



Smoking-attributable medical expenditures by age, sex, and smoking status estimated using a relative risk approach[☆]



Michael V. Maciosek^{a,*}, Xin Xu^b, Amy L. Butani^a, Terry F. Pechacek^b

^a HealthPartners Institute for Education and Research, Minneapolis, MN, USA

^b Office on Smoking and Health, Centers for Disease Control and Prevention, Atlanta, GA, USA

ARTICLE INFO

Available online 4 June 2015

Keywords:

Health care costs
Health expenditures
Smoking
Tobacco
Smoking/economics
Health expenditures/statistics & numerical data
Health services/utilization

ABSTRACT

Objective. To accurately assess the benefits of tobacco control interventions and to better inform decision makers, knowledge of medical expenditures by age, gender, and smoking status is essential.

Method. We propose an approach to distribute smoking-attributable expenditures by age, gender, and cigarette smoking status to reflect the known risks of smoking. We distribute hospitalization days for smoking-attributable diseases according to relative risks of smoking-attributable mortality, and use the method to determine national estimates of smoking-attributable expenditures by age, sex, and cigarette smoking status. Sensitivity analyses explored assumptions of the method.

Results. Both current and former smokers ages 75 and over have about 12 times the smoking-attributable expenditures of their current and former smoker counterparts 35–54 years of age. Within each age group, the expenditures of former smokers are about 70% lower than current smokers. In sensitivity analysis, these results were not robust to large changes to the relative risks of smoking-attributable mortality which were used in the calculations.

Conclusion. Sex- and age-group-specific smoking expenditures reflect observed disease risk differences between current and former cigarette smokers and indicate that about 70% of current smokers' excess medical care costs is preventable by quitting.

© 2015 Elsevier Inc. All rights reserved.

Introduction

January 11th, 2014, marked the 50th anniversary of the release of the first Surgeon General's Report on Smoking and Health in 1964 (Surgeon General's Advisory Committee on Smoking and Health, 1964). While cigarette smoking continues to decline and millions of premature deaths were averted as a result of tobacco control efforts during the last half of the century (Centers for Disease Control and Prevention, 2011; Holford et al., 2014), tobacco use remains the nation's leading preventable cause of death and disease (Surgeon General's Advisory Committee on Smoking and Health, 1964). Annual smoking-attributable economic costs in the United States estimated for the years 2009–2012 were between \$289 and 332.5 billion, including \$132.5–175.9 billion for direct medical care of adults (Centers for Disease Control and Prevention, 2008; Congressional Budget Office, 2012; Levy DE, 2011; Miller et al., 1999; Solberg et al., 2006; U.S.

Department of Health and Human Services, 2014; Warner et al., 1999). Therefore, concerted efforts, including tobacco price increases, high-impact anti-tobacco mass media campaigns, comprehensive smoke-free laws, and barrier-free access to help quitting, are needed to reduce tobacco use initiation and promote cessation.

To accurately assess the benefits of these interventions and to better inform decision makers, knowledge of medical expenditures by age, gender, and smoking status is essential. This paper provides age-group estimates of smoking-attributable medical expenditures based on nationally representative data for policy analyses. Individual-level observational data are complicated by spikes in medical utilization of recent quitters whose cessation was likely prompted by symptoms of smoking-attributable diseases (Centers for Disease Control and Prevention, 2008; Fishman et al., 2003, 2006; Hockenberry et al., 2012; Miller et al., 1999). Accuracy in the economic analysis of preventive interventions requires knowledge of what utilization would have been for all former smokers had they quit prior to symptoms. Moreover, timing of quits in the lifecycle is critical as it affects subsequent medical utilization (Jha et al., 2013; Woloshin et al., 2008). For example, comprehensive smoke-free laws may induce smokers to quit at an earlier age and prior to the development of smoking-attributable illness. To assess the economic impact of these earlier quits, policy analysts need information on the age-specific difference in medical costs between

[☆] **Disclaimer:** The findings and conclusions in this report are those of authors and do not necessarily represent the official positions of the Centers for Disease Control and Prevention.

* Corresponding author at: HealthPartners Institute for Education and Research, Mail stop 21111R, P.O. Box 1524, Minneapolis, MN 55440–1524.

E-mail address: Michael.V.Maciosek@HealthPartners.com (M.V. Maciosek).

continuing smokers and former smokers who quit for reasons other than having developed symptoms of a smoking-attributable illness.

This analysis, aligned with the 2014 Surgeon General's Report on the health consequences of smoking (U.S. Department of Health and Human Services, 2014), provides an option for evaluating smoking-attributable expenditures by age, gender, and smoking status that reflects the known risks of smoking derived from epidemiological data and the benefits of cessation or averted initiation. Studies evaluating financial benefits of smoking prevention policies may adopt this method to be better aligned with health benefits of these interventions.

