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Updating medical expenditures by smoking status in American adults

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Updating medical expenditures by smoking status in American adults

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1 **Abstract**

2 **Objectives:** To assess the medical expenditures of American adults by their smoking status-
3 Current, Former, or Never smokers. We update these expenditures controlling for personal
4 characteristics and medical history. The impact of years-since-quit and decade of life are also
5 examined. **Setting and participants:** Weighted sample of American adults, 2011 – 2015. The
6 National Health Interview Survey (NHIS) and Medical Expenditure Panel Survey (MEPS) are
7 weighted representations of approximately 250 million adults, annually. Sampling of NHIS is
8 multistage and data collected throughout the year. **Primary outcome measures:** Using data
9 from NHIS and MEPS, we collected demographic data, self-reported medical history, and
10 current smoking status. Smoking status was designated as Never, Current, and Former, along
11 with years-since-quit. Total medical expenditures were collected from MEPS for 2011 –
12 2015. We used Manning’s two-part model to model average expenditures per individual and
13 marginal costs for individuals at all levels of smoking status. **Results:** American adults averaged
14 \$4,830 in average medical expenditures. Never smokers (\$4,360, 95% CI = 4154.3 – 4566.3),
15 had lower expenditures than Current (\$5,244, 95% CI = 4707.9 – 5580.3) and Former (\$5,590,
16 95% CI = 5267.4 – 5913.5) smokers. Confidence intervals for Current and Former smokers
17 overlapped. Results were similarly significant when controlling for disease history. Years-since-
18 quitting did not affect expenditures. In each decade of adult life, Former smokers had the highest
19 annual medical expenditures, followed by Current and Never smokers. **Conclusions:** We
20 updated annual medical expenditures for the Obamacare-era for smoking status using the current
21 best practice model. Former smokers had lower medical expenditures than Current smokers in all
22 age groups. While we identify Former smokers as having higher medical expenditures than

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3 1 Current smokers, we do not examine how care-seeking behavior varies between levels of each
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5 2 risk factor.

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8 3 **Article Summary**

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10 4 *Strengths and Limitations*

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12 5 • This is also the first study to report data on medical expenditure by smoking status while
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14 6 major provisions of the Affordable Care Act (a.k.a. Obamacare) were taking effect.
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16 7 • We use the gold standard two-part model developed by Manning to estimate medical
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18 8 expenditures from the MEPS and NHIS surveys.
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20 9 • We separated medical expenditures for Ever Smokers into Current and Former smokers,
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22 10 finding that the latter had slightly increased annual medical expenditures.
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24 11 • Effects of smoking status were examined across decades of life.
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26 12 • Although we controlled for history of comorbidities, the data do not contain any
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28 13 information on reason-for-quitting among former smokers.
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1 Introduction

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

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

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

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3 1 example, a doctor who is scheduling quarterly visits to manage diabetes is unlikely to separately
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5 2 schedule the annual well-care visit recommended for a healthier patient. That well-care visit gets
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7 3 coded as a chronic care visit even though it may not raise annual medical spending[13].
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12 5 While the Manning model is now the gold standard for working with skewed outcomes like
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14 6 medical spending, it is an imperfect tool. Although it statistically assigns costs to given risk
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16 7 factors or medical conditions, it does not tell us the “why” behind each individual medical
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18 8 encounter or expense. Medical spending is influenced by care-seeking behavior. Smokers may
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20 9 avoid visiting the doctor because it is uncomfortable to report their continued smoking behavior
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22 10 or tedious to hear the doctor urge them to change[14]. Health consciousness and associated use
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24 11 of preventive care may be below-average for people who engage in risky behavior. Furthermore,
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26 12 drinking heavily may be a symptom of life management issues that reduce care-seeking. Those
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28 13 differences in health management may mask the impacts of risk behavior on medical spending.
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35 15 *Purpose*

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37 16 This study updates the national estimates for annual medical expenditures of adult Americans by
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39 17 their current smoking status. We examine medical expenditure data for 2011 – 2015 and apply
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41 18 the cutting-edge two-stage Manning model to more accurately assess error around mean
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43 19 expenditures.
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48 49 21 **Methods**

50 51 22 *Data Collection*

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

12
13 Smoking status was identified through the NHIS Supplemental Adult Questionnaire (SAQ). Like
14 earlier studies, we identified Ever smokers as participants who smoked at least 100 cigarettes in
15 their lifetimes. We defined all others as Never smokers[6]. Ever smokers were further subdivided
16 into those who reported quitting smoking, Former smokers, versus those who did not report
17 quitting, Current smokers[7-9]. For Former smokers, we also identified years-since-quitting.

18
19 To conduct regressions, we included the following demographic and behavioral characteristics:
20 age, sex, race/ethnicity, marital status, education level, total family income, family size,
21 employment status, marital status, self-reported binge drinking status, body mass index (BMI),
22 recent pregnancy, educational, employment, and insurance data from MEPS. Age was employed
23 as a continuous variable in the main analyses and divided into ten-year blocks in the age-specific

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

9
10 NHIS and MEPS had data on self-reported diagnosis history for various diseases. Using data
11 from both databases, we generated dichotomous variables for whether a participant had ever
12 been diagnosed with the following diseases: asthma, arthritis, any cancer, cardiovascular diseases
13 (including angina, coronary heart disease, myocardial infarction, or stroke), diabetes, and
14 emphysema. NHIS had data on chronic obstructive pulmonary disease (COPD) available for
15 2013 through 2015 MEPS panels. From MEPS, we obtained scores for the Short Form 12 to
16 measure quality of life[17], the Personal Health Questionnaire (PHQ) metric for depression[18],
17 and the Kessler 6 questionnaire for mental illness[19]. From these variables, we were able to
18 code a partial list of comorbidities that Elixhauser and colleagues[20] suggest controlling for
19 when using administrative medical data.

21 *Regression Analysis*

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

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

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

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6 **Results**

7 An average of 19.7 million adults self-identified as Current smokers in the US from 2011 to
8 2015. The proportion of current smokers decreased over the study period, to approximately 17.5
9 million adults in 2015. An average of 43.6 million adults in the U.S. were Ever smokers. The
10 proportion of former smokers increased through decades of life, peaking over 22% for those
11 older than 70-years-old. Tables 1a and 1b describe smoking status by study year and decade of
12 life, respectively.

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

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

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

5
6 Multiplying costs by average number of smokers for 2011 – 2015, current smokers incurred
7 \$101.4 billion in average annual medical expenses, \$15 billion above the costs for a
8 demographically comparable number of Never smokers. Former smokers incurred an average of
9 \$133.6 billion in annual medical expenditures, a \$29 billion increase over comparable Never
10 smokers. Average annual medical expenditures for Ever smokers are \$235.6 billion,
11 approximately \$45 billion above the costs for a demographically comparable number of Never
12 smokers.

