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Updating medical expenditures by smoking status in American adults

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Abstract

Objectives: To assess the medical expenditures of American adults by their smoking status-Current, Former, or Never smokers. We update these expenditures controlling for personal characteristics and medical history. The impact of years-since-quitting and decade of life are also examined. **Setting and participants:** Weighted sample of American adults, 2011 – 2015. The National Health Interview Survey (NHIS) and Medical Expenditure Panel Survey (MEPS) are weighted representations of approximately 250 million adults, annually. Sampling of NHIS is multistage and data collected throughout the year. **Primary outcome measures:** Using data from NHIS and MEPS, we collected demographic data, self-reported medical history, and current smoking status. Smoking status was designated as Never, Current, and Former, along with years-since-quitting. Total medical expenditures were collected from MEPS for 2011 – 2015. We used Manning's two-part model to model average expenditures per individual and marginal costs for individuals at all levels of smoking status. **Results**: American adults averaged $4,830 in average medical expenditures. Never smokers ($4,360, 95% CI = 4154.3 – 4566.3), had lower expenditures than Current ($5,244, 95% CI = 4707.9 – 5580.3) and Former ($5,590, 95% CI = 5267.4 – 5913.5) smokers. Confidence intervals for Current and Former smokers overlapped. Results were similarly significant when controlling for disease history. Years-since-quitting did not affect expenditures. In each decade of adult life, Former smokers had the highest annual medical expenditures, followed by Current and Never smokers. **Conclusions**: We updated annual medical expenditures for the Obamacare-era for smoking status using the current best practice model. Former smokers had lower medical expenditures than Current smokers in all age groups. While we identify Former smokers as having higher medical expenditures than

Current smokers, we do not examine how care-seeking behavior varies between levels of each risk factor.

Article Summary

Strengths and Limitations

- This is also the first study to report data on medical expenditure by smoking status while major provisions of the Affordable Care Act (a.k.a. Obamacare) were taking effect.
- We use the gold standard two-part model developed by Manning to estimate medical expenditures from the MEPS and NHIS surveys.
- We separated medical expenditures for Ever Smokers into Current and Former smokers, finding that the latter had slightly increased annual medical expenditures.
- Effects of smoking status were examined across decades of life.
- Although we controlled for history of comorbidities, the data do not contain any information on reason-for-quitting among former smokers.

Introduction

It is well-established that smoking can lead to medical conditions requiring acute and chronic treatment[1]. Accurate marginal costs for medical risk factors are important when conducting benefit-cost analyses for health risk behavior interventions[2-4]. The most recent national estimates of medical expenditures by smoking status have only considered a binary smoking variable: current smokers versus current non-smokers[5, 6]. Further, none of these national studies have analyzed medical expenditure data more recently than 2011. A series of state-level analyses by Max and colleagues[7-9] described medical costs in California by current, former, and never smokers.

The California studies used the attributable fraction (AF) method to allocate medical expenditures. The accuracy of the AF method is constrained by how accurately costs are allocated among diagnoses and by the availability of accurate AFs that are not confounded by co-occurring risk factors[10]. The negative outcomes that smokers experience vary widely in nature and timing. Importantly, the method does not measure the standard error for the mean estimated cost per risk-taker[11].

In analyzing the costs of medical conditions, health economics literature has largely shifted from this AF method to analyses of annual per capita medical spending of people with the condition relative to a comparison group (*c.f.* Manning *et al* [12]). This approach captures both mean and standard error. It accounts for complications that may not be coded to the underlying condition. It recognizes that medical visits for conditions related to the behavioral risk factors may displace other medical care that might be sought if an individual did not have a given risk factor. For

example, a doctor who is scheduling quarterly visits to manage diabetes is unlikely to separately schedule the annual well-care visit recommended for a healthier patient. That well-care visit gets coded as a chronic care visit even though it may not raise annual medical spending[13].

While the Manning model is now the gold standard for working with skewed outcomes like medical spending, it is an imperfect tool. Although it statistically assigns costs to given risk factors or medical conditions, it does not tell us the "why" behind each individual medical encounter or expense. Medical spending is influenced by care-seeking behavior. Smokers may avoid visiting the doctor because it is uncomfortable to report their continued smoking behavior or tedious to hear the doctor urge them to change[14]. Health consciousness and associated use of preventive care may be below-average for people who engage in risky behavior. Furthermore, drinking heavily may be a symptom of life management issues that reduce care-seeking. Those differences in health management may mask the impacts of risk behavior on medical spending.

Purpose

This study updates the national estimates for annual medical expenditures of adult Americans by their current smoking status. We examine medical expenditure data for 2011 – 2015 and apply the cutting-edge two-stage Manning model to more accurately assess error around mean expenditures.

Methods

Data Collection

We analyzed data on smoking status from the National Health Interview Survey (NHIS)[15]. The NHIS is an annual, cross-sectional survey designed to monitor health and behaviors of civilian, non-institutionalized Americans through a nationally-representative sample. The Medical Expenditure Panel Survey (MEPS) tracks a nationally representative subsample of NHIS participants for 24 months starting in the year after their NHIS interview. MEPS collects five rounds of data per respondent on healthcare visits and expenditures[16]. It captures all payments for care, regardless of source, and models costs for visits without payment data including charity care and visits bundled into capitated care. We used 2011-2015 MEPS data on total medical expenditures from the individual perspective for adults 18-years and older and the corresponding NHIS 2009 – 2014 data. We linked data from MEPS and NHIS via the Agency for Health Care Quality Data Center, as Xu *et al* and An did in their analyses of smoking costs[5, 6].

Smoking status was identified through the NHIS Supplemental Adult Questionnaire (SAQ). Like earlier studies, we identified Ever smokers as participants who smoked at least 100 cigarettes in their lifetimes. We defined all others as Never smokers[6]. Ever smokers were further subdivided into those who reported quitting smoking, Former smokers, versus those who did not report quitting, Current smokers[7-9]. For Former smokers, we also identified years-since-quitting.

To conduct regressions, we included the following demographic and behavioral characteristics: age, sex, race/ethnicity, marital status, education level, total family income, family size, employment status, marital status, self-reported binge drinking status, body mass index (BMI), recent pregnancy, educational, employment, and insurance data from MEPS. Age was employed as a continuous variable in the main analyses and divided into ten-year blocks in the age-specific

sensitivity analysis. Binge drinking data were also obtained from the SAQ, which used the accepted binge drinking definition of men having 5 or more drinks and women having 4 or more drinks. Those participants who indicated that they had 12 or more instances of binge drinking in the past year were categorized as frequent binge drinkers, and those who had 1-11 instances were categorized as infrequent binge drinkers. BMI data were calculated from self-reported weight and height in the NHIS. We dichotomized BMI into obese for those with a BMI of 30 kg/m2 or greater, and not obese for those with lower BMI. We refer to these variables collectively as personal characteristics.

NHIS and MEPS had data on self-reported diagnosis history for various diseases. Using data from both databases, we generated dichotomous variables for whether a participant had ever been diagnosed with the following diseases: asthma, arthritis, any cancer, cardiovascular diseases (including angina, coronary heart disease, myocardial infarction, or stroke), diabetes, and emphysema. NHIS had data on chronic obstructive pulmonary disease (COPD) available for 2013 through 2015 MEPS panels. From MEPS, we obtained scores for the Short Form 12 to measure quality of life[17], the Personal Health Questionnaire (PHQ) metric for depression[18], and the Kessler 6 questionnaire for mental illness[19]. From these variables, we were able to code a partial list of comorbidities that Elixhauser and colleagues[20] suggest controlling for when using administrative medical data.

Regression Analysis

We used the two-stage model approach developed by Manning and Basu[12] to model discrete-continuous outcomes. The first regression in this method models whether or not an individual

had any medical expenditures in the given year. Then, the second model estimates the costs for individuals who the first model predicted had any costs. We used an ordinary least squares (OLS) logistic regression in the first step, followed by a generalized linear model with a generalized Gamma distribution in the second stage. We used the Stata twopm command developed by Belotti and colleagues to execute the two models[21]. The twopm command allowed us to use the survey weights provided by AHRQ. Data were collected and merged using SAS v9.4 analytical software [SAS Institute, Cary, NC]. Data management was performed in SAS and Stata IC v15 [Stata Corp, College Station, TX]. All data analysis was conducted using Stata.

Our main regression model (Model 1) included personal characteristics and current smoking status. We experimented with including body mass index in the model; however, the variable had near 50% missingness, so we excluded it from our final model. (Including it had negligible on estimated expenditures by smoking status.) We added the disease history to the two-stage model (Model 2). Finally, because COPD comorbidity was only available for the last three years of the study, we excluded COPD and re-ran the model on all five years of the study period. Because controlling for this co-morbidity did not noticeably affect the estimates by smoking status, we chose to report estimates based on 5 years of data, thus increasing our power to probe costs among subgroups. We replicated Model 2 to include data on years-since-quitting for former smokers at 1-, 2-, and 5-year thresholds. Because prevalence of these risk factors changes over the life course, we also examined the marginal effects of smoking on medical expenditures by decade of adult life[21]. Non-overlapping confidence intervals indicated statistically significant differences.

Results

An average of 19.7 million adults self-identified as Current smokers in the US from 2011 to 2015. The proportion of current smokers decreased over the study period, to approximately 17.5 million adults in 2015. An average of 43.6 million adults in the U.S. were Ever smokers. The proportion of former smokers increased through decades of life, peaking over 22% for those older than 70-years-old. Tables 1a and 1b describe smoking status by study year and decade of life, respectively.

Table 2 displays the costs for American adults in 2011 – 2015 by smoking status. In Model 1, mean annual medical expenditures for US adults were $4,830. Costs for adult Never smokers were below the national average ($4,360). Former smokers had the highest annual medical expenses, $5,590 (28% increase over never smokers). Although Current smokers had lower average costs than Former smokers at $5,144 (18% increase over Never smokers), the 95% confidence intervals (CIs) overlap for Current and Former smokers. If we combine Current and Former smokers into Ever smokers and re-run Model 1, the average costs for someone who has ever smoked is $5,400 (95% CI = 5142 – 5659).

In Table 3, a sensitivity analysis for Model 2 that includes years-since-quitting for former smokers does not find a direct relationship between time since smoking cessation and medical expenditures. The mean expenditures by cessation period have small differences, and the 95% CIs greatly overlap. Table 4 identifies that the medical expenditures also are greater for Former smokers at each age decade, for ages 20 through 80. The 95% CIs for Never smokers in Table 4

do not contain the estimate for Former smokers at each decade. The CIs for Former smokers do not contain the estimate for Never smokers at all decades except for age 20. The 95% CIs for Current smokers at each decade include both the Never and Former smoker estimates, and the CIs for Never and Former smokers include the estimate for Current smokers.