Methods

Our method distributes smoking-attributable medical expenditures by age group, sex, and smoking status based upon the portion of disease events that occur among never, current, and former smokers. We first assess the distribution of smoking-attributable disease events in the US population by age and sex. Relative risks of events among never, current, and former smokers are then used to distribute events by smoking status within age and sex groups. For current and former smokers, the portion of events that occur in each age-sex strata is then calculated. These portions are used as a proxy for the distribution of smoking-attributable expenditures by age, sex, and smoking status strata. We demonstrate use of these portions by applying a national estimate of smoking-attributable costs.

We use the distribution of hospitalization days for smoking-attributable conditions as a proxy for the distribution of total smoking-attributable expenditures. Facility bills for hospitalizations comprise 38% of all US personal health care expenditures (Office of the Actuary in the Centers for Medicare & Medicaid Services, 2012). The portion of all smoking-attributable expenditures that are for hospitalizations is approximately 51% (Centers for Disease Control and Prevention, 2007). Other services, including physician services provided during hospitalizations, are correlated with hospitalization expense. Using the 1987 National Medical Expenditure Survey, Miller et al. observed substantial agreement between the smoking-attributable portion of hospital expenditures and other types of care (Miller et al., 1999). They found smoking to be associated with 7.4% and 6.7% of hospital expenditures for ages 35–64 and ages 65 and greater, respectively, and for the same two age groups, smoking was associated with 11.2% and 10.9% of ambulatory expenditures, 7.7% and 8.4% of prescription drug expenditures and 7.2% and 7.6% of other medical expenditures. Using hospitalizations as a proxy for all expenditures has the advantages of a readily available and periodically updated public use, nationally representative data set. Estimates based on hospitalizations can be updated as the relative risks of smoking on medical conditions evolve. More importantly, hospitalizations are coded with a primary discharge diagnosis that allows each appropriate stay to be mapped to a smoking-attributable condition. In contrast, most outpatient encounters, nursing home care, and many pharmaceuticals cannot be readily attributed to a primary diagnosis. We distribute hospitalization days using disease-specific relative risks of smoking-attributable mortality by age and sex for current and former cigarette smokers compared to never smokers. The distribution of hospitalization days by population group is determined through calculation of smoking-attributable fractions. Calculations are provided in the technical appendix.

Data and sources

The method relies on an external estimate of national smoking-attributable medical expenditures, but can be applied to any number of such estimates. Following the latest evidence on smoking-attributable fractions in the U.S. healthcare spending (Solberg et al., 2006; Xu et al., 2015), we use 8.66% of projected 2013 Personal Health Care Expenditures (PHCE) for adults 19 years of age and older less dental care in our example, which is consistent with previous cross-sectional studies that reported smoking-attributable fractions ranging from 6.5% to 14% (Miller et al., 1999; Warner et al., 1999). However, any estimated attributable fractions based on studies published within the last 15 years can be used with this approach (Centers for Disease Control and Prevention, 2002; Congressional Budget Office, 2012; Levy DE, 2011; Miller et al., 1999; Solberg et al., 2006; Warner et al., 1999).

We used the 2012 National Health Interview Survey to determine the distribution of the US population by age, sex, and smoking status. NHIS is an annual, nationally representative, in-person survey of the noninstitutionalized U.S. civilian population aged 18 years or older. Current- and never-smoker status was

determined using common definitions based upon having ever-smoked 100 or more cigarettes (Agaku et al., 2014).

We used first-listed discharge diagnosis code to identify inpatient stays in 2010 National Hospital Discharge Survey (NHDS), the most recent year of data available (Centers for Disease Control and Prevention, 2010). The NHDS is a national probability survey of 239 hospitals that provides information on characteristics of inpatients discharged from US non-Federal, general hospitals with an average length of stay of fewer than 30 days. Data from the sample of inpatients were weighted to produce national estimates and standard errors were tabulated using the generalized variance curves provided by NHDS for use in the public use data set (Centers for Disease Control and Prevention, 2012).

NHDS is abstracted from medical records that do not contain cigarette smoking status for use in calculating relative risks, and relative risks for nonfatal events are not available for a broad range of diseases from another standardized source. Therefore, mortality relative risks were used to distribute hospitalizations among never, current, and former smokers within age and gender groups. Relative risks of smoking-attributable mortality were obtained from the 2014 Surgeon General's Report (U.S. Department of Health and Human Services, 2014) for age groups 35–54, 55–64, 65–74, and 75+ years as shown in Table 1. Compared to the relative risks reported in SAMMEC (Centers for Disease Control and Prevention, 2007), the relative risks used in our calculations were combined into fewer disease categories, reflecting the need to collapse on disease detail in order to expand on age detail using the same underlying data sets. Relative risks are assumed to equal 1.0 for ages below 35.

The use of mortality relative risks assumes that the event-fatality rate is constant across smoking status groups. If this is not the case, then our calculations may over-state or under-state the financial benefits of quitting.