13 14 **Discussion**

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

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

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

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

23

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

16 *Limitations and Strengths*

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

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

3
4 Our estimates for prevalence of smoking (9%) are lower than those found in other surveillance
5 studies. The Behavioral Risk Factor Surveillance System (BRFSS) identified 15% of American
6 adults as current smokers in 2015[32]. This discrepancy between BRFSS and NHIS data may be
7 due to different modes of data collection. While BRFSS collects data through telephone surveys,
8 NHIS collects data via within-household, in-person interviews. Unlike NHIS, BRFSS data
9 collection is de-centralized as is the responsibility of each state health department.

10
11 The goal of this study was to update medical expenditures for smoking to 2015. It was beyond
12 the scope of the study to assess spending by type of medical service utilized. With sufficient
13 budget, doing so might have allowed us to propose more hypotheses as to why certain risks had
14 increased costs over others, as Sturm[33] did for obesity and problem drinking.

15
16 In a period of low inflation, we chose to control for inflation in our multi-year analysis of
17 expenditures by including dummy variables for MEPS year rather than using price adjusters that
18 assume a fixed market basket of medical services. The dummy variables should account not only
19 for year-to-year changes in costs, but for other endogenous temporal effects. Those effects
20 include the many policy features of 2010's Affordable Care Act that went into effect from 2011
21 to 2015[34].

22
23 *Conclusion*

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

8 9 *Acknowledgement and Funding*

10 The research in this paper was conducted at the CFACT Data Center, and the support of AHRQ
11 is acknowledged. The results and conclusions in this paper are those of the authors and do not
12 indicate concurrence by AHRQ or the Department of Health and Human Services.

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14 Enhanced Tobacco Treatment for Hospitalized Smokers) and NCI grant R01CA201873
15 (Optimizing Tobacco Dependence Treatment in the Emergency Department).

16 *Patient and Public Involvement- Cohort Description*

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

23 *Data Sharing-*

1
2
3 1 Data used in this study are held by AHRQ and U.S. DHHS and were used by agreement with the
4
5 2 researchers. Raw data used in this study cannot be shared.
6

7
8 3 *Author contributions*

9
10 4 SLB, TRM, and DIS conceived of the study. DIS, GW, and TRM designed the analysis. DIS
11
12 5 conducted the analysis. DIS and BA wrote and edited drafts of the manuscript. All authors
13
14 6 provided input on the manuscript and approved of the final draft.
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16
17 7 *Competing interests:*

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19 8 All authors state that they have no competing interests.
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- 1 **Table 1.** Prevalence of smoking by year of MEPS data collection (a) and decade of age (b).
 2 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%

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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.

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

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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.

Smoking status	Age							
	20		30		40		50	
	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)
Smoking status	Age							
	60		70		80			
	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.	<u>Title Page</u>
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.	<u>P1 Line 2-19</u>
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.	<u>P1-2</u>
Methods			
Target population and subgroups	4	Describe characteristics of the base case population and subgroups analysed, including why they were chosen.	<u>P4 LG-16</u>
Setting and location	5	State relevant aspects of the system(s) in which the decision(s) need(s) to be made.	<u>N/A</u>
Study perspective	6	Describe the perspective of the study and relate this to the costs being evaluated.	<u>P4 L7</u>
Comparators	7	Describe the interventions or strategies being compared and state why they were chosen.	<u>P4 11-16</u>
Time horizon	8	State the time horizon(s) over which costs and consequences are being evaluated and say why appropriate.	<u>B-P4</u>
Discount rate	9	Report the choice of discount rate(s) used for costs and outcomes and say why appropriate.	<u>P11 L16-21</u>
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.	<u>N/A</u>
Measurement of effectiveness	11a	<i>Single study-based estimates:</i> Describe fully the design features of the single effectiveness study and why the single study was a sufficient source of clinical effectiveness data.	<u>N/A</u>



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	11b	<i>Synthesis-based estimates:</i> Describe fully the methods used for identification of included studies and synthesis of clinical effectiveness data.	<u>N/A</u>
Measurement and valuation of preference based outcomes	12	If applicable, describe the population and methods used to elicit preferences for outcomes.	<u>N/A</u>
Estimating resources and costs	13a	<i>Single study-based economic evaluation:</i> 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.	<u>—</u>
	13b	<i>Model-based economic evaluation:</i> 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.	<u>P4-6</u>
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.	<u>P11</u>
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.	<u>P2-3</u>
Assumptions	16	Describe all structural or other assumptions underpinning the decision-analytical model.	<u>P2,3,6</u>
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.	<u>P2-6,10,11</u>
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.	<u>P7, T1</u>
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.	<u>T1</u>
Characterising uncertainty	20a	<i>Single study-based economic evaluation:</i> Describe the effects of sampling uncertainty for the estimated incremental cost and incremental effectiveness parameters, together with the impact	<u>T2-4</u>



		of methodological assumptions (such as discount rate, study perspective).	
	20b	<i>Model-based economic evaluation</i> : 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.	P45-11
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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3 **1 National medical expenditures by smoking status in American adults: an application of**
4 **2 Manning's two-stage model to nationally-representative data**
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6 **3**

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1 **Abstract**

2 **Objectives:** To assess the medical expenditures of American adults by their smoking status-
3 Current, Former, or Never smokers. We update these expenditures controlling for personal
4 characteristics and medical history and also assess the impact of years-since-quit and decade
5 of life. **Setting and participants:** Weighted sample of American adults, 2011 – 2015. The linked
6 National Health Interview Survey (NHIS) and Medical Expenditure Panel Survey (MEPS) are
7 annual weighted representations of approximately 250 million adults. Sampling of NHIS is
8 multistage with data collected throughout the year. **Primary outcome measures:** Using data
9 from NHIS and MEPS, we collected demographic data, self-reported medical history, and
10 current smoking status. Smoking status was designated as Never, Current, and Former, along
11 with years-since-quit. Total medical expenditures were collected from MEPS for 2011 –
12 2015. We used Manning’s two-part model to estimate average expenditures per individual and
13 marginal costs for individuals at all levels of smoking status. **Results:** American adults averaged
14 \$4,830 in average medical expenditures. Never smokers (\$4,360, 95% CI = 4154.3 – 4566.3),
15 had lower expenditures than Current (\$5,244, 95% CI = 4707.9 – 5580.3) and Former (\$5,590,
16 95% CI = 5267.4 – 5913.5) smokers. Confidence intervals for Current and Former smokers
17 overlapped. Results were similarly significant when controlling for disease history. Years-since-
18 quitting did not affect expenditures. In each decade of adult life, Former smokers had the highest
19 annual medical expenditures, followed by Current and then Never smokers. **Conclusions:** We
20 updated annual medical expenditures during the Affordable Care Act-era by smoking status
21 using the current best practice model. While we identify Former smokers as having higher
22 medical expenditures than Current smokers, we do not examine how care-seeking behavior
23 varies between levels of each risk factor.

1 **Article Summary**

2 *Strengths and Limitations*

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

1 Introduction

2 It is well-established that smoking can lead to medical conditions requiring acute and chronic
3 treatment¹. Accurate marginal costs for medical risk factors are important when conducting
4 benefit-cost analyses for health risk behavior interventions²⁻⁴. The most recent national estimates
5 of medical expenditures by smoking status have only considered a binary smoking variable:
6 current smokers versus current non-smokers^{5 6}. Further, none of these national studies have
7 analyzed medical expenditure data more recently than 2011. A series of state-level analyses by
8 Max and colleagues⁷⁻⁹ described medical costs in California by current, former, and never
9 smokers.

