicare part D for prescription drugs, and introduction of new therapies for the management and treatment of COPD [19–21]. In addition, lower cost generic medications have gained widespread acceptance and availability as an alternative to the high price of their branded counterparts in the last decade [22]. These changes led to an increase in prescription drug access and spending, and a consequent decrease in inpatient care spending over time [23–25].

Given changes in the management of COPD and the US healthcare system in recent years, there exists a need for updated estimates of the direct medical costs of COPD across payers to capture the burden posed by COPD in the USA. In this study we aim to provide an updated, nationally representative estimate of the COPD-specific and all-cause economic burden of COPD by analyzing the 2017–2018 Medical Expenditure Panel Survey (MEPS). We quantify the overall cost, out-of-pocket cost, and cost by service type, including prescription drugs, emergency room visits, inpatient visits, office-based visits, outpatient visits, and home health visits among COPD patients.

2 Methods

2.1 Data Source

We utilized data from the 2017–2018 MEPS, a de-identified, publicly available database provided by the Agency for Healthcare Research and Quality (AHRQ) [26]. The survey collects data from families, medical providers, and employers across the USA and is based on a nationally representative subsample of households. The subsample of households participated in the National Health Interview Survey, which is carried out by the National Center for Health Statistics. AHRQ uses an overlapping panel design to collect data on demographic and socioeconomic characteristics, healthcare utilization, and health status, among other attributes about non-institutionalized individuals from households in the USA. This design involves preliminary contact followed by five rounds of interviews over a 2.5-year period. The data collected covers a period of two calendar years for each household. The sampling design of the survey includes stratification, clustering, multiple stages of selection, and disproportionate sampling (complex survey design methods). Survey sample weights are based on the Current Population Survey and are computed and provided by the MEPS administrators.

The two major components of MEPS data are the household component and the insurance component. We used the full-year consolidated data file and the medical conditions file from the household component of the MEPS dataset. The full-year consolidated data file [26] contains information on demographic characteristics of the sample in addition to employment, health status, quality of care, healthcare spending, patient satisfaction, and health insurance coverage estimates. The medical conditions file [26] contains information on the reported medical conditions among the sample.

2.2 Study Sample

Respondents with COPD were identified using the following International Classification of Diseases (Tenth Revision) Clinical Modification codes (ICD-10 CM): J42 (“unspecified chronic bronchitis”), J43 (“emphysema”), J44 (“chronic obstructive pulmonary disease”) [27]. As COPD diagnosis has been shown to be uncommon in individuals younger than 45 years of age, our sample was limited to adults who were at least 45 years old [28–30]. Nonrespondents and individuals with missing information on variables of interest were excluded. The sample selection process is depicted in Fig. 1.

2.3 Statistical Analysis

Given the cross-sectional study design nature of MEPS, all demographic, socioeconomic, and clinical characteristics were measured during the observation year and reported for both individuals with and without COPD. In addition to the unadjusted all-cause healthcare cost among individuals with COPD, we calculated the COPD-specific cost for the various service categories. Therefore, we estimated cost using two approaches: (1) unadjusted cost and (2) adjusted cost

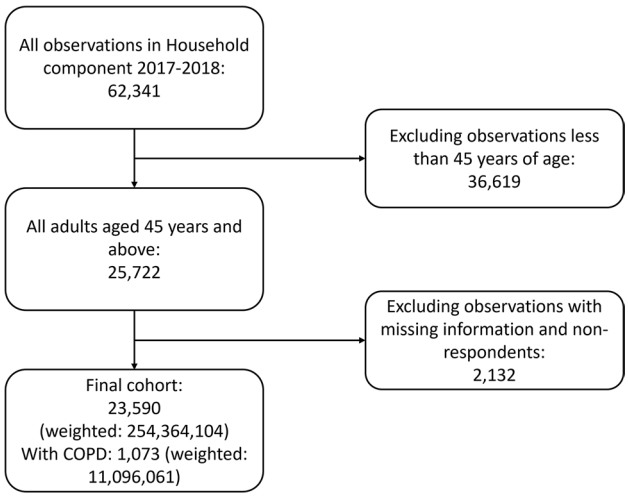

Fig. 1 Flow diagram illustrating the sample selection process

using regressions. For the unadjusted all-cause estimates, only individuals with COPD were included in the analysis. For the regression-based COPD-specific estimates, the entire sample with or without COPD was included in the analysis.