Sensitivity analysis

We explored modified methods by using any discharge diagnosis (rather than first listed) to identify hospital stays for smoking-attributable conditions and by using counts of stays rather than counts of days. In addition, because the method implicitly assigns equal weight to each day of care, we explored differential weighting to approximate the use of condition-specific expenditures per day. For this, we assigned relative cost weights of 1.0 for cardiovascular disease, 2.0 for cancers, and 0.5 for respiratory disease to reflect the potential for cancer to have more intensive out-of-hospital treatments, and for respiratory conditions to be associated with relatively lower inpatient professional services. This hypothetical scenario would imply substantial variation among conditions while still retaining the similar average proportion of smoking-attributable expenditures by care type as noted above.

Results

First-listed discharge diagnosis codes identified a total of 7.1 million hospitalizations and 36.7 million hospitalization days for smoking-attributable conditions. The percent distribution of hospitalization days by condition for each age and sex strata are shown in Table 1. For all age groups, hospitalization days for cardiovascular conditions are the most frequent and therefore the relative risks for cardiovascular conditions have the greatest influence in the results.

Annual rates of smoking-attributable hospital days by age, sex, and smoking status are shown in Table 2. By subtracting hospitalization days that occurred in never smokers, and the portion that occurred in ever smokers that would have occurred even if they never started smoking, we estimate that 30% of the 36.7 million hospitalization days for the diseases included in the analysis are smoking-attributable (not shown). For all age groups, and for both males and females, estimated smoking-attributable hospitalization days for former smokers are about 30% of those of current smokers. The difference is larger for females in the 35–54 year age group.

For illustrative purposes, estimates of smoking-attributable expenditures by age, sex, and smoking status for 2012 are shown in Table 2 assuming 8.66% of PHCE are attributable to smoking (U.S. Department of Health and Human Services, 2014). Smoking-attributable expenditures of female smokers ages 35 to 54 years are \$1,382 compared to \$15,863 for their 75 years and older counterparts (cost ratio = 11.47). Similar ratios between the oldest and youngest age groups are seen across

Table 1
Distribution^a of hospitalization days by age, sex and smoking-attributable disease for stays with a first-listed discharge diagnosis of a smoking-attributable condition, United States adults 35 or more years of age.

Smoking-attributable disease	Males				Females			
	35–54 years	55–64 years	65–74 years	75+ years	35–54 years	55–64 years	65–74 years	75+ years
Lung cancer ^b	0.4% (0.0040)	3.4% (0.0046)	3.4% (0.0041)	2.5% (0.0030)	1.5% (0.0076)	4.2% (0.0054)	2.7% (0.0037)	1.5% (0.0019)
Other cancers ^c	6.7% (0.0159)	9.7% (0.0076)	10.8% (0.0070)	6.3% (0.0047)	13.8% (0.0218)	6.7% (0.0067)	4.7% (0.0048)	4.4% (0.0031)
Coronary heart disease ^d	18.0% (0.0244)	23.5% (0.0109)	19.1% (0.0088)	14.9% (0.0068)	10.0% (0.0189)	17.0% (0.0101)	12.4% (0.0075)	12.6% (0.0051)
Other heart disease ^e			24.2% (0.0096)	32.4% (0.0090)			26.6% (0.0101)	31.7% (0.0071)
Cerebrovascular disease ^f			11.8% (0.0072)	14.2% (0.0067)			17.1% (0.0086)	19.6% (0.0061)
Other vascular diseases ^g			6.2% (0.0054)	3.9% (0.0037)			3.8% (0.0043)	3.2% (0.0027)
Diabetes mellitus ^h			5.8% (0.0052)	4.4% (0.0039)			5.8% (0.0053)	3.4% (0.0028)
Other cardiovascular diseases ⁱ	53.8% (0.0317)	46.5% (0.0128)			49.4% (0.0315)	45.7% (0.0134)		
Influenza, pneumonia, tuberculosis ^j			10.7% (0.0069)	13.8% (0.0066)			12.8% (0.0076)	16.5% (0.0057)
Chronic obstructive pulmonary disease ^k			7.9% (0.0060)	7.7% (0.0051)			14.2% (0.0080)	7.2% (0.0039)
Influenza, pneumonia, tuberculosis, chronic obstructive pulmonary disease ^l	21.2% (0.0259)	16.9% (0.0096)			25.3% (0.0274)	26.4% (0.0118)		

Sources: Authors' estimates based upon the 2010 National Hospital Discharge Survey¹⁹ and relative risks from 2014 Surgeon General's report on the health consequences of smoking.⁴ See text for details.

^a Percentages in table show column percent for each age and sex group. Standard errors in parenthesis. All relative standard errors (not shown) are less than 30%.

^b ICD-9 162.xx.