Multiplying costs by average number of smokers for 2011 – 2015, current smokers incurred $101.4 billion in average annual medical expenses, $15 billion above the costs for a demographically comparable number of Never smokers. Former smokers incurred an average of $133.6 billion in annual medical expenditures, a $29 billion increase over comparable Never smokers. Average annual medical expenditures for Ever smokers are $235.6 billion, approximately $45 billion above the costs for a demographically comparable number of Never smokers.

Discussion

We updated the national estimates for smoking costs in American adults through 2015 using state-of-the-science economic modeling techniques. Our estimates for annual medical expenditures for all civilian non-institutionalized adults was $4,830 for 2011 – 2015. This estimate for the study period was close to Mitchell and Machlin's[22] estimate of average total medical expenditures in 2015 using MEPS data ($4,978). Our estimate for annual expenditures and marginal costs due to smoking are below similar estimates generated using the National Health Expenditure Assessment (NHEA) database[23, 24]. However, the NHEA is more comprehensive than the MEPS in capturing Medicaid costs covering institutionalized adults[24, 25], so identifying lower estimate in MEPS is to be expected.

We find that Former smokers have greater annual medical costs over Current and Never smokers; however, the 95% confident intervals overlap for Current and Former smokers in the main model. Surely, some smokers quit after diagnosis of costly health problems linked to smoking, but the cost differential narrows only slightly after controlling for major chronic conditions (many of which are linked to smoking). Especially at younger ages, quitting appears to be more likely to sort smokers by health consciousness and associated use of medical care.

Some older studies compared medical spending per capita among current, former, and never smokers. Using data from the 1987 National Medical Expenditure Survey (NMES), Miller and colleagues [1999] identified higher annual medical expenditures in former smokers over current smokers. Contrasting with the national studies, two studies using local claims data[26, 27] found that medial expenditures for current and former smokers were nearly identical, with a slight spike in costs for former smokers immediately following quitting.

Some current smokers may experience very high cost medical expenditures over a short period before dying (and thus not incurring any further costs), while former smokers may continue to amass lower cost medical encounters. These former smokers would be gaining up to 10 years of survival and medical expenditures over current smokers[28]. Current smokers also may simply be doctor-phobic, anxious to avoid yet another lecture about their smoking. The persistence and perversity of our finding that higher medical expenditures in former smokers at all ages and regardless of time-since-quitting, suggests exploring the issue using qualitative methods.

We followed the methods of Xu and colleagues[5] and Max and colleagues[7-9] to identify current, former, and never smokers in NHIS/MEPS data. Those studies examined attributable fractions (AFs) for medical expenditures rather than costs to individuals. The two-part model developed by Manning and colleagues has become the gold-standard for estimating costs in a skewed sample, such as medical expenditures[12, 29]. It has been used to study the impact of smoking on healthcare costs across a wide variety of databases[6, 30, 31]. An analysis from An[6] using the two-stage model was performed on medical expenditures associated with smoking status (ever vs. never) and obesity (< 30 BMI vs. 30 ≥ BMI) using MEPS data from 1998 to 2011. In contrast to the present study, An's estimated expenditures did not control for quit status, marital status, family income, family size, or pregnancy. Our estimated cost differences between ever/never smokers and obese/non-obese individuals (data not shown) were lower than in the An study. We believe that the inclusion of quit status and additional personal characteristics in the two-stage models increases the precision of our estimate over this prior study.

Limitations and Strengths

Many of the prior studies assessing the impact of behavioral risk factors on medical expenditures employ the traditional attributable fraction approach, which constructs costs from selected acute and chronic conditions related to the individual risk factors of interest. This method is appropriate unless a study echoes our aim to examine the marginal effects of the risk behaviors on costs to individuals. Using the two-part model[12], our study provides a different assessment of medical expenditures than the attributable fraction method. Attributable fraction studies estimate the smoking-related medical costs incurred in treated diseases that resulted from

smoking. The two-stage modelling approach instead looks at the overall medical spending of the smoking cohort. It can be strongly influenced by a difference in care-seeking propensity.

Our estimates for prevalence of smoking (9%) are lower than those found in other surveillance studies. The Behavioral Risk Factor Surveillance System (BRFSS) identified 15% of American adults as current smokers in 2015[32]. This discrepancy between BRFSS and NHIS data may be due to different modes of data collection. While BRFSS collects data through telephone surveys, NHIS collects data via within-household, in-person interviews. Unlike NHIS, BRFSS data collection is de-centralized as is the responsibility of each state health department.

The goal of this study was to update medical expenditures for smoking to 2015. It was beyond the scope of the study to assess spending by type of medical service utilized. With sufficient budget, doing so might have allowed us to propose more hypotheses as to why certain risks had increased costs over others, as Sturm[33] did for obesity and problem drinking.

In a period of low inflation, we chose to control for inflation in our multi-year analysis of expenditures by including dummy variables for MEPS year rather than using price adjusters that assume a fixed market basket of medical services. The dummy variables should account not only for year-to-year changes in costs, but for other endogenous temporal effects. Those effects include the many policy features of 2010's Affordable Care Act that went into effect from 2011 to 2015[34].

Conclusion

Our data fill a niche by updating medical expenditures nationwide across current smoking status. One clear application of our estimates is in computing the medical spending foregone because behavioral risk-takers have elevated risks of morbidity and mortality. Although tobacco cessation cause declines in chronic illness, early mortality, and associated costs, it appears they may not decrease annual medical expenditures per survivor. That finding suggests studies of return on investment in smoking cessation that use attributable-fraction-based costs may yield skewed results.

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Patient and Public Involvement- Cohort Description

The data for this study were obtained from two datasets generated by the U.S. Department of Health and Human Services: the National Health Interview Survey (NHIS) and the Medical Expenditure Panel Survey (MEPS). Both surveys are samples of American adults that can be used to generate weighted estimates of medical care in the U.S. These pre-existing data were not identified to the researchers, so we could not contact them nor involve them in any aspect of the study design and analysis.

Data Sharing-

Data used in this study are held by AHRQ and U.S. DHHS and were used by agreement with the researchers. Raw data used in this study cannot be shared.

Author contributions

SLB, TRM, and DIS conceived of the study. DIS, GW, and TRM designed the analysis. DIS conducted the analysis. DIS and BA wrote and edited drafts of the manuscript. All authors provided input on the manuscript and approved of the final draft.

Competing interests:

All authors state that they have no competing interests.

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Table 1. Prevalence of smoking by year of MEPS data collection (a) and decade of age (b). Average participants in each category were developed using survey weights.

Table 1a	Smoking status by year of medical expenditure					
	2011	2012	2013	2014	2015	n
Current	7.7%	8.7%	8.4%	7.9%	7.3%	19,716,719
Never	83.7%	81.6%	81.6%	81.6%	82.4%	206,862,703
Former	8.6%	9.7%	10.0%	10.5%	10.3%	23,900,571
Table 1b	Smoking status by decade of life					
	18-30	31-40	41-50	51-60	61-70	70+
Current	6.8%	9.8%	9.2%	9.6%	7.4%	4.4%
Never	90.5%	83.2%	83.8%	79.8%	76.8%	73.3%
Former	2.7%	7.0%	7.1%	10.6%	15.7%	22.3%

Table 2. Results of the two-part model for smoking status on mean medical expenditures per year, 2011 – 2015. Model 1 included smoking and personal characteristics only [a]. Model 2 included personal characteristics, smoking, and comorbidities [b]. (CI = Confidence interval)

	Model 1		Model 2	
	Mean cost	95% CI	Mean cost	95% CI
Never Smoker	$4,360	4154.3 - 4566.3	$4,499	4219.6 - 4778.9
Current Smoker	$5,144	4707.9 - 5580.3	$4,647	4186.9 - 5107.0
Former Smoker	$5,590	5267.4 - 5913.5	$5,012	4618.4 - 5406.4

[a] Covariates included in Model 1 were age (continuous), gender, race/ethnicity (White, African American, Asian, Hispanic origin, Other), education (No high school degree, High school or some college, At least college graduate), marital status (Single/Never married, Current married, Widowed/Divorced/Separated), Pregnancy in the prior year, employment status (Unemployed, Employed, Full-time student, Never worked, Retired), logged-total family income, insurance status (Private, Any public insurance (under age 65), Medicare/Medicaid+, Uninsured), family size, year dummy variables, any binge drinking in the prior year, and BMI (Normal weight or Underweight, Overweight or Obese).

[b] In addition to the variables in Model 1, a history of the following conditions were added to Model 2: any cancer, diabetes, asthma, arthritis, cardiovascular disease (angina, coronary heart disease, myocardial infarction, or stroke), emphysema, quality of life calculated from Short Form 12, depression calculated from the Personal Health Questionnaire, and mental illness from the Kessler 6 questionnaire.

Table 3. Results of separate runs of the two-part model of mean medical expenditures for Former smokers using 1-, 2-, and 5-year thresholds for years-since-quitting smoking. (CI = Confidence interval)

Years since quitting	Mean	95% CI
1 or fewer years	$5,036	3604.4 - 6646.6
More than 1 year	$5,006	4588.8 - 5422.3
2 or fewer years	$5,132	4035.0 - 6229.6
More than 2 years	$4,986	4543.6 - 5429.1
5 or fewer years	$4,957	4182.8 - 5730.7
More than 5 years	$5,028	4551.1 - 5505.2

Table 4. Average annual medical expenditures in American adults for 2011 – 2015 by age for smoking status from a two-part model including personal characteristics and disease history at each decade, age 20 – 80.