2.3.1 Outcomes

The primary outcome of interest was COPD-specific cost. The service categories examined included inpatient stays, outpatient visits, emergency room visits, office-based visits, home health visits, and prescribed medicines. In addition, all-cause medical cost, including both COPD-specific and non-COPD-specific costs, among COPD patients for these categories was determined. Out-of-pocket cost representing the patient economic burden was also estimated. The focus of our analysis was on direct medical cost; other societal costs, such as lost work, disability cost, and caregiver cost, were not included in our model.

2.3.2 Covariates

In the regression model we adjusted for the following covariates: age, insurance coverage, sex, race, marital status, family income, current smoking status, region of residence, education level, and comorbid conditions. Age was categorized into 5-year interval groups "45–49 years," "50–54 years," "55–59 years," "60–64 years," "65–69 years," "70–74 years," "75–79 years," and "80 years and above." The three types of insurance were categorized as "any private," "public only," and "uninsured." Family income as a percentage of the poverty line was grouped as "poor" (less than 100% of the poverty line), "near poor" (100% to less than 125% of the poverty line), "low income" (125% to less than 200% of the poverty line), "middle income" (200% to less than 400% of the poverty line), and "high income" (greater than or equal to 400% of the poverty line). Specific comorbid conditions adjusted for included angina, arthritis, asthma, cancer, chronic heart disease, high cholesterol, diabetes, high blood pressure, myocardial infarction, stroke, other heart conditions, depression, and anxiety, as these conditions have been identified as priority conditions by MEPS [31].

2.3.3 Model

For the regression-based model, the dependent variable was all-cause medical cost. The primary independent variable of interest in the regression was COPD to estimate the incremental contribution of COPD on overall cost. To obtain estimates for the out-of-pocket cost, the regression model was implemented, wherein the outcome of interest was all-cause out-of-pocket cost and presence of COPD was the primary independent variable. Out-of-pocket costs were estimated for prescription drugs, other (cost besides prescription drug cost), and total cost.

The regression approach utilized a two-part model. The first part consisted of a logistic regression wherein the outcome was a binary indicator that took a value of 1 when a respondent reported any expenditure and took on a value of 0 when individuals reported no expenditure. The outcome of the second part of the two-part model was the expenditure amount. The model parameters in the second part were estimated using a generalized linear model (GLM) with a log link function and gamma distribution [32–34]. These procedures were carried out using the "twopm" STATA programs [35]. The marginal effect of COPD on cost was determined to estimate the COPD-specific cost using the delta method. The aforementioned covariates and operationalizations were utilized for both analyses: COPD-specific total cost and COPD-specific out-of-pocket cost.

The complex survey design used to collect the data was accounted for by using appropriate analytical procedures such as SURVEYFREQ, SURVEYMEANS, domain statements, and svy in the analyses [36]. All the costs were adjusted to 2018 values using the Personal Health Care Expenditure (PHCE) component of the National Health Expenditure Accounts provided by the US Department of Health and Human Services, as recommended by Dunn et al. [37–39]. All analyses were carried out using SAS 9.4 and STATA MP 16 [40, 41].

3 Results

The study sample consisted of 23,590 (weighted: 254,364,104) patients, of which 1073 (weighted: 11,096,061) had COPD during the study period. Compared

with individuals without COPD, a higher proportion of COPD patients were female (59% versus 53%), 65 years and older (59% versus 38%), white (88% versus 81%), and had only public insurance (49% versus 27%). In addition, COPD patients were 2.5 times more likely to be current smokers and had a higher prevalence of angina (12% versus 3%), arthritis (69% versus 40%), asthma (40% versus 11%), cancer (28% versus 18%), chronic heart disease (24% versus 8%), high cholesterol (63% versus 46%), diabetes (27% versus 17%), high blood pressure (68% versus 49%), myocardial infarction (18% versus 6%), stroke (15% versus 6%), other heart conditions (35% versus 15%), depression (22% versus 10%), and anxiety (22% versus 10%). The other demographic and clinical characteristics of patients with and without COPD are presented in Table 1.

