Chapter 12
Smoking-Attributable Morbidity, Mortality, and Economic Costs

Introduction

The preceding chapters have reviewed the extensive scientific evidence about the diverse diseases and other adverse effects caused by tobacco use. Policy actions to control tobacco use have long been motivated and informed by the knowledge that smoking causes multiple diseases and decreases life expectancy. To support policy actions and decision-making based on health evidence, quantitative estimates of the burden of disease associated with smoking in the population are made to characterize the size of the smoking epidemic and the potential benefit of tobacco control. These population-level estimates complement the epidemiologic studies that describe the risks to individuals associated with various smoking patterns.

For diseases attributable to a causal risk factor, such as smoking, epidemiologic methods can be used to estimate the disease burden associated with that risk factor for a particular population. Estimates can be based on several types of indicators, such as premature mortality, excess morbidity, disability-adjusted life years lost, changes in disability-adjusted life expectancy, quality-adjusted life years lost, years of potential life lost (YPLL), and economic costs of illness (U.S. Department of Health and Human Services [USDHHS] 2004).

The estimation of population-attributable fraction (PAF)—the percentage of the disease morbidity or mortality that is attributable to an exposure—is central to calculating burden. The calculation of PAF for a particular risk factor represents a form of quantitative risk assessment (National Research Council 1983). Risk assessment is a systematic approach that translates research findings for the purpose of guiding the implementation and evaluation of public health programs and policies (Samet et al. 2006). The elements of a risk assessment include hazard identification (does the exposure cause disease), exposure assessment (what is the population pattern of the exposure), dose-response assessment (how does risk vary with duration and amount of exposure), and risk characterization (what is the disease burden caused by the exposure). PAF was originally proposed in a classic paper by Levin (1953), and the application of this approach to smoking was described in the 1989 and 2004 Surgeon General's reports (USDHHS 1989, 2004).

Measuring changes in smoking-attributable mortality (SAM) periodically provides an ongoing indication of the burden of disease caused by tobacco use. This information can be used to reinforce the importance of comprehensive tobacco control programs at the national and state levels. For example, policymakers and decisionmakers can compare the impact of tobacco use with that of other risk factors when making decisions about resource allocation and needs (McGinnis and Foege 1993). These estimates are also useful for assessing the impact of changes in the prevalence of smoking or the risks associated with smoking over time.

This chapter first describes methods that are used to estimate the burden of disease attributable to smoking, particularly SAM, and then focuses on updates to the Smoking-Attributable Mortality, Morbidity, and Economic Costs (SAMMEC) system from the Centers for Disease Control and Prevention (CDC). These updates reflect the findings of this report which expands the list of diseases caused by smoking. SAMMEC has also been modified to incorporate recent risk estimates which are based on findings in cohort studies over the last decade (see Chapter 11, "General Morbidity and All-Cause Mortality").

The chapter then reviews past estimates of smoking-attributable morbidity and discusses how previous estimates could be updated based on the new findings presented in other chapters in this report. Next, this chapter considers approaches to updating the estimated economic costs of smoking and uses the revised SAMMEC model to estimate the economic burden from active and passive smoking in the United States. Finally, the chapter summarizes international estimates of the global burden of smoking and exposure to secondhand smoke. This chapter is limited to considering the mortality risks from cigarette smoking and does not include those of other tobacco products, either singly or in combination with cigarettes.

Prior to the estimates in this report, CDC last published estimates of smoking-attributable morbidity and mortality in 2008. For the period 2000–2004, CDC estimated approximately 393,000 annual smoking-attributable premature deaths from 19 disease categories and 4 adverse health outcomes in infants that were causally associated with smoking (CDC 2008). An additional 740 deaths from residential fires caused by smoking were counted toward that total as were 49,400 deaths from lung cancer and coronary heart disease (CHD) attributed to exposure to secondhand smoke that were computed separately from deaths caused by active smoking. For the 5-year period, the resulting annual total of attributable mortality was 444,000. Other recent estimates are described in Appendix 12.1.