	Age							
	20		30		40		50	
Smoking status	Estimate	95% CI	Estimate	95% CI	Estimate	95% CI	Estimate	95% CI
Never	$2,743	(2366, 3151)	$3,214	(2857, 3571)	$3,763	(3472, 4054)	$4,401	(4160, 4642)
Current	$2,909	(2390, 3428)	$3,413	(2928, 3897)	$4,000	(3561, 4438)	$4,683	(4284, 5081)
Former	$3,208	(2704, 3711)	$3,754	(3301, 4208)	$4,390	(3947, 4783)	$5,130	(4776, 5483)
	Age							
	60		70		80			
Smoking status	Estimate	95% CI	Estimate	95% CI	Estimate	95% CI		
Never	$5,143	(4846, 5440)	$6,007	(5505, 6508)	$7,010	(6184, 7836)		
Current	$5,478	(5059, 5897)	$6,403	(5839, 6968)	$7,479	(6627, 8331)		
Former	$5,990	(5574, 6407)	$6,990	(6357, 7623)	$8,153	(7160, 9145)		

CHEERS Checklist
Items to include when reporting economic evaluations of health interventions

The **ISPOR CHEERS Task Force Report**, *Consolidated Health Economic Evaluation Reporting Standards (CHEERS)—Explanation and Elaboration: A Report of the ISPOR Health Economic Evaluations Publication Guidelines Good Reporting Practices Task Force,* provides examples and further discussion of the 24-item CHEERS Checklist and the CHEERS Statement. It may be accessed via the *Value in Health* or via the ISPOR Health Economic Evaluation Publication Guidelines – CHEERS: Good Reporting Practices webpage: http://www.ispor.org/TaskForces/EconomicPubGuidelines.asp

Section/item	Item No	Recommendation	Reported on page No/ line No
Title and abstract			
Title	1	Identify the study as an economic evaluation or use more specific terms such as "cost-effectiveness analysis", and describe the interventions compared.	Title Page
Abstract	2	Provide a structured summary of objectives, perspective, setting, methods (including study design and inputs), results (including base case and uncertainty analyses), and conclusions.	P1 Line 2-19
Introduction			
Background and objectives	3	Provide an explicit statement of the broader context for the study. Present the study question and its relevance for health policy or practice decisions.	P1-2
Methods			
Target population and subgroups	4	Describe characteristics of the base case population and subgroups analysed, including why they were chosen.	P4 L6-16
Setting and location	5	State relevant aspects of the system(s) in which the decision(s) need(s) to be made.	N/A
Study perspective	6	Describe the perspective of the study and relate this to the costs being evaluated.	P4 L7
Comparators	7	Describe the interventions or strategies being compared and state why they were chosen.	P4 11-16
Time horizon	8	State the time horizon(s) over which costs and consequences are being evaluated and say why appropriate.	P3-P4
Discount rate	9	Report the choice of discount rate(s) used for costs and outcomes and say why appropriate.	P11 L16-21
Choice of health outcomes	10	Describe what outcomes were used as the measure(s) of benefit in the evaluation and their relevance for the type of analysis performed.	N/A
Measurement of effectiveness	11a	*Single study-based estimates:* Describe fully the design features of the single effectiveness study and why the single study was a sufficient source of clinical effectiveness data.	N/A

	11b	*Synthesis-based estimates:* Describe fully the methods used for identification of included studies and synthesis of clinical effectiveness data.	N/A
Measurement and valuation of preference based outcomes	12	If applicable, describe the population and methods used to elicit preferences for outcomes.	N/A
Estimating resources and costs	13a	*Single study-based economic evaluation:* Describe approaches used to estimate resource use associated with the alternative interventions. Describe primary or secondary research methods for valuing each resource item in terms of its unit cost. Describe any adjustments made to approximate to opportunity costs.	—
	13b	*Model-based economic evaluation:* Describe approaches and data sources used to estimate resource use associated with model health states. Describe primary or secondary research methods for valuing each resource item in terms of its unit cost. Describe any adjustments made to approximate to opportunity costs.	P4-6
Currency, price date, and conversion	14	Report the dates of the estimated resource quantities and unit costs. Describe methods for adjusting estimated unit costs to the year of reported costs if necessary. Describe methods for converting costs into a common currency base and the exchange rate.	P11
Choice of model	15	Describe and give reasons for the specific type of decision-analytical model used. Providing a figure to show model structure is strongly recommended.	P2-3
Assumptions	16	Describe all structural or other assumptions underpinning the decision-analytical model.	P2,3,6
Analytical methods	17	Describe all analytical methods supporting the evaluation. This could include methods for dealing with skewed, missing, or censored data; extrapolation methods; methods for pooling data; approaches to validate or make adjustments (such as half cycle corrections) to a model; and methods for handling population heterogeneity and uncertainty.	P2-6, 10, 11
Results			
Study parameters	18	Report the values, ranges, references, and, if used, probability distributions for all parameters. Report reasons or sources for distributions used to represent uncertainty where appropriate. Providing a table to show the input values is strongly recommended.	P7, T1
Incremental costs and outcomes	19	For each intervention, report mean values for the main categories of estimated costs and outcomes of interest, as well as mean differences between the comparator groups. If applicable, report incremental cost-effectiveness ratios.	T1
Characterising uncertainty	20a	*Single study-based economic evaluation:* Describe the effects of sampling uncertainty for the estimated incremental cost and incremental effectiveness parameters, together with the impact	T2-4

		of methodological assumptions (such as discount rate, study perspective).	
	20b	*Model-based economic evaluation:* Describe the effects on the results of uncertainty for all input parameters, and uncertainty related to the structure of the model and assumptions.	
Characterising heterogeneity	21	If applicable, report differences in costs, outcomes, or cost-effectiveness that can be explained by variations between subgroups of patients with different baseline characteristics or other observed variability in effects that are not reducible by more information.	N/A
Discussion			
Study findings, limitations, generalisability, and current knowledge	22	Summarise key study findings and describe how they support the conclusions reached. Discuss limitations and the generalisability of the findings and how the findings fit with current knowledge.	P6-11
Other			
Source of funding	23	Describe how the study was funded and the role of the funder in the identification, design, conduct, and reporting of the analysis. Describe other non-monetary sources of support.	P12
Conflicts of interest	24	Describe any potential for conflict of interest of study contributors in accordance with journal policy. In the absence of a journal policy, we recommend authors comply with International Committee of Medical Journal Editors recommendations.	

For consistency, the CHEERS Statement checklist format is based on the format of the CONSORT statement checklist

The **ISPOR CHEERS Task Force Report** provides examples and further discussion of the 24-item CHEERS Checklist and the CHEERS Statement. It may be accessed via the *Value in Health* link or via the ISPOR Health Economic Evaluation Publication Guidelines – CHEERS: Good Reporting Practices webpage: http://www.ispor.org/TaskForces/EconomicPubGuidelines.asp

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National medical expenditures by smoking status in American adults: an application of Manning's two-stage model to nationally-representative data

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National medical expenditures by smoking status in American adults: an application of Manning's two-stage model to nationally-representative data

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Abstract

Objectives: To assess the medical expenditures of American adults by their smoking status-Current, Former, or Never smokers. We update these expenditures controlling for personal characteristics and medical history and also assess the impact of years-since-quitting and decade of life. **Setting and participants:** Weighted sample of American adults, 2011 – 2015. The linked National Health Interview Survey (NHIS) and Medical Expenditure Panel Survey (MEPS) are annual weighted representations of approximately 250 million adults. Sampling of NHIS is multistage with data collected throughout the year. **Primary outcome measures:** Using data from NHIS and MEPS, we collected demographic data, self-reported medical history, and current smoking status. Smoking status was designated as Never, Current, and Former, along with years-since-quitting. Total medical expenditures were collected from MEPS for 2011 – 2015. We used Manning's two-part model to estimate average expenditures per individual and marginal costs for individuals at all levels of smoking status. **Results**: American adults averaged $4,830 in average medical expenditures. Never smokers ($4,360, 95% CI = 4154.3 – 4566.3), had lower expenditures than Current ($5,244, 95% CI = 4707.9 – 5580.3) and Former ($5,590, 95% CI = 5267.4 – 5913.5) smokers. Confidence intervals for Current and Former smokers overlapped. Results were similarly significant when controlling for disease history. Years-since-quitting did not affect expenditures. In each decade of adult life, Former smokers had the highest annual medical expenditures, followed by Current and then Never smokers. **Conclusions**: We updated annual medical expenditures during the Affordable Care Act-era by smoking status using the current best practice model. While we identify Former smokers as having higher medical expenditures than Current smokers, we do not examine how care-seeking behavior varies between levels of each risk factor.

Article Summary

Strengths and Limitations

- This is the first study to report medical expenditure by smoking status while major provisions of the Affordable Care Act took effect.
- We use the gold standard two-part model developed by Manning to estimate medical expenditures from the MEPS and NHIS surveys.
- We analyzed medical expenditures for Current smokers and Former smokers- both separately and combined- across decades of life.
- Although we controlled for history of comorbidities, the data do not contain any information on reason-for-quitting among former smokers.
- The cost differences observed incorporate any differences between the groups in care-seeking for conditions unrelated to smoking.

Introduction

It is well-established that smoking can lead to medical conditions requiring acute and chronic treatment[1]. Accurate marginal costs for medical risk factors are important when conducting benefit-cost analyses for health risk behavior interventions[2-4]. The most recent national estimates of medical expenditures by smoking status have only considered a binary smoking variable: current smokers versus current non-smokers[5 6]. Further, none of these national studies have analyzed medical expenditure data more recently than 2011. A series of state-level analyses by Max and colleagues[7-9] described medical costs in California by current, former, and never smokers.

The California studies used the attributable fraction (AF) method to allocate medical expenditures. In their review of the AF method, Rockhill and colleagues define attributable fraction and similarly-phrased terms to be "the proportion of disease risk in a population that can be attributed to the causal effects of a risk factor or set of factors," (p. 15) [10]. Rockhill *et al* find that the AF method has limitations, including that it is constrained by how accurately costs are allocated among diagnoses and by the availability of accurate AFs that are not confounded by co-occurring risk factors[10]. The negative outcomes that smokers experience vary widely in nature and timing. Importantly, the method does not measure the standard error for the mean estimated cost per risk-taker[11].

In analyzing the costs of medical conditions, health economics literature has largely shifted from this AF method to analyses of annual per capita medical spending of people with the condition relative to a comparison group[12-15]. This approach, pioneered by Willard Manning [16] captures

both mean and standard error and it accounts for complications that may not be coded to the underlying condition. That is, these equations take a more holistic view of medical care and expenditures associated with risk factors' coefficients than would a process seeking to attribute specified treatment costs to specified factors. It allows that medical visits for conditions related to the behavioral risk factors may displace other medical care that might be sought if an individual did not have a given risk factor. For example, a doctor who is scheduling quarterly visits to manage diabetes is unlikely to separately schedule the annual well-care visit recommended for a healthier patient. That well-care visit gets coded as a chronic care visit even though it may not raise annual medical spending[17].