^c Includes cancers of the lip, pharynx and oral cavity, esophagus, stomach, colorectal, liver, pancreas, larynx, cervix uteri (women), kidney and renal pelvis, and bladder, and acute myeloid leukemia. ICD-9 140.xx–149.xx; 150.xx–151.xx; 153.xx–155.xx; 157.xx; 161.xx; 188.xx–189.xx; 205.xx.

^d ICD-9 410.xx–414.xx; 429.2.

^e Includes rheumatic heart disease, pulmonary heart disease, and other forms of heart disease. ICD-9 390.xx–398.xx; 415.xx–417.xx; 420–429.1; 429.3x–429.9.x.

^f ICD-9 430.xx–438.xx.

^g Includes atherosclerosis, aortic aneurysm, and other arterial diseases. ICD-9 430.xx–438.xx.

^h ICD-9 250.xx.

ⁱ Includes all conditions listed for other heart disease, cerebrovascular disease, other vascular disease and diabetes. ICD-9 250.xx; 390.xx–398.xx; 415.xx–417.xx; 420–429.1; 429.3x–429.9.x; 430.xx–438.xx; 440.xx–448.xx.

^j ICD-9 010.xx–018.xx, 480.xx–487.xx.

^k Includes bronchitis, emphysema, and chronic airways obstruction. ICD-9 490.xx–492.xx, 496.xx.

^l Includes influenza, pneumonia, TB, and COPD (ICD-9 codes as above).

other sex and smoking status groups. The method, by its definition, yields the same relative difference in expenditures between former and current smokers as it does for hospitalization days.

Based upon the ratio of smoking-attributable expenditures of former smokers to current smokers when the average expenditures are weighted by each smoking groups' age distribution, it might be mistakenly concluded that quitting reduces costs by 48% in men and 47% in women ($1-0.522 = .478$; $1-0.531 = 0.469$). However, the age distribution differs markedly between current and former smokers. Based upon average expenditures weighted by the age distribution of

former smokers, we estimate that quitting reduces expenditures by approximately 72% in both men and women ($1-0.282 = 0.718$; $1-0.280 = 0.720$).

Sensitivity analysis

Basing the estimates on hospitalizations rather than hospitalization days had little impact on the estimates. These results are shown in the first panel (SA 1) of Table 3. Using hospitalizations with a smoking-

Table 2
Annual smoking-attributable hospital days and expenditures by age, sex, and smoking status, per person for US adults 35 more years of age.

Age group	Current smokers ^a		Former smokers ^b		Ratio former to current smokers	
	Males	Females	Males	Females	Males	Females
Annual smoking-attributable hospital days						
35–54 years	0.088	0.083	0.022	0.011	0.25	0.13
55–64 years	0.298	0.236	0.080	0.066	0.27	0.28
65–74 years	0.602	0.492	0.173	0.154	0.29	0.31
75+ years	0.993	0.950	0.288	0.272	0.29	0.29
All ages	0.213	0.194	0.111	0.103	0.52	0.53
Annual smoking-attributable costs if 8.66% of US Personal Health Care Expenditures are attributable to smoking						
35–54 years	\$ 1,472	\$ 1,382	\$ 372	\$ 178	0.25	0.13
55–64 years	\$ 4,979	\$ 3,940	\$ 1,336	\$ 1,103	0.27	0.28
65–74 years	\$10,044	\$ 8,212	\$ 2,886	\$ 2,575	0.29	0.31
75+ years	\$16,569	\$15,863	\$ 4,807	\$ 4,542	0.29	0.29
All ages, weighted by each groups' age distribution	\$ 3,557	\$ 3,237	\$ 1,857	\$ 1,718	0.52	0.53
All ages, weighted by former smokers' age distribution	\$ 6,590	\$ 6,134	\$ 1,857	\$ 1,718	0.28	0.28

Source: Authors' calculations.

^a Current smokers were respondents to the 2012 National Health Interview Survey who reported smoking ≥ 100 cigarettes during their lifetime and, at the time of interview, reported smoking every day or some days.

^b Former smokers were respondents who reported smoking ≥ 100 cigarettes during their lifetime but currently did not smoke.

Table 3

Sensitivity analysis for smoking-attributable expenditures by age, sex, and smoking status, per person for US adults ages 35 or more years of age.