Methodology Used by CDC to Compute Smoking-Attributable Mortality in the United States

The overall approach to estimating SAM includes the following components:

Identifying those diseases caused by (cigarette) smoking;

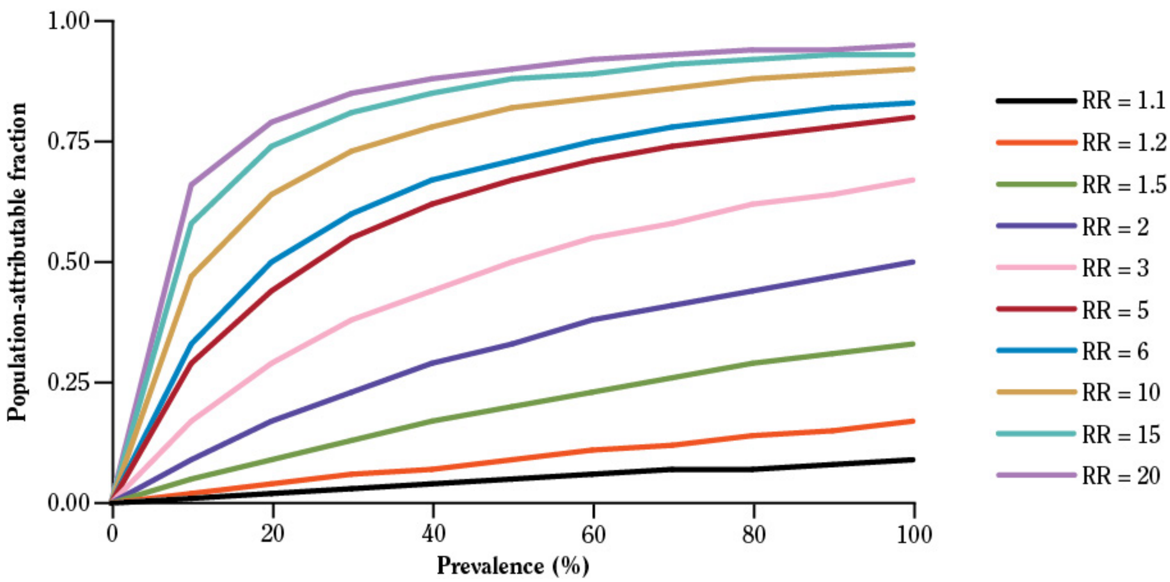
- Developing relative risk (RR) estimates for those diseases for current and former smokers in comparison to lifetime nonsmokers;
- Developing estimates of smoking prevalence for the populations and years of interest;
- Estimating disease- and gender-specific PAFs by age group; and
- Applying the PAFs to disease-specific mortality data for the population to estimate SAM.
- Understanding the parameters of PAF allows researchers to describe any uncertainties associated with the resulting PAF estimates and acknowledges the cross-sectional nature of the SAM estimates for particular calendar time points. The estimates represent the SAM for a population with a defined smoking prevalence profile and a set of disease-specific RR estimates for a given year, based on the assumption that the RR estimates accurately represent those in the population of interest.

There are several methods that have been used for calculating SAM (see Appendix 12.1). The first approach historically, the PAF calculation, is used most commonly and can be calculated as:

$$PAF = \frac{P(RR-1)}{P(RR-1)+1}$$

where P is the prevalence of exposure in the population and RR is the relative risk for disease associated with exposure assumed for the population. The formula shows that PAF varies from 0 (if either P = 0 or RR = 1) to approximately 1 at very high values for P or RR (Figure 12.1). This approach currently underlies the SAMMEC methodology (CDC 2011). The PAF and variants have also been referred to as assigned share, excess risk, etiologic fraction, attributable proportion, attributable risk, and

Figure 12.1 The relationship of relative risk (RR) to the population-attributable fraction at different prevalence levels



Source: Michael Thun, unpublished data.
Note: **RR** = relative risk.

incidence density fraction (Levin 1953; Walter 1976; Rothman 1986; Greenland and Robins 1988; USDHHS 1989; Greenland 1999). These measures estimate the burden (usually premature mortality) from all diseases and conditions combined or from the specific diseases attributed to smoking. When PAF is multiplied by the reported number of deaths in these disease categories, numbers of deaths for a given time period that are attributable to tobacco use can then be estimated. Based on this first application of the attributable risk calculation to available case-control data, Levin (1953) reported that 62–92% of all cases of lung cancer in study populations are caused by smoking.

Methodologic Issues in SAM Calculation

The methodology to estimate PAF for smoking—including sources of data and their limitations, potential confounding factors, sources of uncertainty, and approach to causal inference—has been reviewed and evaluated in detail in the past, including in the 2004 Surgeon General's report (USDHHS 2004), by the U.S. General Accounting Office ([USGAO] 2003) of the U.S. Congress, by an expert panel convened by CDC (SciMetrika 2010), and in the international epidemiologic literature. This section presents an overview of the general uncertainties of SAM estimates and the resulting limitations in their interpretation and application.