While the Manning model is now the gold standard for working with skewed outcomes like medical spending, it is an imperfect tool. Although it statistically assigns costs to given risk factors or medical conditions, it does not tell us the "why" behind each individual medical encounter or expense. Medical spending is influenced by care-seeking behavior. Smokers may avoid visiting the doctor because it is uncomfortable to report their continued smoking behavior or tedious to hear the doctor urge them to change[18]. Health consciousness and associated use of preventive care may be below-average for people who engage in risky behavior. Furthermore, drinking heavily may be a symptom of life management issues that reduce care-seeking. Those differences in health management may mask the impacts of risk behavior on medical spending.

Purpose

This study updates the national estimates for annual medical expenditures of adult Americans by their current smoking status. We examine medical expenditure data for 2011 – 2015 and apply

the cutting-edge two-stage Manning model to more accurately assess error around mean expenditures.

Methods

Data Collection

We analyzed data on smoking status from the National Health Interview Survey (NHIS)[19]. The NHIS is an annual, cross-sectional survey designed to monitor health and behaviors of civilian, non-institutionalized Americans through a nationally-representative sample. The Medical Expenditure Panel Survey (MEPS) tracks a nationally representative subsample of NHIS participants for 24 months starting in the year after their NHIS interview. MEPS collects five rounds of data per respondent on healthcare visits and expenditures[20]. It captures all payments for care, regardless of source, and models costs for visits without payment data including charity care and visits bundled into capitated care. We used 2011-2015 MEPS data on total medical expenditures from the individual perspective for adults 18-years and older and the corresponding NHIS 2009 – 2014 data. Annual medical expenditures were inflated to 2015 US dollars (USD) using the Personal Consumption Expenditures- Medical Care. We linked data from MEPS and NHIS via the Agency for Health Care Quality Data Center, as Xu *et al*[5] did in their analyses of smoking costs[6]. Because our use of the publicly-available data adhered to the government's privacy restrictions, the project was given an Exemption by the Institutional Review Board of the Pacific Institute for Research and Evaluation prior to data analysis.

Smoking status was identified through the NHIS Supplemental Adult Questionnaire (SAQ). Like earlier studies, we identified Ever smokers as participants who smoked at least 100 cigarettes in

their lifetimes. We defined all others as Never smokers[6]. Ever smokers were further subdivided into those who reported quitting smoking, Former smokers, versus those who did not report quitting, Current smokers[7-9]. For Former smokers, we also identified years-since-quitting.

To conduct regressions, we included the following demographic and behavioral characteristics: age, sex, race/ethnicity, marital status, total family income, family size, employment status, marital status, self-reported binge drinking status, body mass index (BMI), recent pregnancy, education level, employment, and insurance data from MEPS. Age was employed as a continuous variable in the main analyses and divided into ten-year blocks in the age-specific sensitivity analysis. Binge drinking data were also obtained from the SAQ, which used the accepted binge drinking definition of men having 5 or more drinks and women having 4 or more drinks. Those participants who indicated that they had 12 or more instances of binge drinking in the past year were categorized as frequent binge drinkers, and those who had 1-11 instances were categorized as infrequent binge drinkers. BMI data were calculated from self-reported weight and height in the NHIS. We dichotomized BMI into obese for those with a BMI of 30 kg/m2 or greater, and not obese for those with lower BMI. We refer to these variables collectively as personal characteristics.

NHIS and MEPS had data on self-reported diagnosis history for various diseases. Using data from both databases, we generated dichotomous variables for whether a participant had ever been diagnosed with the following diseases: asthma, arthritis, any cancer, cardiovascular diseases (including angina, coronary heart disease, myocardial infarction, or stroke), diabetes, and emphysema. NHIS had data on chronic obstructive pulmonary disease (COPD) available for

2013 through 2015 MEPS panels. From MEPS, we obtained scores for the Short Form 12 to measure quality of life[21], the Personal Health Questionnaire (PHQ) metric for depression[22], and the Kessler 6 questionnaire for mental illness[23]. From these variables, we were able to code a partial list of comorbidities that Elixhauser and colleagues[24] suggest controlling for when using administrative medical data.

Regression Analysis

We used the two-stage model approach developed by Manning and Basu[16] to model discrete-continuous outcomes. The first regression in this method models whether or not an individual had any medical expenditures in the given year. Then, the second model estimates the costs for individuals who the first model predicted had any costs. We used an ordinary least squares (OLS) logistic probit regression in the first step, followed by a generalized linear model with a generalized Gamma distribution and log link in the second stage. We used the Stata twopm command developed by Belotti and colleagues to execute the two models[25]. The twopm command allowed us to use the survey weights provided by AHRQ. Data were collected and merged using SAS v9.4 analytical software [SAS Institute, Cary, NC]. Data management was performed in SAS and Stata IC v15 [Stata Corp, College Station, TX]. All data analysis was conducted using Stata.

Our main regression model (Model 1) included personal characteristics and current smoking status. We experimented with including body mass index in the model; however, the variable had near 50% missingness, so we excluded it from our final model. (Further sensitivity analysis indicated that body mass had negligible impact on estimated expenditures by smoking status).

We added the disease history to the two-stage model (Model 2). Finally, because COPD comorbidity was only available for the last three years of the study, we excluded COPD and re-ran the model on all five years of the study period. Because controlling for this co-morbidity did not noticeably affect the estimates by smoking status, we chose to report estimates based on 5 years of data, thus increasing our power to probe costs among subgroups. We further expanded Model 2 to include data on years-since-quitting for Former smokers at 1-, 2-, and 5-year thresholds. Because prevalence of these risk factors changes over the life course, we also examined the marginal effects of smoking on medical expenditures by decade of adult life[25]. Non-overlapping confidence intervals indicated statistically significant differences.

Results

An average of 19.7 million adults self-identified as Current smokers in the US from 2011 to 2015. The proportion of current smokers decreased over the study period, to approximately 17.5 million adults in 2015. An average of 43.6 million adults in the U.S. were Ever smokers. The proportion of former smokers increased through decades of life, peaking over 22% for those older than 70-years-old. Tables 1a and 1b describe smoking status by study year and decade of life, respectively. Among the 23.9 million Former smokers, only 4.3% quit within the prior year, 8.7% quit within the prior 2 years, and 24.4% quit within the 5 years prior to the survey.

Table 2 displays the costs for American adults in 2011 – 2015 by smoking status. In Model 1, mean annual medical expenditures for US adults were $4,830. Costs for adult Never smokers were below the national average ($4,360). Former smokers had the highest annual medical expenses, $5,590 (28% increase over never smokers). Although Current smokers had lower

average costs than Former smokers at $5,144 (18% increase over Never smokers), the 95% confidence intervals (CIs) overlap for Current and Former smokers. If we combine Current and Former smokers into Ever smokers and re-run Model 1, the average costs for someone who has ever smoked is $5,400 (95% CI = 5142 – 5659).

In Table 3, a sensitivity analysis for Model 2 that includes years-since-quitting for former smokers does not find a direct relationship between time since smoking cessation and medical expenditures. The mean expenditures by cessation period have small differences, and the 95% CIs greatly overlap. Table 4 identifies displays how medical expenditures vary across decades of life by smoking status. The 95% CIs for Never smokers in Table 4 do not contain the estimate for Former smokers at each decade. The CIs for Former smokers do not contain the estimate for Never smokers at all decades except for age 20. The 95% CIs for Current smokers at each decade include both the Never and Former smoker estimates, and the CIs for Never and Former smokers include the estimate for Current smokers.

Multiplying costs by average number of smokers for 2011 – 2015, Current smokers incurred $101.4 billion in average annual medical expenses (95% CI = 12.6 billion – 14.1 billion), $15 billion above the costs for a demographically comparable number of Never smokers. Former smokers incurred an average of $133.6 billion in annual medical expenditures (95% CI = 9.28 billion – 110 billion), a $29 billion increase over comparable Never smokers. Average annual medical expenditures for Ever smokers are $235.6 billion (95% CI = 224 billion – 247 billion), approximately $45 billion above the costs for a demographically comparable number of Never smokers.

Discussion

We updated the national estimates for smoking costs in American adults through 2015 using state-of-the-science economic modeling techniques. Our estimates for annual medical expenditures for all civilian non-institutionalized adults was $4,830 for 2011 – 2015, in 2015 USD. This estimate for the study period was close to Mitchell and Machlin's[26] estimate of average total medical expenditures in 2015 using MEPS data ($4,978). Our estimate for annual expenditures and marginal costs due to smoking are below similar estimates generated using the National Health Expenditure Assessment (NHEA) database[27 28]. However, the NHEA is more comprehensive than the MEPS in capturing Medicaid costs covering institutionalized adults (including those in nursing homes), active-duty military, and foreign visitors to the US [28 29], so we expected MEPS to yield lower estimates.

We find that Former smokers have greater annual medical costs over Current and Never smokers; however, the 95% confident intervals overlap for Current and Former smokers in the main model. Surely, some smokers quit after diagnosis of costly health problems linked to smoking, but the cost differential narrows only slightly after controlling for major chronic conditions (many of which are linked to smoking). Especially at younger ages, quitting appears to be more likely to sort smokers by health consciousness and associated use of medical care.

Some older studies compared medical spending per capita among current, former, and never smokers. Using data from the 1987 National Medical Expenditure Survey (NMES), Miller and colleagues [1999] identified higher annual medical expenditures in former smokers over current

smokers. Contrasting with the national studies, two studies using local claims data[30 31] found that medial expenditures for current and former smokers were nearly identical, with a slight spike in costs for former smokers immediately following quitting.

Some current smokers may experience very high cost medical expenditures over a short period before dying (and thus not incurring any further costs), while former smokers may continue to amass lower cost medical encounters. These former smokers would be gaining up to 10 years of survival and medical expenditures over current smokers[32]. Current smokers also may simply be doctor-phobic, anxious to avoid yet another lecture about their smoking. The persistence and perversity of our finding that higher medical expenditures in former smokers at all ages and regardless of time-since-quitting, suggests exploring the issue using qualitative methods.

We followed the methods of Xu and colleagues[5] and Max and colleagues[7-9] to identify current, former, and never smokers in NHIS/MEPS data. Those studies examined attributable fractions (AFs) for medical expenditures rather than costs to individuals. The two-part model developed by Manning and colleagues has become the gold-standard for estimating costs in a skewed sample, such as medical expenditures[16 33]. It has been used to study the impact of smoking on healthcare costs across a wide variety of databases[6 34 35]. An analysis from An[6] using the two-stage model was performed on medical expenditures associated with smoking status (ever vs. never) and obesity (< 30 BMI vs. 30 ≥ BMI) using MEPS data from 1998 to 2011. In contrast to the present study, An's estimated expenditures did not control for quit status, marital status, family income, family size, or pregnancy. Our estimated cost differences between ever/never smokers and obese/non-obese individuals (data not shown) were lower than in the An study. We

believe that the inclusion of quit status and additional personal characteristics in the two-stage models increases the precision of our estimate over this prior study.