Age group	Current smokers ^a		Former smokers ^b		Ratio former to current smokers	
	Males	Females	Males	Females	Males	Females
SA 1: Hospitalizations days replaced with hospitalization counts						
35–54 years	\$ 1,580	\$ 1,387	\$ 348	\$ 187	0.22	0.13
55–64 years	\$ 5,430	\$ 4,033	\$ 1,457	\$ 1,148	0.27	0.28
65–74 years	\$ 11,761	\$ 8,762	\$ 3,305	\$ 2,794	0.28	0.32
75+ years	\$ 16,902	\$ 16,971	\$ 4,847	\$ 5,014	0.29	0.30
SA 2: Hospitalization days with first-listed discharge diagnosis for smoking-attributable disease replaced with days having discharge diagnosis code in any position						
35–54 years	\$ 985	\$ 1,061	\$ 223	\$ 138	0.23	0.13
55–64 years	\$ 4,929	\$ 3,367	\$ 1,280	\$ 984	0.26	0.29
65–74 years	\$ 12,677	\$ 9,152	\$ 3,937	\$ 3,061	0.31	0.33
75+ years	\$ 20,341	\$ 20,655	\$ 5,814	\$ 6,270	0.29	0.30
SA 3: Hypothetical weighting of cancers (×2) and respiratory disease (×0.5) hospitalization days (test for sensitivity to differences in cost per episode)						
35–54 years	\$ 1,399	\$ 1,405	\$ 344	\$ 181	0.25	0.13
55–64 years	\$ 4,778	\$ 4,004	\$ 1,328	\$ 1,121	0.28	0.28
65–74 years	\$ 10,414	\$ 8,346	\$ 3,013	\$ 2,617	0.29	0.31
75+ years	\$ 16,235	\$ 16,122	\$ 4,625	\$ 4,617	0.28	0.29
SA 4: Hypothetical weighting of CVD hospitalization days (×2) (test for sensitivity to differences in cost per episode)						
35–54 years	\$ 1,865	\$ 1,069	\$ 412	\$ 138	0.22	0.13
55–64 years	\$ 5,907	\$ 3,049	\$ 1,667	\$ 853	0.28	0.28
65–74 years	\$ 12,030	\$ 6,354	\$ 3,431	\$ 1,992	0.29	0.31
75+ years	\$ 18,687	\$ 12,274	\$ 5,219	\$ 3,515	0.28	0.29
SA 5: All relative risks increased 50% (test for sensitivity to using mortality RRs)						
35–54 years	\$ 1,153	\$ 1,070	\$ 483	\$ 316	0.42	0.30
55–64 years	\$ 3,545	\$ 2,993	\$ 1,410	\$ 1,214	0.40	0.41
65–74 years	\$ 7,252	\$ 6,220	\$ 3,112	\$ 2,807	0.43	0.45
75+ years	\$ 13,694	\$ 14,250	\$ 6,840	\$ 6,834	0.50	0.48
SA 6: Only former smoker relative risks increased 50% (test for sensitivity to using mortality RRs)						
35–54 years	\$ 708	\$ 687	\$ 736	\$ 484	1.04	0.70
55–64 years	\$ 2,214	\$ 1,795	\$ 2,056	\$ 1,776	0.93	0.99
65–74 years	\$ 4,002	\$ 3,328	\$ 4,159	\$ 3,697	1.04	1.11
75+ years	\$ 5,951	\$ 6,421	\$ 8,217	\$ 8,293	1.38	1.29

Source: Authors' calculations.

^a Current smokers were respondents to the 2012 National Health Interview Survey who reported smoking ≥100 cigarettes during their lifetime and, at the time of interview, reported smoking every day or some days.^b Former smokers were respondents who reported smoking ≥100 cigarettes during their lifetime but currently did not smoke.

related disease diagnostic code in any position rather than first position has modest impact (SA 2).

The sensitivity analysis on weighting of hospitalizations to explore the implications of differences in care treatment costs found virtually no difference (Table 3 SA 3). The increase in weights for cancers was offset by the decrease in weights for respiratory diseases. Therefore, we conducted an additional sensitivity analysis by doubling the weight of cardiovascular disease conditions. As shown in the fourth panel (SA 4), there was no pattern of change with respect to age group, but the difference in average smoking-attributable expenditures between men and women was higher.

Finally, we increased all relative risks of both former and current smokers compared to never smokers by 50% (SA 5), and of former smokers alone (SA 6) to explore the potential impact of systematic bias caused by the use of mortality relative risks as a proxy for expenditure ratios. Increasing the relative risk of former smokers alone virtually eliminates, and in older strata reverses, the difference in relative risks between current and former smokers. This may indicate that the sensitivity analysis does not represent a realistic scenario as the results conflict with the evidence that smoking increases disease risk.

Discussion

For those who are interested in the impacts of smoking and quitting on smoking-attributable medical expenditure, we provide

alternative estimates of smoking-attributable medical expenditures by age group, sex, and smoking status. Based on this approach, we have shown that smoking-attributable medical expenditures increase with age for both current smokers and former smokers. For those aged 55 years old and above, estimated smoking-attributable medical expenditures of former smokers were about 30% of those of their counterpart current smokers. These findings imply that, within each age and gender group, had smokers quit before having any symptoms of smoking-related diseases, approximately 70% of smoking-attributable expenditures could be avoided. The potential percent savings appear to be larger for females in the 35–54-year age group, in large part due to a higher risk of pulmonary disease among current smokers relative to former smokers.