SAM estimates are based on assumptions that include some level of uncertainty. Not all uncertainties are encompassed by the confidence intervals (CIs), which reflect the statistical uncertainty (USDHHS 2004). Nonetheless, the estimates provide policymakers and the public with a general understanding of the magnitude of the burden imposed on the nation by cigarette smoking.

SAMMEC is not an annual surveillance system because single-year SAM calculations can be affected by small numbers of cause-specific deaths and random year-to-year variations. Also, as noted elsewhere in this chapter, when prevalence is declining, the smoking-attributable fraction (SAF) and hence the SAM will be underestimated. These effects are moderated by averaging the estimates over 5 years of prevalence data. When repeated periodically on this longer-term timeframe, SAMMEC estimates can provide insights into the consequences of the changing tobacco epidemic. The estimates are particularly useful if updated inputs are available.

Most estimates of SAM do not include mortality caused by cigar smoking, pipe smoking, or smokeless tobacco use. For example, an estimated 1,000 deaths in the United States were attributable to pipe smoking in 1991 (Nelson et al. 1996). This limitation reflects the lack of appropriate RRs related to tobacco products other than cigarettes. To date, these products cause many fewer deaths than cigarettes. However, given the dynamic nature of the tobacco-related environment, assessment of risk due to other tobacco products use is an emerging priority, particularly because of the introduction of tobacco products claiming to reduce exposure (Samet and Wipfli 2009) and increased dual use of tobacco products (Tomar et al. 2010). Dual use (i.e., use of cigarettes and another product) may complicate estimation of SAM, particularly if dual use extends to persons in age ranges where most smoking-caused deaths occur.

Confounding by such factors as alcohol consumption, education, income, blood pressure, diabetes, and other lifestyle factors has also been a concern. Generally, positive confounding has been postulated. Thun and colleagues (2000) examined the potential for confounding by lifestyle factors to bias SAM estimates and found minimal consequences of potential confounding. The representativeness of the Cancer Prevention Study II (CPS-II) cohort has also been reviewed with regard to SAMMEC estimates (Sterling and Weinkam 1987; Levy 2000). This issue has also been considered and set aside as a source of significant bias (Thun et al. 2000; USDHHS 2004). GAO (2003) reviewed CDC's assumptions, methods, and data sources for SAMMEC and concluded that SAMMEC estimates are sound, noting that appropriate attention had been paid by CDC to the issues of confounding and representativeness.

Further concerns relate to the estimation of the prevalence of smoking and the selection of RRs. The RR values used in past SAMMEC publications (Table 12.1) are based on the first 6 years of follow-up of CPS-II (1982–1988) (Thun et al. 1997b; CDC 2011). However, RR estimates associated with smoking can change over time for specific diseases (Thun and Heath 1997; Thun et al. 1997a). Patterns of smoking may change as might the toxicity and resulting risks of tobacco products. For example, compared to earlier cohorts, more recent cohorts of women began smoking at a younger age; consequently the age-specific RRs are higher (see Chapter 13, "Patterns of Tobacco Use Among U.S. Youth, Young Adults, and Adults"). Changes in tobacco product

Table 12.1 Relative risks for adult mortality from smoking-related diseases, adults 35 years of age and older, based on Cancer Prevention Study II, United States