3.1 All-Cause Medical Cost (Unadjusted) Among COPD Patients

The all-cause medical cost among COPD patients represents both COPD-specific and non-COPD-specific costs. Among COPD patients, the total all-cause mean annual per patient medical cost was 2018 US $19,449 (standard error (SE): US $865; 95% confidence interval (CI): US $17,748–21,151), of which US $6145 (SE: US $295; 95% CI: US $5564–6726) was for prescription drugs, US $592 (SE: US $83; 95% CI: US $429–754) was for emergency room visits, US $5330 (SE: US $504; 95% CI: US $4339–6322) was for inpatient visits, US $3323 (SE: US $183, 95% CI: US $2962–3683) was for office-based visits, US $1399 (SE: US $198, 95% CI: US $1010–1788) was for outpatient visits, and US $1495 (SE: US $208, 95% CI: US $1086–1904) was for home health visits. While the mean annual total cost among COPD patients was US $19,449, there was a significant amount of between-individual variation in annual costs (standard deviation: US $22,647). These results are presented in Table 2.

3.2 COPD-Specific Medical Cost

Based on the regression model, the total COPD-specific incremental expenditure per patient per year was US $4322 (SE: US $577, 95% CI: US $3187–5457), out of which US $1887 (SE: US $216, 95% CI: US $1462–2312) was for prescription drugs, US $137 (SE: US $30, 95% CI: US $78–196) was for emergency room visits, US $1003 (SE: US $233, 95% CI: US $544–1461) was for inpatient visits, US $384 (SE: US $171, 95% CI: US $47–720) was for office-based visits, US $133 (SE: US $117, 95% CI: US −$98–364) was for outpatient visits, and US $250 (SE: US $77, 95% CI: US $98–401) was for home health visits. The results are presented in Table 2. These results represent an annual total cost of US $24.0 billion, with prescription drugs contributing US $10.5 billion of this cost among the total sample of the weighted population with COPD in the USA. The complete regression results of the two-part model for COPD-specific total cost (marginal effects) are presented in Table 3. In addition, the regression results by service categories are provided in the Online Supplemental Appendix (Tables A1–A6).

3.3 COPD-Specific Out-of-Pocket Cost

The mean annual per person out-of-pocket spending for COPD was US $325, which accounted for 7.5% of the total COPD-specific cost. Of this, out-of-pocket spending for COPD prescription drugs was on average US $212 per patient per year, accounting for 11.3% of the total COPD prescription drug cost. The mean annual per person out-of-pocket spending for other COPD costs (other than prescription drug cost) was US $113, accounting for 4.6% of the total other COPD-specific spending. These results are depicted in Fig. 2.

4 Discussion

In this study, we reported COPD-specific and all-cause direct medical costs among patients with COPD estimated using data from a nationally representative sample of non-institutionalized US adults. Our results revealed differences in sociodemographic and clinical characteristics—including differences in comorbidities—between individuals with and without COPD. We found that the mean annual per patient COPD-specific cost and all-cause medical cost were US $4322 and US $19,449, respectively.

In comparison with previous nationally representative studies, our results demonstrated a shift in the age distribution and cost of COPD in recent years in the USA. We found that 59% of COPD patients were 65 years old and above in 2017–2018, compared with 47% in 2007 [21], 63% in 2000 [20], and 74% in 1987 [19]. These aforementioned changes could be due to a complex interplay of factors such as a decrease in the age of first diagnosis of COPD [42], an increase in life expectancy, changes in the age distribution in the population [43], and a steady decrease in the rates of smoking, a major risk factor of COPD over this period [44]. With respect to sex and race distributions among COPD patients, we found no major changes since 2007 [21].