The Congressional Budget Office (CBO) has provided per-person estimates by age by linking Medical Care Expenditure Survey (MEPS) data with NHIS data (Congressional Budget Office, 2012). The same data source also has been used to estimate national expenditures by age group or by payer but did not report per-person estimates (Levy DE, 2011; Xu et al., 2015). Sloan et al. combined MEPS data with additional longitudinal data sources to provide a comprehensive estimate of smoking costs but they did not report age-group estimates for former and current smokers as would be needed in evaluating policies that promote cessation (Sloan, 2004).

The MEPS-NHIS link provides a substantial sample with claims data linked to smoking history and allows analyses that control for

differences among current, former, and never smokers. However, the MEPS-NHIS data also have limitations. The MEPS population is limited to non-institutionalized civilians who were alive at time of the survey and hence the data miss potentially important costs among those who died during the year. MEPS excludes costs for some services such as long-term care stays longer than 45 days. A comparison of 2002 MEPS and Personal Health Care Expenditures (PHCE) found total expenditures for the nation based on MEPS to be 38% lower than PHCE (Sing et al., 2006). Like all claims data, the MEPS data also exhibit spikes of utilization for recent quitters who may be motivated to quit by worsening health.

The estimated smoking-attributable expenditures by age group in our analysis were higher than those reported in the CBO report, which relies on the linked MEP:S-NHIS data (Congressional Budget Office, 2012). The smoking-attributable fraction used in this analysis is assumed to be 8.66% (U.S. Department of Health and Human Services, 2014), which is consistent with previous cross-sectional studies that reported smoking-attributable fractions ranging from 6.5% to 14% but higher than the 7% presented in the CBO report.

Although our analytical approach is consistent and can be easily updated with known disease impacts of smoking and quitting, we do not propose that this approach or estimates presented here are necessarily better than others available. Given the limitations of MEPS-based estimates noted above and limitations of the approach proposed here, we encourage policy analysts to consider age-specific estimates of smoking-attributable costs from both sources to inform a plausible range of cost-inputs and to understand their impact on results. One limitation of this analytical approach is the use of relative risks of mortality of current and never smokers as a proxy for the relative risk of medical expenditures. Large differences between mortality-relative risks and expenditure-relative risks, such as those that might be observed if case-fatality rates differ substantially between never, current, and former smokers, produced meaningful differences in the relative costs of current and former smokers and somewhat impacted the magnitude of difference in smoking-attributable medical expenditures between younger and older current and former smokers. A second important limitation is reliance on hospitalization days as proxy for all utilization. While there is good correspondence between the portion of hospitalization expense attributable to smoking and other medical expenses, there may be variation in this portion among smoking-attributable conditions. Although Miller et al. showed similar smoking-attributable fractions for the broad age groups of 35–64 and 65 and older (Miller et al., 1999), there may also be important variation between the 33–54 year and 75+ age groups reported in our results. While use of inpatient days provides a convenient data source for updating results and attribution of utilization to smoking-related conditions, undoubtedly estimates based on painstakingly assigning all forms of utilization to diagnostic codes through medical records review in a large, representative population would yield more precise estimates.

Other limitations explored in sensitivity analysis did not impact the estimates substantially. Using hospitalizations with a discharge diagnostic code for smoking-related condition in any position rather than just first-listed code did impact the age distribution of the expenditure. However, we believe that using the first-listed diagnosis code is more appropriate because it prevents coded comorbidities that are more common among all older adults, regardless of smoking status, from diluting the observed impact of smoking when it is the primary reason for the visit.

Finally, this analytical approach is focused on the evaluation of medical expenditures attributable to cigarettes smoking among adults only by age and gender. It does not consider potential medical expenditures associated with use of other combustible or non-combustible tobacco products, nor consider those related to maternal and child health or second-hand smoke exposure. Given the

diversification of the tobacco use landscape in recent years, the analysis doesn't fully capture the overall medical expenditures resulting from all tobacco product use (Centers for Disease Control and Prevention, 2013).

Although our estimated smoking-attributable medical expenditures are subject to some limitations, they clearly indicate that former smokers have substantial lower smoking-attributable medical costs than current smokers and the difference in costs increases with age. Since tobacco use remains the leading cause of preventable morbidity and mortality in the United States, continued implementation of evidence-based interventions outlined in the World Health Organization MPOWER package is critical (World Health Organization, 2008). These include increasing the price of tobacco products, implementing and enforcing comprehensive smoke-free laws, warning about the dangers of tobacco use with antismoking media campaigns, and increasing access to help quitting (Centers for Disease Control and Prevention, 2014; Huang and Chaloupka, 2012; McAfee et al., 2013). Future regulatory action by the FDA, such as reducing nicotine to non-addictive levels in cigarettes, has further potential (U.S. Department of Health and Human Services, 2014). Additionally, sustained, comprehensive state tobacco control programs funded at CDC-recommended levels can also reduce the health burden and economic impact of tobacco-related diseases in the United States (Centers for Disease Control and Prevention, 2014).