	Males		Females	
Disease category (ICD–10 code)	**Current smoker**	**Former smoker**	**Current smoker**	**Former smoker**
Malignant neoplasms				
Lip, oral cavity, pharynx (C00–C14)	10.89	3.40	5.08	2.29
Esophagus (C15)	6.76	4.46	7.75	2.79
Stomach (C16)	1.96	1.47	1.36	1.32
Pancreas (C25)	2.31	1.15	2.25	1.55
Larynx (C32)	14.60	6.34	13.02	5.16
Trachea, lung, bronchus (C33–C34)	23.26	8.70	12.69	4.53
Cervix uteri (C53)	n/a	n/a	1.59	1.14
Kidney and renal pelvis (C64–C65)	2.72	1.73	1.29	1.05
Urinary bladder (C67)	3.27	2.09	2.22	1.89
Acute myeloid leukemia (C92.0)	1.86	1.33	1.13	1.38
Cardiovascular diseases				
Coronary heart disease (I20–I25)				
Persons 35–64 years of age	2.80	1.64	3.08	1.32
Persons ≥65 years of age	1.51	1.21	1.60	1.20
Other heart disease (I00–I09, I26–I28, I29–I51)	1.78	1.22	1.49	1.14
Cerebrovascular disease (I60–I69)				
Persons 35–64 years of age	3.27	1.04	4.00	1.30
Persons ≥65 years of age	1.63	1.04	1.49	1.03
Atherosclerosis (I70)	2.44	1.33	1.83	1.00
Aortic aneurysm (I71)	6.21	3.07	7.07	2.07
Other arterial disease (I72–I78)	2.07	1.01	2.17	1.12
Respiratory diseases				
Influenza, pneumonia (J10–J11, J12–J18)	1.75	1.36	2.17	1.10
Bronchitis, emphysema (J40–J42, J43)	17.10	15.64	12.04	11.77
Chronic airways obstruction (J44)	10.58	6.80	13.08	6.78

Source: Thun et al. 1997a; Centers for Disease Control and Prevention 2011.
Note: **ICD** = International Classification of Diseases.

composition, which could affect risk, have occurred over time (USDHHS 2010). Changing rates in the comparison population of never smokers also affect RRs. As reviewed in Chapter 8, "Cardiovascular Diseases," declining death rates from cardiovascular diseases in lifelong nonsmokers during the past half century indicate that the risk of cardiovascular death has decreased for the overall population.

Other uncertainties may also influence SAM estimates, including potential differences in the strength of association between smoking and disease or death across different racial/ethnic groups, different socioeconomic strata, and different age groups—all of which are potential modifiers of risk. A particular aspect of heterogeneity is related to the age groups for which RRs and SAM are estimated. Most deaths from cardiovascular diseases occur at older ages, and the U.S. population is aging. In 2006, 36% of all deaths from coronary heart disease occurred in persons 85 years of age and older, and 29% occurred in persons 75–84 years of age (Heron et al. 2009). At the same time, most smokers quit smoking, or die because of it, by 75 years of age. With increasing age, particularly above 60–70 years, the RR for death from cardiovascular disease declines sharply. Crude age stratification in the estimation of PAF will not adequately reflect this age-related change, potentially leading to overestimation of the PAF; however, SAMMEC originally included only two age categories (35–64 years of age and 65 years of age and older).

Another issue is that SAMMEC estimates are based on the prevalence of current and former smokers at the present time. However, the deaths that occur during a given year are primarily among persons who began smoking 30–50 years earlier. Many people quit smoking during the later decades of the twentieth century (Malarcher et al. 1997). The RRs of former smokers are lower than those of current smokers for most diseases and for any cohort; the risks for former smokers reflect the distribution of times since quitting. Unless smoking behavior (including cessation) is stable over time, cross-sectional SAM estimates do not accurately reflect the risks of past cohorts of smokers. When the prevalence of smoking is declining, as in the United States (see Chapter 13), the SAMMEC methodology will tend to understate the number of deaths caused by smoking (USDHHS 2004). Table 12.2 shows the annual prevalence of current and former smoking among adults, 35 years of age and older, from 1965–2011. The ratio of former smokers to current smokers has greatly increased over the past half-century for both men and women.

Using survey data to derive estimates of exposure (e.g., prevalence of current and former cigarette smoking) is another source of uncertainty in SAM calculations. Although population-based surveys using self-reported data provide reasonably consistent estimates of adult smoking prevalence and are generally considered to be sufficiently accurate for tracking the general pattern of tobacco use in populations, a comparison of smoking self-reports and the biomarker cotinine in National Health and Nutrition Examination Survey (NHANES) data indicates that some underestimation is likely (Caraballo et al. 2001; Brener et al. 2003; USDHHS 2004, 2006, 2010) (see Chapter 13). The ongoing decrease in the percentage of U.S. households possessing landline phones and the decreasing participation rates in telephone surveys of households with landline phones (Steeh et al. 2001; Biener et al. 2004; Delnevo and Bauer 2009) can result in an underestimation of current smoking in landline telephone-based surveys (Blumberg et al. 2008; Delnevo and Bauer 2009) because smokers are more likely to live in wireless-only households than nonsmokers (Blumberg et al. 2006, 2008) and are less likely to participate in health-related surveys (Galea and Tracy 2007). Although this issue would not affect prevalence estimates from the National Health Interview Survey (NHIS), which is based on household sampling, it could have affected state smoking prevalence estimates from the Behavioral Risk Factor Surveillance System (BRFSS) before 2011 (the year cell phone sampling was instituted); states often use BRFSS data to calculate state-specific SAM. Finally, neither NHIS nor BRFSS include institutionalized populations and persons in the military, which prevents the generalization of the results to these groups. A probable net consequence of these survey issues is some underestimation of smoking in the U.S. population in widely cited state and national surveys of smoking behavior (see Chapter 13). Any downward bias in survey estimates of smoking will lead to underestimation of SAM.