11 The California studies used the attributable fraction (AF) method to allocate medical
12 expenditures. In their review of the AF method, Rockhill and colleagues define attributable
13 fraction and similarly-phrased terms to be “the proportion of disease risk in a population that can
14 be attributed to the causal effects of a risk factor or set of factors,” (p. 15)¹⁰. Rockhill *et al* find
15 that the AF method has limitations, including that it is constrained by how accurately costs are
16 allocated among diagnoses and by the availability of accurate AFs that are not confounded by
17 co-occurring risk factors¹⁰. The negative outcomes that smokers experience vary widely in nature
18 and timing. Importantly, the method does not measure the standard error for the mean estimated
19 cost per risk-taker¹¹.

21 In analyzing the costs of medical conditions, health economics literature has largely shifted from
22 this AF method to analyses of annual per capita medical spending of people with the condition
23 relative to a comparison group¹²⁻¹⁵. This approach, pioneered by Willard Manning¹⁶ captures

1 both mean and standard error and it accounts for complications that may not be coded to the
2 underlying condition. That is, these equations take a more holistic view of medical care and
3 expenditures associated with risk factors' coefficients than would a process seeking to attribute
4 specified treatment costs to specified factors. It allows that medical visits for conditions related
5 to the behavioral risk factors may displace other medical care that might be sought if an
6 individual did not have a given risk factor. For example, a doctor who is scheduling quarterly
7 visits to manage diabetes is unlikely to separately schedule the annual well-care visit
8 recommended for a healthier patient. That well-care visit gets coded as a chronic care visit even
9 though it may not raise annual medical spending¹⁷.

11 While the Manning model is now the gold standard for working with skewed outcomes like
12 medical spending, it is an imperfect tool. Although it statistically assigns costs to given risk
13 factors or medical conditions, it does not tell us the "why" behind each individual medical
14 encounter or expense. Medical spending is influenced by care-seeking behavior. Smokers may
15 avoid visiting the doctor because it is uncomfortable to report their continued smoking behavior
16 or tedious to hear the doctor urge them to change¹⁸. Health consciousness and associated use of
17 preventive care may be below-average for people who engage in risky behavior. Furthermore,
18 drinking heavily may be a symptom of life management issues that reduce care-seeking. Those
19 differences in health management may mask the impacts of risk behavior on medical spending.

21 *Purpose*

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

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

3 4 **Methods**

5 *Data Collection*

6 We analyzed data on smoking status from the National Health Interview Survey (NHIS)¹⁹. The
7 NHIS is an annual, cross-sectional survey designed to monitor health and behaviors of civilian,
8 non-institutionalized Americans through a nationally-representative sample. The Medical
9 Expenditure Panel Survey (MEPS) tracks a nationally representative subsample of NHIS
10 participants for 24 months starting in the year after their NHIS interview. MEPS collects five
11 rounds of data per respondent on healthcare visits and expenditures²⁰. It captures all payments
12 for care, regardless of source, and models costs for visits without payment data including charity
13 care and visits bundled into capitated care. We used 2011-2015 MEPS data on total medical
14 expenditures from the individual perspective for adults 18-years and older and the corresponding
15 NHIS 2009 – 2014 data. Annual medical expenditures were inflated to 2015 US dollars (USD)
16 using the Personal Consumption Expenditures- Medical Care. We linked data from MEPS and
17 NHIS via the Agency for Health Care Quality Data Center, as Xu *et al*⁵ did in their analyses of
18 smoking costs⁶. Because our use of the publicly-available data adhered to the government's
19 privacy restrictions, the project was given an Exemption by the Institutional Review Board of the
20 Pacific Institute for Research and Evaluation prior to data analysis.

21
22 Smoking status was identified through the NHIS Supplemental Adult Questionnaire (SAQ). Like
23 earlier studies, we identified Ever smokers as participants who smoked at least 100 cigarettes in

1 their lifetimes. We defined all others as Never smokers⁶. Ever smokers were further subdivided
2 into those who reported quitting smoking, Former smokers, versus those who did not report
3 quitting, Current smokers⁷⁻⁹. For Former smokers, we also identified years-since-quitting.

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

18
19 NHIS and MEPS had data on self-reported diagnosis history for various diseases. Using data
20 from both databases, we generated dichotomous variables for whether a participant had ever
21 been diagnosed with the following diseases: asthma, arthritis, any cancer, cardiovascular diseases
22 (including angina, coronary heart disease, myocardial infarction, or stroke), diabetes, and
23 emphysema. NHIS had data on chronic obstructive pulmonary disease (COPD) available for

1 2013 through 2015 MEPS panels. From MEPS, we obtained scores for the Short Form 12 to
2
3 measure quality of life²¹, the Personal Health Questionnaire (PHQ) metric for depression²², and
4
5 the Kessler 6 questionnaire for mental illness²³. From these variables, we were able to code a
6
7 partial list of comorbidities that Elixhauser and colleagues²⁴ suggest controlling for when using
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9 administrative medical data.
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17 *Regression Analysis*

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19 We used the two-stage model approach developed by Manning and Basu¹⁶ to model discrete-
20
21 continuous outcomes. The first regression in this method models whether or not an individual
22
23 had any medical expenditures in the given year. Then, the second model estimates the costs for
24
25 individuals who the first model predicted had any costs. We used an ordinary least squares
26
27 (OLS) logistic probit regression in the first step, followed by a generalized linear model with a
28
29 generalized Gamma distribution and log link in the second stage. We used the Stata twopm
30
31 command developed by Belotti and colleagues to execute the two models²⁵. The twopm
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33 command allowed us to use the survey weights provided by AHRQ. Data were collected and
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35 merged using SAS v9.4 analytical software [SAS Institute, Cary, NC]. Data management was
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37 performed in SAS and Stata IC v15 [Stata Corp, College Station, TX]. All data analysis was
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39 conducted using Stata.
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47 Our main regression model (Model 1) included personal characteristics and current smoking
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49 status. We experimented with including body mass index in the model; however, the variable had
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51 near 50% missingness, so we excluded it from our final model. (Further sensitivity analysis
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53 indicated that body mass had negligible impact on estimated expenditures by smoking status).
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1 We added the disease history to the two-stage model (Model 2). Finally, because COPD
2 comorbidity was only available for the last three years of the study, we excluded COPD and re-
3 ran the model on all five years of the study period. Because controlling for this co-morbidity did
4 not noticeably affect the estimates by smoking status, we chose to report estimates based on 5
5 years of data, thus increasing our power to probe costs among subgroups. We further expanded
6 Model 2 to include data on years-since-quit for Former smokers at 1-, 2-, and 5-year
7 thresholds. Because prevalence of these risk factors changes over the life course, we also
8 examined the marginal effects of smoking on medical expenditures by decade of adult life²⁵.
9 Non-overlapping confidence intervals indicated statistically significant differences.