Conflict of interest statement

The authors declare that there are no conflicts of interests.

Appendix

Annual hospitalization days for each smoking-attributable condition can be disaggregated by smoking status age group i , and sex j , according to the formula:

$$N_{i,j}R_{h,i,j} = \sum_{k \in S} N_{i,j,k}R_{h,i,j,k}$$

where $N_{i,j}$ is the population size for each age i and sex j strata and $R_{h,i,j}$ is their annual rate of hospitalization days for each smoking-attributable disease h . Smoking status S is defined by three values for k representing never (NS), current (CS), and former (FS) smokers. The rate of hospitalization days of never smokers for each condition known to be caused by smoking cigarettes is obtained by first multiplying the right-hand side of the equation by one in the form of $R_{h,i,j,NS}/R_{h,i,j,NS}$. Then substituting the relative risk of each smoking status k , age group and sex compared to never smokers of the same age and sex group ($RR_{h,i,j,k} = R_{h,i,j,k}/R_{h,i,j,NS}$) and rearranging the equation yields:

$$R_{h,i,j,NS} = R_{h,i,j} / \left(\sum_{k \in S} \frac{N_{i,j,k}}{N_{i,j}} * RR_{h,i,j,k} \right)$$

The rate of hospitalizations days for current and former smokers is then computed by multiplying their relative rates by the rate of hospitalization days of never smokers.

For each age, sex, and smoking status group, the smoking-attributable rate of hospitalization days ($SAR_{i,j,k}$), is the sum across all smoking-attributable conditions of the difference in rate between each smoking status group rate and the rate of never smokers:

$$SAR_{i,j,k} = \sum_h (R_{h,i,j,k} - R_{h,i,j,NS})$$

The SAR of never smokers is zero, by definition and mathematically. Finally, the distribution of hospitalization days is used to allocate smoking-attributable expenditures by age group, sex and smoking status. For each population group, an estimate of national smoking-

attributable medical expenditures (*SAME*) was multiplied by the percent of all smoking-attributable hospitalizations occurring in that group. That product was divided by group size to obtain per-person expenditures by age, sex, and smoking status:

$$\text{SAME-}I_{i,j,k} = \frac{\text{SAME} * \left(\text{SAR}_{i,j,k} / \sum_{i,j,k} \text{SAR}_{i,j,k} \right)}{N_{i,j,k}}$$

Where *SAME- $I_{i,j,k}$* is the annual smoking-attributable medical expenditures of an individual of age group *i*, sex *j*, and smoking status *k*.

In sensitivity analysis, the calculation of weighted smoking-attributable risk (*WSAR*) was determined by:

$$\text{WSAR}_{i,j,k} = \sum_h (R_{h,i,j,k} - R_{h,i,j,NS}) * w_h$$

where w_h is the relative weight for condition *h*. Finally, we systematically altered relative risks to test the implicit assumption that event-fatality rates are constant by smoking status.