Limitations and Strengths

Many of the prior studies assessing the impact of behavioral risk factors on medical expenditures employ the traditional attributable fraction approach, which constructs costs from selected acute and chronic conditions related to the individual risk factors of interest. This method is appropriate unless a study echoes our aim to examine the marginal effects of the risk behaviors on costs to individuals. Using the two-part model[16], our study provides a different assessment of medical expenditures than the attributable fraction method. Attributable fraction studies estimate the smoking-related medical costs incurred in treated diseases that resulted from smoking. The two-stage modelling approach instead looks at the overall medical spending of the smoking cohort. It can be strongly influenced by a difference in care-seeking propensity.

Our estimates for prevalence of smoking (9%) are lower than those found in other surveillance studies. The Behavioral Risk Factor Surveillance System (BRFSS) identified 15% of American adults as current smokers in 2015[36]. This discrepancy between BRFSS and NHIS data may be due to different modes of data collection. While BRFSS collects data through telephone surveys, NHIS collects data via within-household, in-person interviews. Unlike NHIS, BRFSS data collection is de-centralized as is the responsibility of each state health department.

The goal of this study was to update medical expenditures for smoking to 2015. It was beyond the scope of the study to assess spending by type of medical service utilized. With sufficient

budget, doing so might have allowed us to propose more hypotheses as to why certain risks had increased costs over others, as Sturm[37] did for obesity and problem drinking.

In a period of low inflation, we chose to control for inflation in our multi-year analysis of expenditures by including dummy variables for MEPS year rather than using price adjusters that assume a fixed market basket of medical services. The dummy variables should account not only for year-to-year changes in costs, but for other endogenous temporal effects. Those effects include the many policy features of 2010's Affordable Care Act that went into effect from 2011 to 2015[38].

Conclusion

Our data fill a niche by updating medical expenditures nationwide across current smoking status. One clear application of our estimates is in computing the medical spending foregone because behavioral risk-takers have elevated risks of morbidity and mortality. Although tobacco cessation cause declines in chronic illness, early mortality, and associated costs, it appears they may not decrease annual medical expenditures per survivor. That finding suggests studies of return on investment in smoking cessation that use attributable-fraction-based costs may yield skewed results.

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Patient and Public Involvement- Cohort Description

The data for this study were obtained from two datasets generated by the U.S. Department of Health and Human Services: The National Health Interview Survey (NHIS) and the Medical Expenditure Panel Survey (MEPS). Both surveys are samples of American adults that can be used to generate weighted estimates of medical care in the U.S. These pre-existing data were not identified to the researchers, so we could not contact them nor involve them in any aspect of the study design and analysis.

Data Sharing-

Data used in this study are held by AHRQ and U.S. DHHS and were used by agreement with the researchers. Raw data used in this study cannot be shared.

Author contributions

SLB, TRM, and DIS conceived of the study. DIS, GW, and TRM designed the analysis. DIS conducted the analysis. DIS and BA wrote and edited drafts of the manuscript. All authors provided input on the manuscript and approved of the final draft.

Competing interests:

All authors state that they have no competing interests.

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Table 1. Prevalence of smoking by year of MEPS data collection (a) and decade of age (b). Average participants in each category were developed using survey weights.

Table 1a	Smoking status by year of medical expenditure					
	2011	2012	2013	2014	2015	n
Current	7.7%	8.7%	8.4%	7.9%	7.3%	19,716,719
Never	83.7%	81.6%	81.6%	81.6%	82.4%	206,862,703
Former	8.6%	9.7%	10.0%	10.5%	10.3%	23,900,571
Table 1b	Smoking status by decade of life					
	18-30	31-40	41-50	51-60	61-70	70+
Current	6.8%	9.8%	9.2%	9.6%	7.4%	4.4%
Never	90.5%	83.2%	83.8%	79.8%	76.8%	73.3%
Former	2.7%	7.0%	7.1%	10.6%	15.7%	22.3%

Table 2. Results of the two-part model for smoking status on mean medical expenditures per year, 2011 – 2015, in 2015 US$. Model 1 included smoking and personal characteristics only [a]. Model 2 included personal characteristics, smoking, and comorbidities [b]. (CI = Confidence interval)

	Model 1		Model 2	
	Mean cost	95% CI	Mean cost	95% CI
Never Smoker	$4,360	4154.3 - 4566.3	$4,499	4219.6 - 4778.9
Current Smoker	$5,144	4707.9 - 5580.3	$4,647	4186.9 - 5107.0
Former Smoker	$5,590	5267.4 - 5913.5	$5,012	4618.4 - 5406.4

[a] Covariates included in Model 1 were age (continuous), gender, race/ethnicity (White, African American, Asian, Hispanic origin, Other), education (No high school degree, High school or some college, At least college graduate), marital status (Single/Never married, Current married, Widowed/Divorced/Separated), Pregnancy in the prior year, employment status (Unemployed, Employed, Full-time student, Never worked, Retired), logged-total family income, insurance status (Private, Any public insurance (under age 65), Medicare/Medicaid+, Uninsured), family size, year dummy variables, any binge drinking in the prior year, and BMI (Normal weight or Underweight, Overweight or Obese).

[b] In addition to the variables in Model 1, a history of the following conditions were added to Model 2: any cancer, diabetes, asthma, arthritis, cardiovascular disease (angina, coronary heart disease, myocardial infarction, or stroke), emphysema, quality of life calculated from Short Form 12, depression calculated from the Personal Health Questionnaire, and mental illness from the Kessler 6 questionnaire.

Table 3. Results of separate runs of the two-part model of mean medical expenditures for Former smokers using 1-, 2-, and 5-year thresholds for years-since-quitting smoking. (CI = Confidence interval) in 2015 US$.

Years since quitting	Mean	95% CI
1 or fewer years	$5,036	3604.4 - 6646.6
More than 1 year	$5,006	4588.8 - 5422.3
2 or fewer years	$5,132	4035.0 - 6229.6
More than 2 years	$4,986	4543.6 - 5429.1
5 or fewer years	$4,957	4182.8 - 5730.7
More than 5 years	$5,028	4551.1 - 5505.2

Table 4. Average annual medical expenditures in 2011 – 2015 for American adults of selected ages by smoking status, from a two-part model including personal characteristics and disease history at each decade of life ages 20 – 80, in 2015 US$.

	Age							
	20		30		40		50	
Smoking status	Estimate	95% CI	Estimate	95% CI	Estimate	95% CI	Estimate	95% CI
Never	$2,743	(2366, 3151)	$3,214	(2857, 3571)	$3,763	(3472, 4054)	$4,401	(4160, 4642)
Current	$2,909	(2390, 3428)	$3,413	(2928, 3897)	$4,000	(3561, 4438)	$4,683	(4284, 5081)
Former	$3,208	(2704, 3711)	$3,754	(3301, 4208)	$4,390	(3947, 4783)	$5,130	(4776, 5483)
	Age							
	60		70		80			
Smoking status	Estimate	95% CI	Estimate	95% CI	Estimate	95% CI		
Never	$5,143	(4846, 5440)	$6,007	(5505, 6508)	$7,010	(6184, 7836)		
Current	$5,478	(5059, 5897)	$6,403	(5839, 6968)	$7,479	(6627, 8331)		
Former	$5,990	(5574, 6407)	$6,990	(6357, 7623)	$8,153	(7160, 9145)		

CHEERS Checklist
Items to include when reporting economic evaluations of health interventions

The **ISPOR CHEERS Task Force Report**, *Consolidated Health Economic Evaluation Reporting Standards (CHEERS)—Explanation and Elaboration: A Report of the ISPOR Health Economic Evaluations Publication Guidelines Good Reporting Practices Task Force,* provides examples and further discussion of the 24-item CHEERS Checklist and the CHEERS Statement. It may be accessed via the *Value in Health* or via the ISPOR Health Economic Evaluation Publication Guidelines – CHEERS: Good Reporting Practices webpage: http://www.ispor.org/TaskForces/EconomicPubGuidelines.asp

Section/item	Item No	Recommendation	Reported on page No/ line No
Title and abstract			
Title	1	Identify the study as an economic evaluation or use more specific terms such as "cost-effectiveness analysis", and describe the interventions compared.	Title Page
Abstract	2	Provide a structured summary of objectives, perspective, setting, methods (including study design and inputs), results (including base case and uncertainty analyses), and conclusions.	P1 Line 2-19
Introduction			
Background and objectives	3	Provide an explicit statement of the broader context for the study. Present the study question and its relevance for health policy or practice decisions.	P1-2
Methods			
Target population and subgroups	4	Describe characteristics of the base case population and subgroups analysed, including why they were chosen.	P4 L6-16
Setting and location	5	State relevant aspects of the system(s) in which the decision(s) need(s) to be made.	N/A
Study perspective	6	Describe the perspective of the study and relate this to the costs being evaluated.	P4 L7
Comparators	7	Describe the interventions or strategies being compared and state why they were chosen.	P4 11-16
Time horizon	8	State the time horizon(s) over which costs and consequences are being evaluated and say why appropriate.	P3-P4
Discount rate	9	Report the choice of discount rate(s) used for costs and outcomes and say why appropriate.	P11 L16-21
Choice of health outcomes	10	Describe what outcomes were used as the measure(s) of benefit in the evaluation and their relevance for the type of analysis performed.	N/A
Measurement of effectiveness	11a	*Single study-based estimates:* Describe fully the design features of the single effectiveness study and why the single study was a sufficient source of clinical effectiveness data.	N/A