11 Results

12 An average of 19.7 million adults self-identified as Current smokers in the US from 2011 to
13 2015. The proportion of current smokers decreased over the study period, to approximately 17.5
14 million adults in 2015. An average of 43.6 million adults in the U.S. were Ever smokers. The
15 proportion of former smokers increased through decades of life, peaking over 22% for those
16 older than 70-years-old. Tables 1a and 1b describe smoking status by study year and decade of
17 life, respectively. Among the 23.9 million Former smokers, only 4.3% quit within the prior year,
18 8.7% quit within the prior 2 years, and 24.4% quit within the 5 years prior to the survey.

19
20 Table 2 displays the costs for American adults in 2011 – 2015 by smoking status. In Model 1,
21 mean annual medical expenditures for US adults were \$4,830. Costs for adult Never smokers
22 were below the national average (\$4,360). Former smokers had the highest annual medical
23 expenses, \$5,590 (28% increase over never smokers). Although Current smokers had lower

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

5
6 In Table 3, a sensitivity analysis for Model 2 that includes years-since-quit for former
7 smokers does not find a direct relationship between time since smoking cessation and medical
8 expenditures. The mean expenditures by cessation period have small differences, and the 95%
9 CIs greatly overlap. Table 4 identifies displays how medical expenditures vary across decades of
10 life by smoking status. The 95% CIs for Never smokers in Table 4 do not contain the estimate
11 for Former smokers at each decade. The CIs for Former smokers do not contain the estimate for
12 Never smokers at all decades except for age 20. The 95% CIs for Current smokers at each decade
13 include both the Never and Former smoker estimates, and the CIs for Never and Former smokers
14 include the estimate for Current smokers.

15
16 Multiplying costs by average number of smokers for 2011 – 2015, Current smokers incurred
17 \$101.4 billion in average annual medical expenses (95% CI = 12.6 billion – 14.1 billion), \$15
18 billion above the costs for a demographically comparable number of Never smokers. Former
19 smokers incurred an average of \$133.6 billion in annual medical expenditures (95% CI = 9.28
20 billion – 110 billion), a \$29 billion increase over comparable Never smokers. Average annual
21 medical expenditures for Ever smokers are \$235.6 billion (95% CI = 224 billion – 247 billion),
22 approximately \$45 billion above the costs for a demographically comparable number of Never
23 smokers.

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45 2 **Discussion**

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8 3 We updated the national estimates for smoking costs in American adults through 2015 using
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10 4 state-of-the-science economic modeling techniques. Our estimates for annual medical
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12 5 expenditures for all civilian non-institutionalized adults was \$4,830 for 2011 – 2015, in 2015
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14 6 USD. This estimate for the study period was close to Mitchell and Machlin's²⁶ estimate of
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16 7 average total medical expenditures in 2015 using MEPS data (\$4,978). Our estimate for annual
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18 8 expenditures and marginal costs due to smoking are below similar estimates generated using the
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20 9 National Health Expenditure Assessment (NHEA) database^{27 28}. However, the NHEA is more
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22 10 comprehensive than the MEPS in capturing Medicaid costs covering institutionalized adults
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24 11 (including those in nursing homes), active-duty military, and foreign visitors to the US ^{28 29}, so
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26 12 we expected MEPS to yield lower estimates.
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33 14 We find that Former smokers have greater annual medical costs over Current and Never
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35 15 smokers; however, the 95% confident intervals overlap for Current and Former smokers in the
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37 16 main model. Surely, some smokers quit after diagnosis of costly health problems linked to
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39 17 smoking, but the cost differential narrows only slightly after controlling for major chronic
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41 18 conditions (many of which are linked to smoking). Especially at younger ages, quitting appears
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43 19 to be more likely to sort smokers by health consciousness and associated use of medical care.
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49 21 Some older studies compared medical spending per capita among current, former, and never
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51 22 smokers. Using data from the 1987 National Medical Expenditure Survey (NMES), Miller and
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53 23 colleagues [1999] identified higher annual medical expenditures in former smokers over current
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1 smokers. Contrasting with the national studies, two studies using local claims data^{30 31} found that
2 medial expenditures for current and former smokers were nearly identical, with a slight spike in
3 costs for former smokers immediately following quitting.

4
5 Some current smokers may experience very high cost medical expenditures over a short period
6 before dying (and thus not incurring any further costs), while former smokers may continue to
7 amass lower cost medical encounters. These former smokers would be gaining up to 10 years of
8 survival and medical expenditures over current smokers³². Current smokers also may simply be
9 doctor-phobic, anxious to avoid yet another lecture about their smoking. The persistence and
10 perversity of our finding that higher medical expenditures in former smokers at all ages and
11 regardless of time-since-quitting, suggests exploring the issue using qualitative methods.

12
13 We followed the methods of Xu and colleagues⁵ and Max and colleagues⁷⁻⁹ to identify current,
14 former, and never smokers in NHIS/MEPS data. Those studies examined attributable fractions
15 (AFs) for medical expenditures rather than costs to individuals. The two-part model developed
16 by Manning and colleagues has become the gold-standard for estimating costs in a skewed
17 sample, such as medical expenditures^{16 33}. It has been used to study the impact of smoking on
18 healthcare costs across a wide variety of databases^{6 34 35}. An analysis from An⁶ using the two-
19 stage model was performed on medical expenditures associated with smoking status (ever vs.
20 never) and obesity (< 30 BMI vs. $30 \geq$ BMI) using MEPS data from 1998 to 2011. In contrast to
21 the present study, An's estimated expenditures did not control for quit status, marital status,
22 family income, family size, or pregnancy. Our estimated cost differences between ever/never
23 smokers and obese/non-obese individuals (data not shown) were lower than in the An study. We

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3 1 believe that the inclusion of quit status and additional personal characteristics in the two-stage
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5 2 models increases the precision of our estimate over this prior study.
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10 4 *Limitations and Strengths*

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12 5 Many of the prior studies assessing the impact of behavioral risk factors on medical expenditures
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14 6 employ the traditional attributable fraction approach, which constructs costs from selected acute
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16 7 and chronic conditions related to the individual risk factors of interest. This method is
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18 8 appropriate unless a study echoes our aim to examine the marginal effects of the risk behaviors
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20 9 on costs to individuals. Using the two-part model¹⁶, our study provides a different assessment of
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22 10 medical expenditures than the attributable fraction method. Attributable fraction studies estimate
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24 11 the smoking-related medical costs incurred in treated diseases that resulted from smoking. The
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26 12 two-stage modelling approach instead looks at the overall medical spending of the smoking
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28 13 cohort. It can be strongly influenced by a difference in care-seeking propensity.
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35 15 Our estimates for prevalence of smoking (9%) are lower than those found in other surveillance
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37 16 studies. The Behavioral Risk Factor Surveillance System (BRFSS) identified 15% of American
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39 17 adults as current smokers in 2015³⁶. This discrepancy between BRFSS and NHIS data may be
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41 18 due to different modes of data collection. While BRFSS collects data through telephone surveys,
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43 19 NHIS collects data via within-household, in-person interviews. Unlike NHIS, BRFSS data
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45 20 collection is de-centralized as is the responsibility of each state health department.
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51 22 The goal of this study was to update medical expenditures for smoking to 2015. It was beyond
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53 23 the scope of the study to assess spending by type of medical service utilized. With sufficient
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1 budget, doing so might have allowed us to propose more hypotheses as to why certain risks had
2 increased costs over others, as Sturm³⁷ did for obesity and problem drinking.