References

- Agaku, I.T., King, B.A., Dube, S.R., 2014. Current cigarette smoking among adults—United States, 2005–2012. *MMWR Morb. Mortal. Wkly Rep.* 63, 29–34.
- Centers for Disease Control and Prevention, 2002. Annual smoking-attributable mortality, years of potential life lost, and economic costs—United States, 1995–1999. *MMWR Morb. Mortal. Wkly Rep.* 51, 300–303.
- Centers for Disease Control and Prevention, 2007. Smoking-Attributable Mortality, Morbidity, and Economic Costs (SAMMEC): Adult SAMMEC and Child Health (MCH) SAMMEC software.
- Centers for Disease Control and Prevention, 2008. Smoking-attributable mortality, years of potential life lost, and productivity losses—United States, 2000–2004. *MMWR Morb. Mortal. Wkly Rep.* 57, 1226–1228.
- Centers for Disease Control and Prevention, 2010. National Hospital Discharge Survey. Centers for Disease Control and Prevention, 2011. Vital signs: current cigarette smoking among adults aged ≥ 18 years—United States, 2005–2010. *MMWR Morb. Mortal. Wkly Rep.* 60, 1207–1212.
- Centers for Disease Control and Prevention, 2012. National Hospital Discharge Survey 2010 Public Use Data File Documentation, Mar 2012 ed.
- Centers for Medicare and Medicaid Services, Office of the Actuary, 2012. National Health Expenditure Projections 2011–2021 <http://www.cms.gov/Research-Statistics-Data-and-Systems/Statistics-Trends-and-Reports/NationalHealthExpendData/Downloads/Proj2011PDF.pdf>. (Accessed July 24, 2013).
- Centers for Disease Control and Prevention, 2013. Tobacco product use among middle and high school students—United States, 2011 and 2012. *MMWR Morb. Mortal. Wkly Rep.* 62, 893–897.
- Centers for Disease Control and Prevention, 2014. Best Practices for Comprehensive Tobacco Control Programs – 2014. U.S. Department of Health and Human Services, C.f.D.C.a.P., National Center For Chronic Disease Prevention and Health Promotion, Office of Smoking and Health, Atlanta.
- Congressional Budget Office, 2012. Raising the Excise Tax on Cigarettes: Effects on Health and the Federal Budget. Congressional Budget Office, Washington.
- Fishman, P.A., Khan, Z.M., Thompson, E.E., Curry, S.J., 2003. Health care costs among smokers, former smokers, and never smokers in an HMO. *Health Serv. Res.* 38, 733–749.
- Fishman, P.A., Thompson, E.E., Merikle, E., Curry, S.J., 2006. Changes in health care costs before and after smoking cessation. *Nicotine Tob. Res.* 8, 393–401.
- Hockenberry, J.M., Curry, S.J., Fishman, P.A., Baker, T.B., Fraser, D.L., Cisler, R.A., Jackson, T.C., Fiore, M.C., 2012. Healthcare costs around the time of smoking cessation. *Am. J. Prev. Med.* 42, 596–601.
- Holford, T.R., Meza, R., Warner, K.E., Meernik, C., Jeon, J., Moolgavkar, S.H., Levy, D.T., 2014. Tobacco control and the reduction in smoking-related premature deaths in the United States, 1964–2012. *JAMA* 311, 164–171.
- Huang, J., Chaloupka IV, F.J., 2012. NBER Working Papers - York University., National Bureau of Economic Research. The Impact of the 2009 Federal Tobacco Excise Tax Increase on Youth Tobacco Use, NBER working paper series no. w18026. National Bureau of Economic Research, Cambridge, Mass.
- Jha, P., Ramasundaramhettige, C., Landsman, V., Rostron, B., Thun, M., Anderson, R.N., McAfee, T., Peto, R., 2013. 21st-century hazards of smoking and benefits of cessation in the United States. *N. Engl. J. Med.* 368, 341–350.
- Levy DE, N.J., 2011. Assessing the effects of tobacco policy changes on smoking-related health expenditures. In: Bearman PS, N.K., Wright, L. (Eds.), *After Tobacco: What Would Happen If Americans Stopped Smoking?* Columbia University Press, New York, pp. 256–289.
- McAfee, T., Davis, K.C., Alexander Jr., R.L., Pechacek, T.F., Bunnell, R., 2013. Effect of the first federally funded US antismoking national media campaign. *Lancet* 382, 2003–2011.
- Miller, V.P., Ernst, C., Collin, F., 1999. Smoking-attributable medical care costs in the USA. *Soc. Sci. Med.* 48, 375–391.
- Sing, M., Banthine, J.S., Selden, T.M., Cowan, C.A., Keehan, S.P., 2006. Reconciling medical expenditure estimates from the MEPS and NHEA, 2002. *Health Care Financ. Rev.* 28, 25–40.
- Sloan, F.A., 2004. *The price of smoking*. MIT Press, Cambridge, Mass.
- Solberg, L.I., Maciosek, M.V., Edwards, N.M., Khanchandani, H.S., Goodman, M.J., 2006. Repeated tobacco-use screening and intervention in clinical practice health impact and cost effectiveness. *Am. J. Prev. Med.* 31, 62–71.
- Surgeon General's Advisory Committee on Smoking and Health, 1964. *Smoking and health; report of the advisory committee to the Surgeon General of the Public Health Service*. U.S. Dept. of Health, Education, and Welfare, Public Health Service; for sale by the Superintendent of Documents. U.S. Govt. Print. Off, Washington.
- U.S. Department of Health Human Services, 2014. *The Health Consequences of Smoking—50 Years of Progress: A Report of the Surgeon General*, 2014. U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Center for Chronic Disease Prevention and Health Promotion. Office on Smoking and Health, Atlanta, GA.
- Warner, K.E., Hodgson, T.A., Carroll, C.E., 1999. Medical costs of smoking in the United States: Estimates, their validity, and their implications. *Tob. Control.* 8, 290–300.
- Woloshin, S., Schwartz, L.M., Welch, H.G., 2008. The risk of death by age, sex, and smoking status in the United States: Putting health risks in context. *J. Natl. Cancer Inst.* 100, 845–853.
- World Health Organization, 2008. *WHO report on the global tobacco epidemic, 2008: the MPOWER package*. World Health Organization, Geneva.
- Xu, X., Bishop, E.E., Kennedy, S.M., Simpson, S.A., Pechacek, T.F., 2015. Annual healthcare spending attributable to cigarette smoking: an update. *Am. J. Prev. Med.* 48, 326–333.