Our findings are indicative of a shift in the distribution and drivers of COPD-specific cost in recent years. While inpatient care and prescription drugs respectively accounted for 68% and 8% of the total all-cause unadjusted expenditures among COPD patients in 1987 [19], the corresponding

Table 1 Demographic characteristics of individuals with COPD and individuals without COPD, 2017–2018

Covariates	Among individuals with COPD			Among non-COPD individuals			Rao-Scott chi-square test
	Frequency	Weighted frequency	Percent	Frequency	Weighted frequency	Percent	*P*-value
Age = 45–49 years	44	503,468	4.54%	3386	37,135,886	15.27%	< 0.01
Age = 50–54 years	85	739,231	6.66%	3419	38,237,946	15.72%	< 0.01
Age = 55–59 years	147	1,502,817	13.54%	3500	38,106,852	15.66%	0.14
Age = 60–64 years	177	1,837,374	16.56%	3223	36,735,440	15.10%	0.33
Age = 65–79 years	164	1,604,982	14.46%	3008	31,299,027	12.87%	0.23
Age = 70–74 years	184	1,933,165	17.42%	2395	24,526,841	10.08%	< 0.01
Age = 75–79 years	136	1,504,519	13.56%	1532	15,937,489	6.55%	< 0.01
Age = 80 years and above	136	1,470,505	13.25%	2054	21,288,562	8.75%	< 0.01
Region = Northeast	173	1,822,303	16.42%	3776	43,632,653	17.94%	0.40
Region = Midwest	272	2,658,704	23.96%	4620	52,092,364	21.41%	0.23
Region = West	177	1,757,187	15.84%	5500	56,441,568	23.20%	< 0.01
Region = South	658	4,857,867	43.78%	8621	91,101,458	37.45%	0.01
Highest education: less than high school	226	1,845,717	16.63%	3500	25,180,093	10.35%	< 0.01
Highest education: high school/ GED	602	6,507,975	58.65%	10,322	108,802,541	44.73%	< 0.01
Highest education: other degree	113	1,322,915	11.92%	2076	26,129,043	10.74%	0.38
Highest education: bachelor's degree	83	900,357	8.11%	3939	49,676,744	20.42%	< 0.01
Highest education: master's/Ph.D. degree	49	519,097	4.68%	2680	33,479,622	13.76%	< 0.01
Insurance = any private	460	5,395,585	48.63%	13,953	167,119,953	68.70%	< 0.01
Insurance = public only	589	5,434,224	48.97%	7192	64,531,798	26.53%	< 0.01
Insurance = uninsured	24	266,252	2.40%	1372	11,616,292	4.78%	< 0.01
Sex = female	658	6,566,796	59.18%	12,277	128,530,524	52.83%	< 0.01
Race = white only	892	9,728,594	87.68%	17,019	196,494,946	80.77%	< 0.01
Race = black only	132	955,157	8.61%	3589	27,055,754	11.12%	0.02
Race = other/multiple reported	49	412,310	3.72%	1909	19,717,343	8.11%	< 0.01
Marital status = currently married	425	4,665,197	42.04%	13,001	149,383,029	61.41%	< 0.01
Family income = poor	255	2,046,598	18.44%	3004	21,510,481	8.84%	< 0.01
Family income = near poor	88	864,116	7.79%	1022	8,704,289	3.58%	< 0.01
Family income = low	191	1,882,671	16.97%	3038	27,790,254	11.42%	< 0.01
Family income = medium	301	3,347,452	30.17%	6209	63,552,902	26.12%	0.03
Family income = high	238	2,955,224	26.63%	9244	121,710,117	50.03%	< 0.01
Current smoker	364	3,587,698	32.33%	3142	31,880,363	13.11%	< 0.01
Angina	129	1,360,232	12.26%	724	7,634,168	3.14%	< 0.01
Arthritis	773	7,681,255	69.23%	9195	97,301,240	40.00%	< 0.01
Asthma	463	4,471,728	40.30%	2471	26,012,876	10.69%	< 0.01
Cancer	303	3,074,670	27.71%	3728	42,945,141	17.65%	< 0.01
Chronic heart disease	250	2,660,880	23.98%	1899	19,017,297	7.82%	< 0.01
High cholesterol	697	6,981,095	62.92%	10,554	112,171,359	46.11%	< 0.01
Diabetes	304	2,996,928	27.01%	4282	41,057,347	16.88%	< 0.01
High blood pressure	766	7,562,243	68.15%	11,519	118,023,644	48.52%	< 0.01
Myocardial infarction	192	2,050,501	18.48%	1386	13,629,466	5.60%	< 0.01
Stroke	163	1,685,397	15.19%	1522	14,691,288	6.04%	< 0.01
Other heart conditions	370	3,853,877	34.73%	3451	37,138,898	15.27%	< 0.01
Depression	249	2,489,952	22.44%	2263	23,508,682	9.66%	< 0.01
Anxiety	258	2,461,395	22.18%	2195	24,011,770	9.87%	< 0.01
Total	1073	11,096,061	100.00%	22,517	243,268,043	100.00%	