3
4 In a period of low inflation, we chose to control for inflation in our multi-year analysis of
5 expenditures by including dummy variables for MEPS year rather than using price adjusters that
6 assume a fixed market basket of medical services. The dummy variables should account not only
7 for year-to-year changes in costs, but for other endogenous temporal effects. Those effects
8 include the many policy features of 2010's Affordable Care Act that went into effect from 2011
9 to 2015³⁸.

11 *Conclusion*

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

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22 is acknowledged. The results and conclusions in this paper are those of the authors and do not
23 indicate concurrence by AHRQ or the Department of Health and Human Services.

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2 Enhanced Tobacco Treatment for Hospitalized Smokers) and NCI grant R01CA201873
3 (Optimizing Tobacco Dependence Treatment in the Emergency Department).

4 *Patient and Public Involvement- Cohort Description*

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

11 *Data Sharing-*

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

14 *Author contributions*

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

18 *Competing interests:*

19 All authors state that they have no competing interests.

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

Table 1a	Smoking status by year of medical expenditure					n
	2011	2012	2013	2014	2015	
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.

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

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For peer review only

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\$.

Smoking status	Age							
	20		30		40		50	
	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)
Smoking status	Age							
	60		70		80			
	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)		

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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.	<u>Title Page</u>
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.	<u>P1 Line 2-19</u>
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.	<u>P1-2</u>
Methods			
Target population and subgroups	4	Describe characteristics of the base case population and subgroups analysed, including why they were chosen.	<u>P4 LG-16</u>
Setting and location	5	State relevant aspects of the system(s) in which the decision(s) need(s) to be made.	<u>N/A</u>
Study perspective	6	Describe the perspective of the study and relate this to the costs being evaluated.	<u>P4 L7</u>
Comparators	7	Describe the interventions or strategies being compared and state why they were chosen.	<u>P4 11-16</u>
Time horizon	8	State the time horizon(s) over which costs and consequences are being evaluated and say why appropriate.	<u>B-P4</u>
Discount rate	9	Report the choice of discount rate(s) used for costs and outcomes and say why appropriate.	<u>P11 L16-21</u>
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.	<u>N/A</u>
Measurement of effectiveness	11a	<i>Single study-based estimates:</i> Describe fully the design features of the single effectiveness study and why the single study was a sufficient source of clinical effectiveness data.	<u>N/A</u>



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	11b	<i>Synthesis-based estimates:</i> Describe fully the methods used for identification of included studies and synthesis of clinical effectiveness data.	<u>N/A</u>
Measurement and valuation of preference based outcomes	12	If applicable, describe the population and methods used to elicit preferences for outcomes.	<u>N/A</u>
Estimating resources and costs	13a	<i>Single study-based economic evaluation:</i> 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.	<u>—</u>
	13b	<i>Model-based economic evaluation:</i> 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.	<u>P4-6</u>
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.	<u>P11</u>
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.	<u>P2-3</u>
Assumptions	16	Describe all structural or other assumptions underpinning the decision-analytical model.	<u>P2,3,6</u>
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.	<u>P2-6,10,11</u>
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.	<u>P7, T1</u>
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.	<u>T1</u>
Characterising uncertainty	20a	<i>Single study-based economic evaluation:</i> Describe the effects of sampling uncertainty for the estimated incremental cost and incremental effectiveness parameters, together with the impact	<u>T2-4</u>



		of methodological assumptions (such as discount rate, study perspective).	
	20b	<i>Model-based economic evaluation</i> : 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.	P45-11
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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BMJ Open

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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Primary Subject Heading:	Smoking and tobacco
Secondary Subject Heading:	Health economics, Health services research
Keywords:	HEALTH ECONOMICS, PUBLIC HEALTH, STATISTICS & RESEARCH METHODS, Affordable Care Act

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Manuscripts

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2
3 **1 National medical expenditures by smoking status in American adults: an application of**
4 **2 Manning's two-stage model to nationally-representative data**
5
6 **3**

7 **4 David I. Swedler, PhD¹**

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Keywords: economics; quit status; age effects; MEPS

1 **Abstract**

2 **Objectives:** To assess the medical expenditures of American adults by their smoking status-
3 Current, Former, or Never smokers. We update these expenditures through 2015 controlling for
4 personal characteristics and medical history and assess the impact of years-since-quit and
5 decade of life. **Setting and participants:** Weighted sample of American adults, 2011 – 2015.
6 The linked National Health Interview Survey (NHIS) and Medical Expenditure Panel Survey
7 (MEPS) are annual weighted representations of approximately 250 million adults. Sampling of
8 NHIS is multistage with data collected throughout the year. **Primary outcome measures:** Using
9 data from NHIS and MEPS, we collected demographic data, self-reported medical history, and
10 current smoking status. Smoking status was designated as Never, Current, and Former, along
11 with years-since-quit. Total medical expenditures were collected from MEPS for 2011 –
12 2015. We used Manning’s two-part model to estimate average expenditures per individual and
13 marginal costs for individuals at all levels of smoking status. **Results:** American adults averaged
14 \$4,830 in average medical expenditures. Never smokers (\$4,360, 95% CI = 4154.3 – 4566.3),
15 had lower expenditures than Current (\$5,244, 95% CI = 4707.9 – 5580.3) and Former (\$5,590,
16 95% CI = 5267.4 – 5913.5) smokers. Confidence intervals for Current and Former smokers
17 overlapped. Results were similarly significant when controlling for disease history. Years-since-
18 quitting did not affect expenditures. In each decade of adult life, Former smokers had the highest
19 annual medical expenditures, followed by Current and then Never smokers. **Conclusions:** We
20 updated annual medical expenditures during the Affordable Care Act-era by smoking status
21 using the current best practice model. While we identify Former smokers as having higher
22 medical expenditures than Current smokers, we do not examine how care-seeking behavior
23 varies between levels of each risk factor.