	11b	*Synthesis-based estimates:* Describe fully the methods used for identification of included studies and synthesis of clinical effectiveness data.	N/A
Measurement and valuation of preference based outcomes	12	If applicable, describe the population and methods used to elicit preferences for outcomes.	N/A
Estimating resources and costs	13a	*Single study-based economic evaluation:* Describe approaches used to estimate resource use associated with the alternative interventions. Describe primary or secondary research methods for valuing each resource item in terms of its unit cost. Describe any adjustments made to approximate to opportunity costs.	—
	13b	*Model-based economic evaluation:* Describe approaches and data sources used to estimate resource use associated with model health states. Describe primary or secondary research methods for valuing each resource item in terms of its unit cost. Describe any adjustments made to approximate to opportunity costs.	P4-6
Currency, price date, and conversion	14	Report the dates of the estimated resource quantities and unit costs. Describe methods for adjusting estimated unit costs to the year of reported costs if necessary. Describe methods for converting costs into a common currency base and the exchange rate.	P11
Choice of model	15	Describe and give reasons for the specific type of decision-analytical model used. Providing a figure to show model structure is strongly recommended.	P2-3
Assumptions	16	Describe all structural or other assumptions underpinning the decision-analytical model.	P2,3,6
Analytical methods	17	Describe all analytical methods supporting the evaluation. This could include methods for dealing with skewed, missing, or censored data; extrapolation methods; methods for pooling data; approaches to validate or make adjustments (such as half cycle corrections) to a model; and methods for handling population heterogeneity and uncertainty.	P2-6, 10, 11
Results			
Study parameters	18	Report the values, ranges, references, and, if used, probability distributions for all parameters. Report reasons or sources for distributions used to represent uncertainty where appropriate. Providing a table to show the input values is strongly recommended.	P7, T1
Incremental costs and outcomes	19	For each intervention, report mean values for the main categories of estimated costs and outcomes of interest, as well as mean differences between the comparator groups. If applicable, report incremental cost-effectiveness ratios.	T1
Characterising uncertainty	20a	*Single study-based economic evaluation:* Describe the effects of sampling uncertainty for the estimated incremental cost and incremental effectiveness parameters, together with the impact	T2-4

		of methodological assumptions (such as discount rate, study perspective).	
	20b	*Model-based economic evaluation:* Describe the effects on the results of uncertainty for all input parameters, and uncertainty related to the structure of the model and assumptions.	
Characterising heterogeneity	21	If applicable, report differences in costs, outcomes, or cost-effectiveness that can be explained by variations between subgroups of patients with different baseline characteristics or other observed variability in effects that are not reducible by more information.	N/A
Discussion			
Study findings, limitations, generalisability, and current knowledge	22	Summarise key study findings and describe how they support the conclusions reached. Discuss limitations and the generalisability of the findings and how the findings fit with current knowledge.	P6-11
Other			
Source of funding	23	Describe how the study was funded and the role of the funder in the identification, design, conduct, and reporting of the analysis. Describe other non-monetary sources of support.	P12
Conflicts of interest	24	Describe any potential for conflict of interest of study contributors in accordance with journal policy. In the absence of a journal policy, we recommend authors comply with International Committee of Medical Journal Editors recommendations.	

For consistency, the CHEERS Statement checklist format is based on the format of the CONSORT statement checklist

The **ISPOR CHEERS Task Force Report** provides examples and further discussion of the 24-item CHEERS Checklist and the CHEERS Statement. It may be accessed via the *Value in Health* link or via the ISPOR Health Economic Evaluation Publication Guidelines – CHEERS: Good Reporting Practices webpage: http://www.ispor.org/TaskForces/EconomicPubGuidelines.asp

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National medical expenditures by smoking status in American adults: an application of Manning's two-stage model to nationally-representative data

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National medical expenditures by smoking status in American adults: an application of Manning's two-stage model to nationally-representative data

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Abstract

Objectives: To assess the medical expenditures of American adults by their smoking status-Current, Former, or Never smokers. We update these expenditures through 2015 controlling for personal characteristics and medical history and assess the impact of years-since-quitting and decade of life. **Setting and participants:** Weighted sample of American adults, 2011 – 2015. The linked National Health Interview Survey (NHIS) and Medical Expenditure Panel Survey (MEPS) are annual weighted representations of approximately 250 million adults. Sampling of NHIS is multistage with data collected throughout the year. **Primary outcome measures:** Using data from NHIS and MEPS, we collected demographic data, self-reported medical history, and current smoking status. Smoking status was designated as Never, Current, and Former, along with years-since-quitting. Total medical expenditures were collected from MEPS for 2011 – 2015. We used Manning's two-part model to estimate average expenditures per individual and marginal costs for individuals at all levels of smoking status. **Results**: American adults averaged $4,830 in average medical expenditures. Never smokers ($4,360, 95% CI = 4154.3 – 4566.3), had lower expenditures than Current ($5,244, 95% CI = 4707.9 – 5580.3) and Former ($5,590, 95% CI = 5267.4 – 5913.5) smokers. Confidence intervals for Current and Former smokers overlapped. Results were similarly significant when controlling for disease history. Years-since-quitting did not affect expenditures. In each decade of adult life, Former smokers had the highest annual medical expenditures, followed by Current and then Never smokers. **Conclusions**: We updated annual medical expenditures during the Affordable Care Act-era by smoking status using the current best practice model. While we identify Former smokers as having higher medical expenditures than Current smokers, we do not examine how care-seeking behavior varies between levels of each risk factor.

Article Summary

Strengths and Limitations

- By using data from 2011 – 2015, this is the first study to report medical expenditure by smoking status while major provisions of the Affordable Care Act took effect.
- We use the gold standard two-part model developed by Manning to estimate medical expenditures from the MEPS and NHIS surveys.
- We analyzed medical expenditures for Current smokers and Former smokers- both separately and combined- across decades of life.
- Although we controlled for history of comorbidities, the data do not contain any information on reason-for-quitting among former smokers.
- The cost differences observed incorporate any differences between the groups in care-seeking for conditions unrelated to smoking.

Introduction

It is well-established that smoking can lead to medical conditions requiring acute and chronic treatment[1]. Accurate marginal costs for medical risk factors are important when conducting benefit-cost analyses for health risk behavior interventions[2-4]. The most recent national estimates of medical expenditures by smoking status have only considered a binary smoking variable: current smokers versus current non-smokers[5 6]. Further, none of these national studies have analyzed medical expenditure data more recently than 2011. Since that time, major reforms have been implemented to the medical care systems in the United State (US). [7]

A series of state-level analyses by Max and colleagues[8-10] described medical costs in California by current, former, and never smokers. The California studies used the attributable fraction (AF) method to allocate medical expenditures. In their review of the AF method, Rockhill and colleagues define attributable fraction and similarly-phrased terms to be "the proportion of disease risk in a population that can be attributed to the causal effects of a risk factor or set of factors," (p. 15) [11]. Rockhill *et al* find that the AF method has limitations, including that it is constrained by how accurately costs are allocated among diagnoses and by the availability of accurate AFs that are not confounded by co-occurring risk factors[11]. The negative outcomes that smokers experience vary widely in nature and timing. Importantly, the method does not measure the standard error for the mean estimated cost per risk-taker[12].

In summary, the AF method has too much uncertainty in risk factor allocation as well as calculation of standard errors. In analyzing the costs of medical conditions, health economics literature has largely shifted from this AF method to analyses of annual per capita medical

spending of people with the condition relative to a comparison group[13-16]. This approach, pioneered by Willard Manning [17] captures both mean and standard error and it accounts for complications that may not be coded to the underlying condition. That is, these equations take a more holistic view of medical care and expenditures associated with risk factors' coefficients than would a process seeking to attribute specified treatment costs to specified factors. It allows that medical visits for conditions related to the behavioral risk factors may displace other medical care that might be sought if an individual did not have a given risk factor. For example, a doctor who is scheduling quarterly visits to manage diabetes is unlikely to separately schedule the annual well-care visit recommended for a healthier patient. That well-care visit gets coded as a chronic care visit even though it may not raise annual medical spending[18].

While the Manning model is now the gold standard for working with skewed outcomes like medical spending, it is an imperfect tool. Although it statistically assigns costs to given risk factors or medical conditions, it does not tell us the "why" behind each individual medical encounter or expense. Medical spending is influenced by care-seeking behavior. Smokers may avoid visiting the doctor because it is uncomfortable to report their continued smoking behavior or tedious to hear the doctor urge them to change[19]. Health consciousness and associated use of preventive care may be below-average for people who engage in risky behavior. Furthermore, drinking heavily may be a symptom of life management issues that reduce care-seeking. Those differences in health management may mask the impacts of risk behavior on medical spending.

Purpose

This study updates the national estimates during the implementation of many major provisions of the Patient Protection and Affordable Care Act (ACA) for annual medical expenditures of adult Americans by their current smoking status. We examine medical expenditure data for 2011 – 2015 and apply the cutting-edge two-stage Manning model to more accurately assess error around mean expenditures.

Methods

Data Collection

We analyzed data on smoking status from the National Health Interview Survey (NHIS)[20]. The NHIS is an annual, cross-sectional survey designed to monitor health and behaviors of civilian, non-institutionalized Americans through a nationally-representative sample. The Medical Expenditure Panel Survey (MEPS) tracks a nationally representative subsample of NHIS participants for 24 months starting in the year after their NHIS interview. MEPS collects five rounds of data per respondent on healthcare visits and expenditures[21]. It captures all payments for care, regardless of source, and models costs for visits without payment data including charity care and visits bundled into capitated care. We used 2011-2015 MEPS data on total medical expenditures from the individual perspective for adults 18-years and older and the corresponding NHIS 2009 – 2014 data. Annual medical expenditures were inflated to 2015 US dollars (USD) using the Personal Consumption Expenditures- Medical Care. We linked data from MEPS and NHIS via the Agency for Health Care Quality Data Center, as Xu *et al*[5] did in their analyses of smoking costs[6]. Because our use of the publicly-available data adhered to the government's privacy restrictions, the project was given an Exemption by the Institutional Review Board of the Pacific Institute for Research and Evaluation prior to data analysis.

Smoking status was identified through the NHIS Supplemental Adult Questionnaire (SAQ). Like earlier studies, we identified Ever smokers as participants who smoked at least 100 cigarettes in their lifetimes. We defined all others as Never smokers[6]. Ever smokers were further subdivided into those who reported quitting smoking, Former smokers, versus those who did not report quitting, Current smokers[8-10]. For Former smokers, we also identified years-since-quitting.

To conduct regressions, we included the following demographic and behavioral characteristics: age, sex, race/ethnicity, marital status, total family income, family size, employment status, marital status, self-reported binge drinking status, body mass index (BMI), recent pregnancy, education level, employment, and insurance data from MEPS. Age was employed as a continuous variable in the main analyses and divided into ten-year blocks in the age-specific sensitivity analysis. Binge drinking data were also obtained from the SAQ, which used the accepted binge drinking definition of men having 5 or more drinks and women having 4 or more drinks. Those participants who indicated that they had 12 or more instances of binge drinking in the past year were categorized as frequent binge drinkers, and those who had 1-11 instances were categorized as infrequent binge drinkers. BMI data were calculated from self-reported weight and height in the NHIS. We dichotomized BMI into obese for those with a BMI of 30 kg/m2 or greater, and not obese for those with lower BMI. We refer to these variables collectively as personal characteristics.