Table 2 Healthcare costs (COPD-specific and all-cause medical) among COPD patients, by visit type

Service category	All-cause (unadjusted) medical cost	Fully adjusted model COPD-specific (regression approach) medical cost[a,b]
	Mean annual per person cost (standard error; 95% confidence interval; 2018 US $)	
Prescription drugs	US $6,145 (SE: 295; 95% CI: US $5564–6726)	US $1887 (SE: 216; 95% CI: US $1462–2312)*
Emergency room	US $592 (SE: 83; 95% CI: US $429–754)	US $137 (SE: 30; 95% CI: US $78–196)*
Inpatient	US $5330 (SE: 504; 95% CI: US $4339–6322)	US $1003 (SE: 233; 95% CI: US $544–1461)*
Office-based	US $3323 (SE: 183; 95% CI: US $2962–3683)	US $384 (SE: 171; 95% CI: US $47–720)*
Outpatient	US $1399 (SE: 198; 95% CI: US $1010–1788)	US $133 (SE: 117; 95% CI: US −$98–364)
Home health	US $1495 (SE: 208; 95% CI: US $1086–1904)	US $250 (SE: 77; 95% CI: US $98–401)*
Total	US $19,449 (SE: 865; 95% CI: US $17,748–21,151)	US $4322 (SE: 577; 95% CI: US $3187–5457)*

*Difference is statistically significant at the 95% confidence level

[a]Covariates adjusted for include: age (categorized into 5-year intervals), insurance status, sex, race, region, highest level of education, marital status, family income, current smoking status, and comorbid conditions (angina, arthritis, asthma, cancer, chronic heart disease, high cholesterol, diabetes, high blood pressure, myocardial infarction, stroke, other heart conditions, depression, and anxiety)

[b]For two-part regression: first part: logit; second part: generalized linear model (family = gamma, link = log)

estimates in our study were 27% and 32%. This is an interesting finding, as it shows over time the proportion of all-cause expenditures due to inpatient care reduced while spendings on prescription drugs increased. Recent work by Celi et al. has demonstrated that COPD treatments, especially newer options, were able to not only improve symptoms and reduce exacerbations, but were also shown to improve patient prognosis in terms of all-cause mortality, which may partially help explain the recent shift in cost [45].

When compared with MEPS 2000 data [20], our study showed an increase of 72% in mean annual COPD-specific medical cost. The main driver for this increase is an eight-fold rise in the mean COPD-attributable prescription drug cost. Such an increase in prescription drug cost was accompanied by a 27% decrease in inpatient spending compared with data from 2000 [20]. Higher prescription drug cost and lower inpatient cost compared with earlier periods are indicative of a shift in the way COPD is managed and perhaps the introduction of novel, more effective drugs that lead to better management of COPD, but at an increased prescription drug cost [46].

The shift toward higher prescription drugs cost and lower inpatient cost suggests effectiveness of maintenance therapy in reducing costly healthcare events such as hospitalizations [47]. Therefore, efforts to increase access and adherence to medications can be pivotal in preventing future hospitalizations while saving money for patients and payers.

At the individual level, we estimated the mean annual COPD-specific direct medical costs to be US $4322 per patient. Our MEPS-derived estimate for cost of COPD is in line with previous costs estimates for moderate-to-severe COPD ($3706–5675) [9]. Given that lung function data is not available in MEPS, we could not define the distribution of our study participants across different clinical severity grades of COPD. However, given COPD is underdiagnosed in milder stages of disease, and that a good proportion of individuals included in our study had at least one healthcare resource use due to COPD, our results may be more representative of moderate-to-severe COPD [9, 48, 49].

Further, this study found that the patient burden in terms of out-of-pocket cost was on average US $325 per year, which was 7.5% of the total COPD-specific spending. Our out-of-pocket cost estimate is nearly three-fold higher than the estimate reported in a previous study (US $111), mainly because the population in the previous study was restricted to working individuals with COPD [50], and their sample was younger. In addition, it is most likely that the out-of-pocket costs vary by insurer, but we were not able to obtain such estimates due to the small sample sizes for subgroup analysis across insurers.