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3 **1 Article Summary**
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5 **2 *Strengths and Limitations***
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- 7
- 8 3 • By using data from 2011 – 2015, this is the first study to report medical expenditure by
9
10 4 smoking status while major provisions of the Affordable Care Act took effect.
11
- 12 5 • We use the gold standard two-part model developed by Manning to estimate medical
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14 6 expenditures from the MEPS and NHIS surveys.
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17 7 • We analyzed medical expenditures for Current smokers and Former smokers- both
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19 8 separately and combined- across decades of life.
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22 9 • Although we controlled for history of comorbidities, the data do not contain any
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24 10 information on reason-for-quitting among former smokers.
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27 11 • The cost differences observed incorporate any differences between the groups in care-
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29 12 seeking for conditions unrelated to smoking.
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1 Introduction

2 It is well-established that smoking can lead to medical conditions requiring acute and chronic
3 treatment¹. Accurate marginal costs for medical risk factors are important when conducting
4 benefit-cost analyses for health risk behavior interventions²⁻⁴. The most recent national estimates
5 of medical expenditures by smoking status have only considered a binary smoking variable:
6 current smokers versus current non-smokers^{5 6}. Further, none of these national studies have
7 analyzed medical expenditure data more recently than 2011. Since that time, major reforms have
8 been implemented to the medical care systems in the United State (US).⁷

9
10 A series of state-level analyses by Max and colleagues⁸⁻¹⁰ described medical costs in California
11 by current, former, and never smokers. The California studies used the attributable fraction (AF)
12 method to allocate medical expenditures. In their review of the AF method, Rockhill and
13 colleagues define attributable fraction and similarly-phrased terms to be “the proportion of
14 disease risk in a population that can be attributed to the causal effects of a risk factor or set of
15 factors,” (p. 15)¹¹. Rockhill *et al* find that the AF method has limitations, including that it is
16 constrained by how accurately costs are allocated among diagnoses and by the availability of
17 accurate AFs that are not confounded by co-occurring risk factors¹¹. The negative outcomes that
18 smokers experience vary widely in nature and timing. Importantly, the method does not measure
19 the standard error for the mean estimated cost per risk-taker¹².

20
21 In summary, the AF method has too much uncertainty in risk factor allocation as well as
22 calculation of standard errors. In analyzing the costs of medical conditions, health economics
23 literature has largely shifted from this AF method to analyses of annual per capita medical

1 spending of people with the condition relative to a comparison group¹³⁻¹⁶. This approach,
2 pioneered by Willard Manning¹⁷ captures both mean and standard error and it accounts for
3 complications that may not be coded to the underlying condition. That is, these equations take a
4 more holistic view of medical care and expenditures associated with risk factors' coefficients
5 than would a process seeking to attribute specified treatment costs to specified factors. It allows
6 that medical visits for conditions related to the behavioral risk factors may displace other medical
7 care that might be sought if an individual did not have a given risk factor. For example, a doctor
8 who is scheduling quarterly visits to manage diabetes is unlikely to separately schedule the
9 annual well-care visit recommended for a healthier patient. That well-care visit gets coded as a
10 chronic care visit even though it may not raise annual medical spending¹⁸.

11
12 While the Manning model is now the gold standard for working with skewed outcomes like
13 medical spending, it is an imperfect tool. Although it statistically assigns costs to given risk
14 factors or medical conditions, it does not tell us the "why" behind each individual medical
15 encounter or expense. Medical spending is influenced by care-seeking behavior. Smokers may
16 avoid visiting the doctor because it is uncomfortable to report their continued smoking behavior
17 or tedious to hear the doctor urge them to change¹⁹. Health consciousness and associated use of
18 preventive care may be below-average for people who engage in risky behavior. Furthermore,
19 drinking heavily may be a symptom of life management issues that reduce care-seeking. Those
20 differences in health management may mask the impacts of risk behavior on medical spending.

21
22 *Purpose*

1 This study updates the national estimates during the implementation of many major provisions of
2 the Patient Protection and Affordable Care Act (ACA) for annual medical expenditures of adult
3 Americans by their current smoking status. We examine medical expenditure data for 2011 –
4 2015 and apply the cutting-edge two-stage Manning model to more accurately assess error
5 around mean expenditures.

7 **Methods**

8 *Data Collection*

9 We analyzed data on smoking status from the National Health Interview Survey (NHIS)²⁰. The
10 NHIS is an annual, cross-sectional survey designed to monitor health and behaviors of civilian,
11 non-institutionalized Americans through a nationally-representative sample. The Medical
12 Expenditure Panel Survey (MEPS) tracks a nationally representative subsample of NHIS
13 participants for 24 months starting in the year after their NHIS interview. MEPS collects five
14 rounds of data per respondent on healthcare visits and expenditures²¹. It captures all payments
15 for care, regardless of source, and models costs for visits without payment data including charity
16 care and visits bundled into capitated care. We used 2011-2015 MEPS data on total medical
17 expenditures from the individual perspective for adults 18-years and older and the corresponding
18 NHIS 2009 – 2014 data. Annual medical expenditures were inflated to 2015 US dollars (USD)
19 using the Personal Consumption Expenditures- Medical Care. We linked data from MEPS and
20 NHIS via the Agency for Health Care Quality Data Center, as Xu *et al*⁵ did in their analyses of
21 smoking costs⁶. Because our use of the publicly-available data adhered to the government's
22 privacy restrictions, the project was given an Exemption by the Institutional Review Board of the
23 Pacific Institute for Research and Evaluation prior to data analysis.

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5 2 Smoking status was identified through the NHIS Supplemental Adult Questionnaire (SAQ). Like
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8 3 earlier studies, we identified Ever smokers as participants who smoked at least 100 cigarettes in
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10 4 their lifetimes. We defined all others as Never smokers⁶. Ever smokers were further subdivided
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12 5 into those who reported quitting smoking, Former smokers, versus those who did not report
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14 6 quitting, Current smokers⁸⁻¹⁰. For Former smokers, we also identified years-since-quitting.
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19 8 To conduct regressions, we included the following demographic and behavioral characteristics:
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21 9 age, sex, race/ethnicity, marital status, total family income, family size, employment status,
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23 10 marital status, self-reported binge drinking status, body mass index (BMI), recent pregnancy,
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25 11 education level, employment, and insurance data from MEPS. Age was employed as a
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27 12 continuous variable in the main analyses and divided into ten-year blocks in the age-specific
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29 13 sensitivity analysis. Binge drinking data were also obtained from the SAQ, which used the
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31 14 accepted binge drinking definition of men having 5 or more drinks and women having 4 or more
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33 15 drinks. Those participants who indicated that they had 12 or more instances of binge drinking in
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35 16 the past year were categorized as frequent binge drinkers, and those who had 1-11 instances were
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37 17 categorized as infrequent binge drinkers. BMI data were calculated from self-reported weight
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39 18 and height in the NHIS. We dichotomized BMI into obese for those with a BMI of 30 kg/m² or
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41 19 greater, and not obese for those with lower BMI. We refer to these variables collectively as
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43 20 personal characteristics.
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51 22 NHIS and MEPS had data on self-reported diagnosis history for various diseases. Using data
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53 23 from both databases, we generated dichotomous variables for whether a participant had ever
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3 1 been diagnosed with the following diseases: asthma, arthritis, any cancer, cardiovascular diseases
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5 2 (including angina, coronary heart disease, myocardial infarction, or stroke), diabetes, and
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7 3 emphysema. NHIS had data on chronic obstructive pulmonary disease (COPD) available for
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9 4 2013 through 2015 MEPS panels. From MEPS, we obtained scores for the Short Form 12 to
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11 5 measure quality of life²², the Personal Health Questionnaire (PHQ) metric for depression²³, and
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13 6 the Kessler 6 questionnaire for mental illness²⁴. From these variables, we were able to code a
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15 7 partial list of comorbidities that Elixhauser and colleagues²⁵ suggest controlling for when using
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17 8 administrative medical data.
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24 10 *Regression Analysis*