Table 12.2 Annual prevalence of current smoking and former smoking among adults, 35 years of age and older, for selected years; National Health Interview Survey (NHIS), United States, 1965–2011

	Men (years of age)								Women (years of age)							
	35–54		55–64		65–74		≥75		35–54		55–64		65–74		≥75	
Year	%CS	%FS	%CS	%FS	%CS	%FS	%CS	%FS	%CS	%FS	%CS	%FS	%CS	%FS	%CS	%FS
1965	57.1	21.2	46.6	27.1	33.1	30.1	19.3	24.2	40.8	9.4	25.0	7.6	12.4	5.1	4.5	3.6
1970	48.7	28.6	41.1	34.9	27.1	41.5	15.7	36.3	37.9	13.3	28.5	12.1	14.4	9.0	5.6	5.5
1974	48.8	30.2	37.7	40.0	29.2	43.0	15.9	38.7	37.9	14.1	30.4	16.0	16.0	12.5	5.8	7.6
1977	46.5	29.5	37.0	36.4	26.7	44.6	15.9	41.6	37.5	14.9	32.4	16.0	17.5	13.4	6.6	10.2
1980	42.7	30.9	38.5	39.4	22.2	48.0	9.0	46.3	34.3	17.9	27.9	17.6	21.8	17.6	8.9	8.8
1983	40.1	30.7	32.6	45.4	26.7	46.6	12.2	51.2	33.9	17.2	28.0	19.7	17.6	22.6	6.3	12.8
1985	36.5	34.2	31.9	47.2	21.9	53.2	15.0	51.1	31.9	20.1	27.4	22.2	17.9	23.5	7.0	17.9
1987	35.4	32.2	30.3	45.2	20.6	55.1	11.4	52.4	30.2	19.8	25.6	23.6	18.9	21.4	7.2	14.8
1988	35.6	30.9	28.0	48.4	21.4	53.9	11.4	54.5	28.3	21.0	26.2	24.4	16.7	23.8	7.3	16.3
1990	33.5	31.8	25.9	45.8	18.3	53.0	7.6	59.5	26.3	22.1	20.5	24.3	15.6	25.9	5.8	19.6
1992	34.0	31.1	25.4	45.7	19.6	53.1	10.7	52.0	27.8	20.9	22.6	23.9	14.9	23.3	7.5	24.2
1994	32.2	30.7	24.7	47.5	16.1	57.1	8.4	60.3	25.8	21.7	20.7	29.5	13.4	30.9	8.2	21.7
1995	29.7	28.1	26.9	43.3	18.1	51.5	9.6	55.2	25.9	21.2	23.7	24.4	14.4	29.7	7.9	23.1
1997[a]	31.1	26.1	24.1	45.2	16.2	56.1	7.7	56.4	25.4	20.6	19.0	27.6	15.3	28.3	7.0	22.9
1998	30.1	25.9	24.2	44.4	13.3	58.2	6.2	59.0	25.4	19.6	20.1	26.7	15.3	30.3	6.5	23.3
1999	29.1	25.2	22.3	44.8	12.6	57.8	7.5	58.1	25.0	19.4	17.7	29.5	14.0	29.6	7.1	25.9
2000	29.6	22.1	22.6	45.0	13.7	53.9	5.4	58.6	24.4	19.8	20.8	28.3	12.2	28.8	6.2	23.8
2001	27.5	23.5	24.2	44.1	14.5	55.6	7.4	55.8	24.2	18.2	19.8	27.2	12.8	28.6	5.3	25.6
2002	28.4	23.5	20.7	44.3	12.4	55.1	7.0	58.3	23.2	18.7	18.8	28.1	11.4	31.2	5.8	25.7
2003	27.0	22.1	21.2	41.8	13.3	52.8	5.9	54.1	22.9	17.6	18.2	26.4	11.0	32.4	5.6	27.9
2004	26.6	21.1	22.7	40.3	12.8	52.7	5.9	55.5	21.2	18.2	18.6	26.1	11.2	28.9	5.0	28.3
2005	27.0	19.8	21.1	41.7	11.4	52.5	5.7	56.8	21.1	17.5	16.1	26.5	10.8	30.2	5.9	26.7
2006	25.7	20.7	21.5	41.1	17.4	45.4	6.2	59.0	21.5	16.9	14.9	26.1	11.2	29.8	5.4	25.9
2007	24.0	20.6	19.6	38.6	12.5	51.8	5.1	58.3	20.9	17.0	16.2	25.1	11.9	30.2	3.2	26.0
2008	25.4	20.8	22.6	34.5	14.6	51.3	5.1	59.0	22.3	18.2	16.3	24.7	10.5	31.6	6.1	29.8
2009	26.4	20.3	20.8	40.3	12.5	52.5	5.5	56.2	21.7	16.7	16.1	26.6	12.5	33.1	6.3	25.8
2010	23.9	21.7	20.7	35.6	12.6	50.4	5.5	55.5	20.2	16.6	16.5	25.2	13.3	30.2	4.8	28.4
2011	24.2	20.5	21.4	36.1	11.7	49.9	5.0	54.9	20.8	17.0	15.0	25.5	9.9	34.6	4.0	30.6