NHIS and MEPS had data on self-reported diagnosis history for various diseases. Using data from both databases, we generated dichotomous variables for whether a participant had ever

been diagnosed with the following diseases: asthma, arthritis, any cancer, cardiovascular diseases (including angina, coronary heart disease, myocardial infarction, or stroke), diabetes, and emphysema. NHIS had data on chronic obstructive pulmonary disease (COPD) available for 2013 through 2015 MEPS panels. From MEPS, we obtained scores for the Short Form 12 to measure quality of life[22], the Personal Health Questionnaire (PHQ) metric for depression[23], and the Kessler 6 questionnaire for mental illness[24]. From these variables, we were able to code a partial list of comorbidities that Elixhauser and colleagues[25] suggest controlling for when using administrative medical data.

Regression Analysis

We used the two-stage model approach developed by Manning and Basu[17] to model discrete-continuous outcomes. The first regression in this method models whether or not an individual had any medical expenditures in the given year. Then, the second model estimates the costs for individuals who the first model predicted had any costs. We used an ordinary least squares (OLS) logistic probit regression in the first step, followed by a generalized linear model with a generalized Gamma distribution and log link in the second stage. We used the Stata twopm command developed by Belotti and colleagues to execute the two models[26]. The twopm command allowed us to use the survey weights provided by AHRQ. Data were collected and merged using SAS v9.4 analytical software [SAS Institute, Cary, NC]. Data management was performed in SAS and Stata IC v15 [Stata Corp, College Station, TX]. All data analysis was conducted using Stata.

Our main regression model (Model 1) included personal characteristics and current smoking status. We experimented with including body mass index in the model; however, the variable had near 50% missingness, so we excluded it from our final model. (Further sensitivity analysis indicated that body mass had negligible impact on estimated expenditures by smoking status). We added the disease history to the two-stage model (Model 2). Finally, because COPD comorbidity was only available for the last three years of the study, we excluded COPD and re-ran the model on all five years of the study period. Because controlling for this co-morbidity did not noticeably affect the estimates by smoking status, we chose to report estimates based on 5 years of data, thus increasing our power to probe costs among subgroups. We further expanded Model 2 to include data on years-since-quitting for Former smokers at 1-, 2-, and 5-year thresholds. Because prevalence of these risk factors changes over the life course, we also examined the marginal effects of smoking on medical expenditures by decade of adult life[26]. Non-overlapping confidence intervals indicated statistically significant differences.

Results

An average of 19.7 million adults self-identified as Current smokers in the US from 2011 to 2015. The proportion of current smokers decreased over the study period, to approximately 17.5 million adults in 2015. An average of 43.6 million adults in the U.S. were Ever smokers. The proportion of former smokers increased through decades of life, peaking over 22% for those older than 70-years-old. Tables 1a and 1b describe smoking status by study year and decade of life, respectively. Among the 23.9 million Former smokers, only 4.3% quit within the prior year, 8.7% quit within the prior 2 years, and 24.4% quit within the 5 years prior to the survey.

Table 2 displays the costs for American adults in 2011 – 2015 by smoking status. In Model 1, mean annual medical expenditures for US adults were $4,830. Costs for adult Never smokers were below the national average ($4,360). Former smokers had the highest annual medical expenses, $5,590 (28% increase over never smokers). Although Current smokers had lower average costs than Former smokers at $5,144 (18% increase over Never smokers), the 95% confidence intervals (CIs) overlap for Current and Former smokers. If we combine Current and Former smokers into Ever smokers and re-run Model 1, the average costs for someone who has ever smoked is $5,400 (95% CI = 5142 – 5659).

In Table 3, a sensitivity analysis for Model 2 that includes years-since-quitting for former smokers does not find a direct relationship between time since smoking cessation and medical expenditures. The mean expenditures by cessation period have small differences, and the 95% CIs greatly overlap. Table 4 identifies displays how medical expenditures vary across decades of life by smoking status. The 95% CIs for Never smokers in Table 4 do not contain the estimate for Former smokers at each decade. The CIs for Former smokers do not contain the estimate for Never smokers at all decades except for age 20. The 95% CIs for Current smokers at each decade include both the Never and Former smoker estimates, and the CIs for Never and Former smokers include the estimate for Current smokers.

Multiplying costs by average number of smokers for 2011 – 2015, Current smokers incurred $101.4 billion in average annual medical expenses (95% CI = 12.6 billion – 14.1 billion), $15 billion above the costs for a demographically comparable number of Never smokers. Former smokers incurred an average of $133.6 billion in annual medical expenditures (95% CI = 9.28

billion – 110 billion), a $29 billion increase over comparable Never smokers. Average annual medical expenditures for Ever smokers are $235.6 billion (95% CI = 224 billion – 247 billion), approximately $45 billion above the costs for a demographically comparable number of Never smokers.

Discussion

We updated the national estimates for smoking costs in American adults through 2015 using state-of-the-science economic modeling techniques. This was a period when major provisions of the ACA were being enacted, e.g., state Medicaid expansion; the "individual mandate" in 2014.[7] Our estimates for annual medical expenditures for all civilian non-institutionalized adults was $4,830 for 2011 – 2015, in 2015 USD. This estimate for the study period was close to Mitchell and Machlin's[27] estimate of average total medical expenditures in 2015 using MEPS data ($4,978). Our estimate for annual expenditures and marginal costs due to smoking are below similar estimates generated using the National Health Expenditure Assessment (NHEA) database[28 29]. However, the NHEA is more comprehensive than the MEPS in capturing Medicaid costs covering institutionalized adults (including those in nursing homes), active-duty military, and foreign visitors to the US [29 30], so we expected MEPS to yield lower estimates.

We find that Former smokers have greater annual medical costs over Current and Never smokers; however, the 95% confident intervals overlap for Current and Former smokers in the main model. Surely, some smokers quit after diagnosis of costly health problems linked to smoking, but the cost differential narrows only slightly after controlling for major chronic

conditions (many of which are linked to smoking). Especially at younger ages, quitting appears to be more likely to sort smokers by health consciousness and associated use of medical care.

Some older studies compared medical spending per capita among current, former, and never smokers. Using data from the 1987 National Medical Expenditure Survey (NMES), Miller and colleagues [1999] identified higher annual medical expenditures in former smokers over current smokers. Contrasting with the national studies, two studies using local claims data[31 32] found that medial expenditures for current and former smokers were nearly identical, with a slight spike in costs for former smokers immediately following quitting.

Some current smokers may experience very high cost medical expenditures over a short period before dying (and thus not incurring any further costs), while former smokers may continue to amass lower cost medical encounters. These former smokers would be gaining up to 10 years of survival and medical expenditures over current smokers[33]. Current smokers also may simply be doctor-phobic, anxious to avoid yet another lecture about their smoking. The persistence and perversity of our finding that higher medical expenditures in former smokers at all ages and regardless of time-since-quitting, suggests exploring the issue using qualitative methods.

We followed the methods of Xu and colleagues[5] and Max and colleagues[8-10] to identify current, former, and never smokers in NHIS/MEPS data. Those studies examined attributable fractions (AFs) for medical expenditures rather than costs to individuals. The two-part model developed by Manning and colleagues has become the gold-standard for estimating costs in a skewed sample, such as medical expenditures[17 34]. It has been used to study the impact of smoking on

healthcare costs across a wide variety of databases[6 35 36]. An analysis from An[6] using the two-stage model was performed on medical expenditures associated with smoking status (ever vs. never) and obesity (< 30 BMI vs. 30 ≥ BMI) using MEPS data from 1998 to 2011. In contrast to the present study, An's estimated expenditures did not control for quit status, marital status, family income, family size, or pregnancy. Our estimated cost differences between ever/never smokers and obese/non-obese individuals (data not shown) were lower than in the An study. We believe that the inclusion of quit status and additional personal characteristics in the two-stage models increases the precision of our estimate over this prior study.

Limitations and Strengths

Many of the prior studies assessing the impact of behavioral risk factors on medical expenditures employ the traditional attributable fraction approach, which constructs costs from selected acute and chronic conditions related to the individual risk factors of interest. This method is appropriate unless a study echoes our aim to examine the marginal effects of the risk behaviors on costs to individuals. Using the two-part model[17], our study provides a different assessment of medical expenditures than the attributable fraction method. Attributable fraction studies estimate the smoking-related medical costs incurred in treated diseases that resulted from smoking. The two-stage modelling approach instead looks at the overall medical spending of the smoking cohort. It can be strongly influenced by a difference in care-seeking propensity.

Our estimates for prevalence of smoking (9%) are lower than those found in other surveillance studies. The Behavioral Risk Factor Surveillance System (BRFSS) identified 15% of American adults as current smokers in 2015[37]. This discrepancy between BRFSS and NHIS data may be

due to different modes of data collection. While BRFSS collects data through telephone surveys, NHIS collects data via within-household, in-person interviews. Unlike NHIS, BRFSS data collection is de-centralized as is the responsibility of each state health department.

The goal of this study was to update medical expenditures for smoking to 2015. It was beyond the scope of the study to assess spending by type of medical service utilized. With sufficient budget, doing so might have allowed us to propose more hypotheses as to why certain risks had increased costs over others, as Sturm[38] did for obesity and problem drinking.

In a period of low inflation, we chose to control for inflation in our multi-year analysis of expenditures by including dummy variables for MEPS year rather than using price adjusters that assume a fixed market basket of medical services. The dummy variables should account not only for year-to-year changes in costs, but for other endogenous temporal effects. Those effects include the many policy features of 2010's Affordable Care Act that went into effect from 2011 to 2015[7]. Further analysis of the impacts of all components of the ACA on medical expenditures is warranted.

Conclusion

Our data are the most recent examination of medical expenditures nationwide across current smoking status. One clear application of our estimates is in computing the medical spending foregone because behavioral risk-takers have elevated risks of morbidity and mortality. Although tobacco cessation cause declines in chronic illness, early mortality, and associated costs, it appears they may not decrease annual medical expenditures per survivor. That finding suggests

studies of return on investment in smoking cessation that use attributable-fraction-based costs may yield skewed results.

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Patient and Public Involvement- Cohort Description

The data for this study were obtained from two datasets generated by the U.S. Department of Health and Human Services: The National Health Interview Survey (NHIS) and the Medical Expenditure Panel Survey (MEPS). Both surveys are samples of American adults that can be used to generate weighted estimates of medical care in the U.S. These pre-existing data were not identified to the researchers, so we could not contact them nor involve them in any aspect of the study design and analysis.