Appropriate use of medications is necessary for disease management, but paying high out-of-pocket cost can be expensive for some patients and can be a barrier for filling prescription drugs and maintaining adherence [51–55]. While policies to increase access to, and reduce copays for, medications can save money for the healthcare system in the long run, given the heterogeneity of lung function decline and progression of COPD [56], ensuring the provision of right medication that meets the clinical needs and preferences of a given patient can be as important. Certain medications for COPD are most effective in more severe clinical stages of the disease while providing a lesser effect for milder COPD [57, 58]. For example, Yu et al. found that roflumilast provided a net benefit only when used by COPD patients at a high risk of severe exacerbations [57]. Other researchers have shown how COPD treatments could be personalized based on benefit–harm modeling frameworks [59]. In addition, clinical risk-stratification models that incorporate patients' preferences may optimize treatment benefits while increasing patients' adherence.

Table 3 Results of marginal effect two-part regression to determine excess cost of COPD on total healthcare expenditure

Covariate	Reference	Marginal effect	Standard error	*P*-value
Race = black only	Race = white only	−478.26	556.64	0.39
Race = other/multiple reported		−1931.44	673.08	< 0.01
Age = 50–54 years	Age = 45–50 years	2273.89	807.49	< 0.01
Age = 55–59 years		1355.79	659.22	0.04
Age = 60–64 years		2495.48	741.67	< 0.01
Age = 65–69 years		2377.35	641.97	< 0.01
Age = 70–74 years		2269.05	713.16	< 0.01
Age = 75–79 years		1947.01	731.38	< 0.01
Age = 80 years and older		3967.38	776.76	< 0.01
Marital status = currently married	Marital status = not currently married	−562.18	348.51	0.11
Region = Northeast	Region = South	1311.32	619.43	0.04
Region = Midwest		308.93	535.12	0.56
Region =West		714.73	582.85	0.22
Sex = female	Sex = male	−201.61	362.89	0.58
Highest education: high School/ GED	Highest education: less than high school	885.32	597.29	0.14
Highest education: other degree		1237.20	760.21	0.11
Highest education: bachelor's degree		961.03	684.46	0.16
Highest education: master's/Ph.D. degree		2026.58	812.63	0.01
Current smoker	Not current smoker	604.68	543.95	0.27
Insurance = uninsured	Insurance = any private	−9569.09	1222.43	< 0.01
Insurance = public only		−498.97	375.76	0.19
Family income = poor	Family income = medium	1757.19	633.74	< 0.01
Family income = near poor		1415.56	785.53	0.07
Family income = low		254.62	625.26	0.68
Family income = high		519.32	398.37	0.19
Angina	No angina	−381.21	727.20	0.60
Arthritis	No arthritis	3122.23	347.84	< 0.01
Asthma	No asthma	3004.80	596.20	< 0.01
Cancer	No cancer	4475.02	447.27	< 0.01
Chronic heart disease	No chronic heart disease	2513.72	510.22	< 0.01
High cholesterol	No high cholesterol	30.41	374.75	0.94
Diabetes	No diabetes	5136.56	496.96	< 0.01
High blood pressure	No high blood pressure	1724.31	361.17	< 0.01
Myocardial infarction	No myocardial infarction	2465.04	593.01	< 0.01
Other heart conditions	No other heart conditions	3147.90	388.78	< 0.01
Stroke	No stroke	3551.34	632.29	< 0.01
Depression	No depression	2901.41	437.12	< 0.01
Anxiety	No anxiety	3559.01	498.11	< 0.01
Chronic obstructive pulmonary disease	No chronic obstructive pulmonary disease	4322.22	576.92	< 0.01

A major strength of our study is that it uses nationally representative data of non-institutionalized US adults and provides updated estimates of the economic burden of morbidity from both patient and payer perspectives. Nonetheless, our study is subject to some limitations, and the results of this analysis should be interpreted in light of the following caveats. Since MEPS is a survey that is conducted among non-institutionalized individuals, our results do not extend to individuals who are institutionalized. Given that a single household member responds to the survey on behalf of all other household members, the data is susceptible to survey and recall biases. MEPS attempts to overcome these limitations in a number of ways, including using the medical provider component to supplement, replace, validate, and impute health care expenditures [60]. Some of the covariates adjusted for are not truly independent of COPD and are linked both through cigarette smoking as well as susceptibility and other mechanisms. A regression approach controlling