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26 11 We used the two-stage model approach developed by Manning and Basu¹⁷ to model discrete-
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28 12 continuous outcomes. The first regression in this method models whether or not an individual
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30 13 had any medical expenditures in the given year. Then, the second model estimates the costs for
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32 14 individuals who the first model predicted had any costs. We used an ordinary least squares
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34 15 (OLS) logistic probit regression in the first step, followed by a generalized linear model with a
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36 16 generalized Gamma distribution and log link in the second stage. We used the Stata twopm
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38 17 command developed by Belotti and colleagues to execute the two models²⁶. The twopm
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40 18 command allowed us to use the survey weights provided by AHRQ. Data were collected and
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42 19 merged using SAS v9.4 analytical software [SAS Institute, Cary, NC]. Data management was
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44 20 performed in SAS and Stata IC v15 [Stata Corp, College Station, TX]. All data analysis was
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46 21 conducted using Stata.
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3 1 Our main regression model (Model 1) included personal characteristics and current smoking
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5 2 status. We experimented with including body mass index in the model; however, the variable had
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7 3 near 50% missingness, so we excluded it from our final model. (Further sensitivity analysis
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9 4 indicated that body mass had negligible impact on estimated expenditures by smoking status).
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11 5 We added the disease history to the two-stage model (Model 2). Finally, because COPD
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13 6 comorbidity was only available for the last three years of the study, we excluded COPD and re-
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15 7 ran the model on all five years of the study period. Because controlling for this co-morbidity did
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17 8 not noticeably affect the estimates by smoking status, we chose to report estimates based on 5
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19 9 years of data, thus increasing our power to probe costs among subgroups. We further expanded
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21 10 Model 2 to include data on years-since-quit for Former smokers at 1-, 2-, and 5-year
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23 11 thresholds. Because prevalence of these risk factors changes over the life course, we also
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25 12 examined the marginal effects of smoking on medical expenditures by decade of adult life²⁶.
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27 13 Non-overlapping confidence intervals indicated statistically significant differences.
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35 **Results**

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37 16 An average of 19.7 million adults self-identified as Current smokers in the US from 2011 to
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39 17 2015. The proportion of current smokers decreased over the study period, to approximately 17.5
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41 18 million adults in 2015. An average of 43.6 million adults in the U.S. were Ever smokers. The
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43 19 proportion of former smokers increased through decades of life, peaking over 22% for those
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45 20 older than 70-years-old. Tables 1a and 1b describe smoking status by study year and decade of
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47 21 life, respectively. Among the 23.9 million Former smokers, only 4.3% quit within the prior year,
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49 22 8.7% quit within the prior 2 years, and 24.4% quit within the 5 years prior to the survey.
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3 1 Table 2 displays the costs for American adults in 2011 – 2015 by smoking status. In Model 1,
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5 2 mean annual medical expenditures for US adults were \$4,830. Costs for adult Never smokers
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7 3 were below the national average (\$4,360). Former smokers had the highest annual medical
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9 4 expenses, \$5,590 (28% increase over never smokers). Although Current smokers had lower
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11 5 average costs than Former smokers at \$5,144 (18% increase over Never smokers), the 95%
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13 6 confidence intervals (CIs) overlap for Current and Former smokers. If we combine Current and
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15 7 Former smokers into Ever smokers and re-run Model 1, the average costs for someone who has
16
17 8 ever smoked is \$5,400 (95% CI = 5142 – 5659).
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24 10 In Table 3, a sensitivity analysis for Model 2 that includes years-since-quitting for former
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26 11 smokers does not find a direct relationship between time since smoking cessation and medical
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28 12 expenditures. The mean expenditures by cessation period have small differences, and the 95%
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30 13 CIs greatly overlap. Table 4 identifies displays how medical expenditures vary across decades of
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32 14 life by smoking status. The 95% CIs for Never smokers in Table 4 do not contain the estimate
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34 15 for Former smokers at each decade. The CIs for Former smokers do not contain the estimate for
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36 16 Never smokers at all decades except for age 20. The 95% CIs for Current smokers at each decade
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38 17 include both the Never and Former smoker estimates, and the CIs for Never and Former smokers
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40 18 include the estimate for Current smokers.
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47 20 Multiplying costs by average number of smokers for 2011 – 2015, Current smokers incurred
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49 21 \$101.4 billion in average annual medical expenses (95% CI = 12.6 billion – 14.1 billion), \$15
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51 22 billion above the costs for a demographically comparable number of Never smokers. Former
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53 23 smokers incurred an average of \$133.6 billion in annual medical expenditures (95% CI = 9.28
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1 billion – 110 billion), a \$29 billion increase over comparable Never smokers. Average annual
2 medical expenditures for Ever smokers are \$235.6 billion (95% CI = 224 billion – 247 billion),
3 approximately \$45 billion above the costs for a demographically comparable number of Never
4 smokers.

6 Discussion

7 We updated the national estimates for smoking costs in American adults through 2015 using
8 state-of-the-science economic modeling techniques. This was a period when major provisions of
9 the ACA were being enacted, e.g., state Medicaid expansion; the “individual mandate” in 2014.⁷
10 Our estimates for annual medical expenditures for all civilian non-institutionalized adults was
11 \$4,830 for 2011 – 2015, in 2015 USD. This estimate for the study period was close to Mitchell
12 and Machlin’s²⁷ estimate of average total medical expenditures in 2015 using MEPS data
13 (\$4,978). Our estimate for annual expenditures and marginal costs due to smoking are below
14 similar estimates generated using the National Health Expenditure Assessment (NHEA)
15 database^{28 29}. However, the NHEA is more comprehensive than the MEPS in capturing Medicaid
16 costs covering institutionalized adults (including those in nursing homes), active-duty military,
17 and foreign visitors to the US ^{29 30}, so we expected MEPS to yield lower estimates.

18
19 We find that Former smokers have greater annual medical costs over Current and Never
20 smokers; however, the 95% confident intervals overlap for Current and Former smokers in the
21 main model. Surely, some smokers quit after diagnosis of costly health problems linked to
22 smoking, but the cost differential narrows only slightly after controlling for major chronic

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

3
4 Some older studies compared medical spending per capita among current, former, and never
5 smokers. Using data from the 1987 National Medical Expenditure Survey (NMES), Miller and
6 colleagues [1999] identified higher annual medical expenditures in former smokers over current
7 smokers. Contrasting with the national studies, two studies using local claims data^{31 32} found that
8 medial expenditures for current and former smokers were nearly identical, with a slight spike in
9 costs for former smokers immediately following quitting.

10
11 Some current smokers may experience very high cost medical expenditures over a short period
12 before dying (and thus not incurring any further costs), while former smokers may continue to
13 amass lower cost medical encounters. These former smokers would be gaining up to 10 years of
14 survival and medical expenditures over current smokers³³. Current smokers also may simply be
15 doctor-phobic, anxious to avoid yet another lecture about their smoking. The persistence and
16 perversity of our finding that higher medical expenditures in former smokers at all ages and
17 regardless of time-since-quit, suggests exploring the issue using qualitative methods.