Data Sharing-

Data used in this study are held by AHRQ and U.S. DHHS and were used by agreement with the researchers. Raw data used in this study cannot be shared.

Author contributions

SLB, TRM, and DIS conceived of the study. DIS, GW, and TRM designed the analysis. DIS conducted the analysis. DIS and BA wrote and edited drafts of the manuscript. All authors provided input on the manuscript and approved of the final draft.

Competing interests:

All authors state that they have no competing interests.

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Table 1. Prevalence of smoking by year of MEPS data collection (a) and decade of age (b). Average participants in each category were developed using survey weights.

Table 1a	Smoking status by year of medical expenditure					
	2011	2012	2013	2014	2015	n
Current	7.7%	8.7%	8.4%	7.9%	7.3%	19,716,719
Never	83.7%	81.6%	81.6%	81.6%	82.4%	206,862,703
Former	8.6%	9.7%	10.0%	10.5%	10.3%	23,900,571
Table 1b	Smoking status by decade of life					
	18-30	31-40	41-50	51-60	61-70	70+
Current	6.8%	9.8%	9.2%	9.6%	7.4%	4.4%
Never	90.5%	83.2%	83.8%	79.8%	76.8%	73.3%
Former	2.7%	7.0%	7.1%	10.6%	15.7%	22.3%

Table 2. Results of the two-part model for smoking status on mean medical expenditures per year, 2011 – 2015, in 2015 US$. Model 1 included smoking and personal characteristics only [a]. Model 2 included personal characteristics, smoking, and comorbidities [b]. (CI = Confidence interval)

	Model 1		Model 2	
	Mean cost	95% CI	Mean cost	95% CI
Never Smoker	$4,360	4154.3 - 4566.3	$4,499	4219.6 - 4778.9
Current Smoker	$5,144	4707.9 - 5580.3	$4,647	4186.9 - 5107.0
Former Smoker	$5,590	5267.4 - 5913.5	$5,012	4618.4 - 5406.4

[a] Covariates included in Model 1 were age (continuous), gender, race/ethnicity (White, African American, Asian, Hispanic origin, Other), education (No high school degree, High school or some college, At least college graduate), marital status (Single/Never married, Current married, Widowed/Divorced/Separated), Pregnancy in the prior year, employment status (Unemployed, Employed, Full-time student, Never worked, Retired), logged-total family income, insurance status (Private, Any public insurance (under age 65), Medicare/Medicaid+, Uninsured), family size, year dummy variables, any binge drinking in the prior year, and BMI (Normal weight or Underweight, Overweight or Obese).

[b] In addition to the variables in Model 1, a history of the following conditions were added to Model 2: any cancer, diabetes, asthma, arthritis, cardiovascular disease (angina, coronary heart disease, myocardial infarction, or stroke), emphysema, quality of life calculated from Short Form 12, depression calculated from the Personal Health Questionnaire, and mental illness from the Kessler 6 questionnaire.

Table 3. Results of separate runs of the two-part model of mean medical expenditures for Former smokers using 1-, 2-, and 5-year thresholds for years-since-quitting smoking. (CI = Confidence interval) in 2015 US$.

Years since quitting	Mean	95% CI
1 or fewer years	$5,036	3604.4 - 6646.6
More than 1 year	$5,006	4588.8 - 5422.3
2 or fewer years	$5,132	4035.0 - 6229.6
More than 2 years	$4,986	4543.6 - 5429.1
5 or fewer years	$4,957	4182.8 - 5730.7
More than 5 years	$5,028	4551.1 - 5505.2

Table 4. Average annual medical expenditures in 2011 – 2015 for American adults of selected ages by smoking status, from a two-part model including personal characteristics and disease history at each decade of life ages 20 – 80, in 2015 US$.

	Age							
	20		30		40		50	
Smoking status	Estimate	95% CI	Estimate	95% CI	Estimate	95% CI	Estimate	95% CI
Never	$2,743	(2366, 3151)	$3,214	(2857, 3571)	$3,763	(3472, 4054)	$4,401	(4160, 4642)
Current	$2,909	(2390, 3428)	$3,413	(2928, 3897)	$4,000	(3561, 4438)	$4,683	(4284, 5081)
Former	$3,208	(2704, 3711)	$3,754	(3301, 4208)	$4,390	(3947, 4783)	$5,130	(4776, 5483)
	Age							
	60		70		80			
Smoking status	Estimate	95% CI	Estimate	95% CI	Estimate	95% CI		
Never	$5,143	(4846, 5440)	$6,007	(5505, 6508)	$7,010	(6184, 7836)		
Current	$5,478	(5059, 5897)	$6,403	(5839, 6968)	$7,479	(6627, 8331)		
Former	$5,990	(5574, 6407)	$6,990	(6357, 7623)	$8,153	(7160, 9145)		

CHEERS Checklist
Items to include when reporting economic evaluations of health interventions

The **ISPOR CHEERS Task Force Report**, *Consolidated Health Economic Evaluation Reporting Standards (CHEERS)—Explanation and Elaboration: A Report of the ISPOR Health Economic Evaluations Publication Guidelines Good Reporting Practices Task Force,* provides examples and further discussion of the 24-item CHEERS Checklist and the CHEERS Statement. It may be accessed via the *Value in Health* or via the ISPOR Health Economic Evaluation Publication Guidelines – CHEERS: Good Reporting Practices webpage: http://www.ispor.org/TaskForces/EconomicPubGuidelines.asp

Section/item	Item No	Recommendation	Reported on page No/ line No
Title and abstract			
Title	1	Identify the study as an economic evaluation or use more specific terms such as "cost-effectiveness analysis", and describe the interventions compared.	Title Page
Abstract	2	Provide a structured summary of objectives, perspective, setting, methods (including study design and inputs), results (including base case and uncertainty analyses), and conclusions.	P1 Line 2-19
Introduction			
Background and objectives	3	Provide an explicit statement of the broader context for the study. Present the study question and its relevance for health policy or practice decisions.	P1-2
Methods			
Target population and subgroups	4	Describe characteristics of the base case population and subgroups analysed, including why they were chosen.	P4 L6-16
Setting and location	5	State relevant aspects of the system(s) in which the decision(s) need(s) to be made.	N/A
Study perspective	6	Describe the perspective of the study and relate this to the costs being evaluated.	P4 L7
Comparators	7	Describe the interventions or strategies being compared and state why they were chosen.	P4 11-16
Time horizon	8	State the time horizon(s) over which costs and consequences are being evaluated and say why appropriate.	P3-P4
Discount rate	9	Report the choice of discount rate(s) used for costs and outcomes and say why appropriate.	P11 L16-21
Choice of health outcomes	10	Describe what outcomes were used as the measure(s) of benefit in the evaluation and their relevance for the type of analysis performed.	N/A
Measurement of effectiveness	11a	*Single study-based estimates:* Describe fully the design features of the single effectiveness study and why the single study was a sufficient source of clinical effectiveness data.	N/A

	11b	*Synthesis-based estimates:* Describe fully the methods used for identification of included studies and synthesis of clinical effectiveness data.	N/A
Measurement and valuation of preference based outcomes	12	If applicable, describe the population and methods used to elicit preferences for outcomes.	N/A
Estimating resources and costs	13a	*Single study-based economic evaluation:* Describe approaches used to estimate resource use associated with the alternative interventions. Describe primary or secondary research methods for valuing each resource item in terms of its unit cost. Describe any adjustments made to approximate to opportunity costs.	—
	13b	*Model-based economic evaluation:* Describe approaches and data sources used to estimate resource use associated with model health states. Describe primary or secondary research methods for valuing each resource item in terms of its unit cost. Describe any adjustments made to approximate to opportunity costs.	P4-6
Currency, price date, and conversion	14	Report the dates of the estimated resource quantities and unit costs. Describe methods for adjusting estimated unit costs to the year of reported costs if necessary. Describe methods for converting costs into a common currency base and the exchange rate.	P11
Choice of model	15	Describe and give reasons for the specific type of decision-analytical model used. Providing a figure to show model structure is strongly recommended.	P2-3
Assumptions	16	Describe all structural or other assumptions underpinning the decision-analytical model.	P2,3,6
Analytical methods	17	Describe all analytical methods supporting the evaluation. This could include methods for dealing with skewed, missing, or censored data; extrapolation methods; methods for pooling data; approaches to validate or make adjustments (such as half cycle corrections) to a model; and methods for handling population heterogeneity and uncertainty.	P2-6, 10, 11
Results			
Study parameters	18	Report the values, ranges, references, and, if used, probability distributions for all parameters. Report reasons or sources for distributions used to represent uncertainty where appropriate. Providing a table to show the input values is strongly recommended.	P7, T1
Incremental costs and outcomes	19	For each intervention, report mean values for the main categories of estimated costs and outcomes of interest, as well as mean differences between the comparator groups. If applicable, report incremental cost-effectiveness ratios.	T1
Characterising uncertainty	20a	*Single study-based economic evaluation:* Describe the effects of sampling uncertainty for the estimated incremental cost and incremental effectiveness parameters, together with the impact	T2-4

		of methodological assumptions (such as discount rate, study perspective).	
	20b	*Model-based economic evaluation:* Describe the effects on the results of uncertainty for all input parameters, and uncertainty related to the structure of the model and assumptions.	
Characterising heterogeneity	21	If applicable, report differences in costs, outcomes, or cost-effectiveness that can be explained by variations between subgroups of patients with different baseline characteristics or other observed variability in effects that are not reducible by more information.	N/A
Discussion			
Study findings, limitations, generalisability, and current knowledge	22	Summarise key study findings and describe how they support the conclusions reached. Discuss limitations and the generalisability of the findings and how the findings fit with current knowledge.	P6-11
Other			
Source of funding	23	Describe how the study was funded and the role of the funder in the identification, design, conduct, and reporting of the analysis. Describe other non-monetary sources of support.	P12
Conflicts of interest	24	Describe any potential for conflict of interest of study contributors in accordance with journal policy. In the absence of a journal policy, we recommend authors comply with International Committee of Medical Journal Editors recommendations.	

For consistency, the CHEERS Statement checklist format is based on the format of the CONSORT statement checklist

The **ISPOR CHEERS Task Force Report** provides examples and further discussion of the 24-item CHEERS Checklist and the CHEERS Statement. It may be accessed via the *Value in Health* link or via the ISPOR Health Economic Evaluation Publication Guidelines – CHEERS: Good Reporting Practices webpage: http://www.ispor.org/TaskForces/EconomicPubGuidelines.asp

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