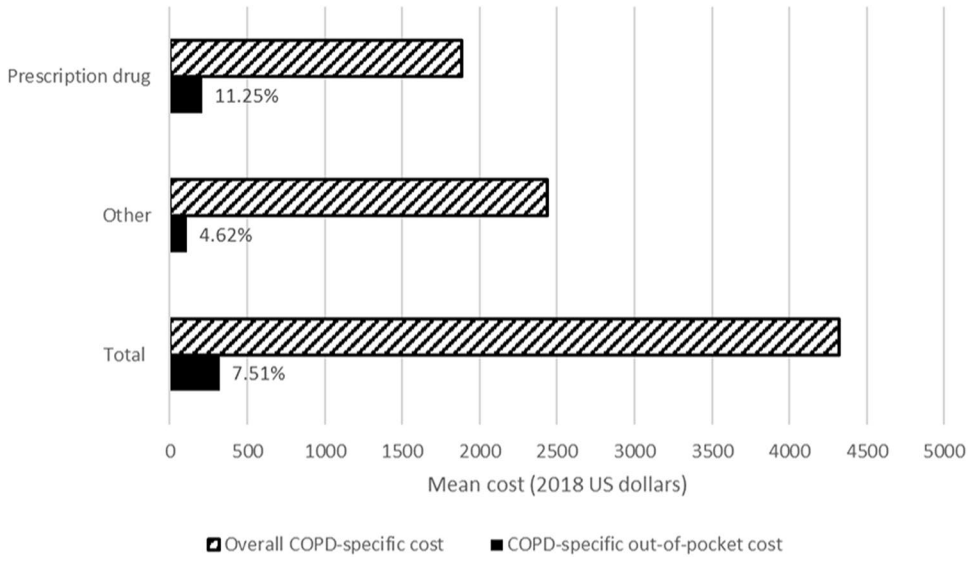

Fig. 2 Mean annual out-of-pocket and overall COPD-specific cost, by service category, per person with COPD. All values are in 2018 US dollars. Prescription and total cost are based on the results of a fully adjusted two-part regression (described in text). Other costs estimated by the difference in results of the regression analyses for total and prescription drug costs

for these comorbidities is really taking a very conservative approach to estimation. It also is important to note that the comorbidities included in the regression models are not necessarily mutually independent and were chosen to control for confounding. In addition, omitted variable bias due to unmeasured confounding may affect the results. Though our study utilized a regression-based incremental cost approach, other approaches may also be utilized to estimate cost-of-illness [61, 62]. Costs examined in this study were all medical in nature and did not include other societal costs such as lost work, disability, caregiver, and other intangible costs. As such, the cost estimates provided here underestimate the true societal burden.

5 Conclusion

This study quantifies the substantial economic burden of COPD in the USA. With projected population ageing in the years to come, the national burden of COPD will remain on the rise. An interesting finding of this study is the shift in the proportion of costs toward pharmacy and away from hospitalizations in COPD patients over time, with prescription drugs accounting for almost half of the overall direct medical cost among COPD patients in more recent years.

Supplementary Information The online version contains supplementary material available at https://doi.org/10.1007/s40258-023-00814-8.

Declarations

Funding No funding was received for this work.

Conflict of Interest Authors declare no conflict of interests.

Ethics Approval Not applicable as publicly available de-identified data provided by AHRQ.

Consent to Participate Not applicable.

Consent for Publication (from Patients/Participants) Not applicable.

Data Availability Statement The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Code Availability The codes during the current study are available from the corresponding author on reasonable request.

Authors' Contributions CHS developed the idea, designed the analytical model, performed statistical analyses, and wrote the first version of the manuscript. ZZ, RMR, LW, EO, and MG helped develop the research idea, provided supervision and clinical and methodological insights, and helped with writing the first version of the manuscript. All authors contributed to the manuscript in writing and development.

Trial Registration Not applicable.

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