18
19 We followed the methods of Xu and colleagues⁵ and Max and colleagues⁸⁻¹⁰ to identify current,
20 former, and never smokers in NHIS/MEPS data. Those studies examined attributable fractions
21 (AFs) for medical expenditures rather than costs to individuals. The two-part model developed
22 by Manning and colleagues has become the gold-standard for estimating costs in a skewed
23 sample, such as medical expenditures^{17 34}. It has been used to study the impact of smoking on

1 healthcare costs across a wide variety of databases^{6 35 36}. An analysis from An⁶ using the two-
2 stage model was performed on medical expenditures associated with smoking status (ever vs.
3 never) and obesity (< 30 BMI vs. $30 \geq$ BMI) using MEPS data from 1998 to 2011. In contrast to
4 the present study, An's estimated expenditures did not control for quit status, marital status,
5 family income, family size, or pregnancy. Our estimated cost differences between ever/never
6 smokers and obese/non-obese individuals (data not shown) were lower than in the An study. We
7 believe that the inclusion of quit status and additional personal characteristics in the two-stage
8 models increases the precision of our estimate over this prior study.

9 10 *Limitations and Strengths*

11 Many of the prior studies assessing the impact of behavioral risk factors on medical expenditures
12 employ the traditional attributable fraction approach, which constructs costs from selected acute
13 and chronic conditions related to the individual risk factors of interest. This method is
14 appropriate unless a study echoes our aim to examine the marginal effects of the risk behaviors
15 on costs to individuals. Using the two-part model¹⁷, our study provides a different assessment of
16 medical expenditures than the attributable fraction method. Attributable fraction studies estimate
17 the smoking-related medical costs incurred in treated diseases that resulted from smoking. The
18 two-stage modelling approach instead looks at the overall medical spending of the smoking
19 cohort. It can be strongly influenced by a difference in care-seeking propensity.

20
21 Our estimates for prevalence of smoking (9%) are lower than those found in other surveillance
22 studies. The Behavioral Risk Factor Surveillance System (BRFSS) identified 15% of American
23 adults as current smokers in 2015³⁷. This discrepancy between BRFSS and NHIS data may be

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

4
5 The goal of this study was to update medical expenditures for smoking to 2015. It was beyond
6 the scope of the study to assess spending by type of medical service utilized. With sufficient
7 budget, doing so might have allowed us to propose more hypotheses as to why certain risks had
8 increased costs over others, as Sturm³⁸ did for obesity and problem drinking.

9
10 In a period of low inflation, we chose to control for inflation in our multi-year analysis of
11 expenditures by including dummy variables for MEPS year rather than using price adjusters that
12 assume a fixed market basket of medical services. The dummy variables should account not only
13 for year-to-year changes in costs, but for other endogenous temporal effects. Those effects
14 include the many policy features of 2010's Affordable Care Act that went into effect from 2011
15 to 2015⁷. Further analysis of the impacts of all components of the ACA on medical expenditures
16 is warranted.

17 18 *Conclusion*

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

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

3 4 *Acknowledgement and Funding*

5 The research in this paper was conducted at the CFACT Data Center, and the support of AHRQ
6 is acknowledged. The results and conclusions in this paper are those of the authors and do not
7 indicate concurrence by AHRQ or the Department of Health and Human Services.
8 Funding for this project was provided by NHLBI grant AN: 3421751 (Implementation of HIT-
9 Enhanced Tobacco Treatment for Hospitalized Smokers) and NCI grant R01CA201873
10 (Optimizing Tobacco Dependence Treatment in the Emergency Department).

11 *Patient and Public Involvement- Cohort Description*

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

18 *Data Sharing-*

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

21 *Author contributions*

1
2
3 1 SLB, TRM, and DIS conceived of the study. DIS, GW, and TRM designed the analysis. DIS
4
5 2 conducted the analysis. DIS and BA wrote and edited drafts of the manuscript. All authors
6
7 3 provided input on the manuscript and approved of the final draft.
8
9

10 4 *Competing interests:*
11

12 5 All authors state that they have no competing interests.
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1 **Table 1.** Prevalence of smoking by year of MEPS data collection (a) and decade of age (b).
 2 Average participants in each category were developed using survey weights.

Table 1a	Smoking status by year of medical expenditure					n
	2011	2012	2013	2014	2015	
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.

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

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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\$.

Smoking status	Age							
	20		30		40		50	
	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)
Smoking status	Age							
	60		70		80			
	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)		

4

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.	<u>Title Page</u>
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.	<u>P1 Line 2-19</u>
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.	<u>P1-2</u>
Methods			
Target population and subgroups	4	Describe characteristics of the base case population and subgroups analysed, including why they were chosen.	<u>P4 LG-16</u>
Setting and location	5	State relevant aspects of the system(s) in which the decision(s) need(s) to be made.	<u>N/A</u>
Study perspective	6	Describe the perspective of the study and relate this to the costs being evaluated.	<u>P4 L7</u>
Comparators	7	Describe the interventions or strategies being compared and state why they were chosen.	<u>P4 11-16</u>
Time horizon	8	State the time horizon(s) over which costs and consequences are being evaluated and say why appropriate.	<u>B-P4</u>
Discount rate	9	Report the choice of discount rate(s) used for costs and outcomes and say why appropriate.	<u>P11 L16-21</u>
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.	<u>N/A</u>
Measurement of effectiveness	11a	<i>Single study-based estimates:</i> Describe fully the design features of the single effectiveness study and why the single study was a sufficient source of clinical effectiveness data.	<u>N/A</u>



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2		11b	<i>Synthesis-based estimates</i> : Describe fully the methods used for identification of included studies and synthesis of clinical effectiveness data. <u>N/A</u>
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5	Measurement and	12	If applicable, describe the population and methods used to elicit preferences for outcomes. <u>N/A</u>
6	valuation of preference		
7	based outcomes		
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9	Estimating resources	13a	<i>Single study-based economic evaluation</i> : 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. <u>—</u>
10	and costs		
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12		13b	<i>Model-based economic evaluation</i> : 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. <u>P4-6</u>
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22	Currency, price date,	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. <u>P11</u>
23	and conversion		
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28	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. <u>P2-3</u>
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31	Assumptions	16	Describe all structural or other assumptions underpinning the decision-analytical model. <u>P2,3,6</u>
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34	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. <u>P2-6,10,11</u>
35			
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41	Results		
42	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. <u>P7, T1</u>
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48	Incremental costs and	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. <u>T1</u>
49	outcomes		
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52	Characterising	20a	<i>Single study-based economic evaluation</i> : Describe the effects of sampling uncertainty for the estimated incremental cost and incremental effectiveness parameters, together with the impact <u>T2-4</u>
53	uncertainty		
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		of methodological assumptions (such as discount rate, study perspective).	
	20b	<i>Model-based economic evaluation:</i> 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.	<u>N/A</u>
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.	<u>P45-11</u>
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.	<u>P12</u>
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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