Source: National Center for Health Statistics, public use data sets, 1965, 1970, 1974, 1977, 1980, 1983, 1985, 1987–1988, 1990, 1992, 1994–1995, 1997–2011. The NHIS sample is representative of the civilian, noninstitutionalized population of the United States.

Note: **CS** = current smokers, defined as having smoked at least 100 cigarettes and currently smoking every day or some days (the some days condition was added in 1992); **FS** = former smokers, defined as having smoked at least 100 cigarettes but not currently smoking.

[a]A questionnaire redesign of NHIS was implemented in 1997. Data preceding this year may not be directly comparable with data from 1997 and later.

2013 Update to SAMMEC Methodology

In 2013, CDC updated its SAMMEC methodology for adults to incorporate RRs based on more recent datasets. The update also refined the age ranges used in SAMMEC to more accurately capture the changes in risk with age. These changes reflect recommendations made by an expert panel convened by CDC in 2009–2010 to review its methodology for estimating SAM in the United States (SciMetrika 2010) and advise on whether updates were needed. The expert panel noted that the SAMMEC methodology had been evaluated repeatedly and was found to provide a credible indication of the mortality burden of the disease consequences of smoking. Thus, the panel did not find a need for substantive changes to the PAF methodology (SciMetrika 2010). However, the panel recommended that RRs be updated and calculated separately, to the extent possible, for individual racial/ethnic groups and older age strata. In addition, the panel noted that as sufficient evidence emerges to conclude that causal associations exist between smoking and new health conditions, data for these additional diseases should be included in future SAM estimates. The specific changes made are described below.

Age Stratification

As discussed previously, the effect of age on SAM is a particularly important consideration because death rates increase with age and the association between cardiovascular death and current smoking decreases with age. Consequently, CDC expanded the number of age strata used in SAMMEC calculations from two (35–64 years of age and 65 years of age and older) to four (35–54 years of age, 55–64 years of age, 65–74 years of age, and 75 years of age and older) and applied them to all disease categories.

Adult RR Estimates

Subsequent to the previous SAMMEC estimates, Thun and colleagues (2013) pooled data from five large contemporary cohort studies: the National Institutes of Health-AARP Diet and Health Study, the American Cancer Society's CPS-II Nutrition Cohort (a subset of the original CPS-II mortality study), the Women's Health Initiative (WHI), the Nurses' Health Study, and the Health Professionals Follow-Up Study. Each had updated smoking and endpoint information for participants 55 years of age and older during 2000–2010. Cox proportional hazards regression was used to calculate RRs of current smokers and former smokers, with the latter group limited to those who had quit smoking at least 2 years before the start of the follow-up period. Models were adjusted for age or age plus cohort, race, and educational level. The multivariable-adjusted RR of death was similar for men and women: about 2.8 for all causes in current smokers and 1.5 for all causes in former smokers. RRs for men and women were also very similar for chronic obstructive pulmonary disease (COPD), CHD, and stroke.

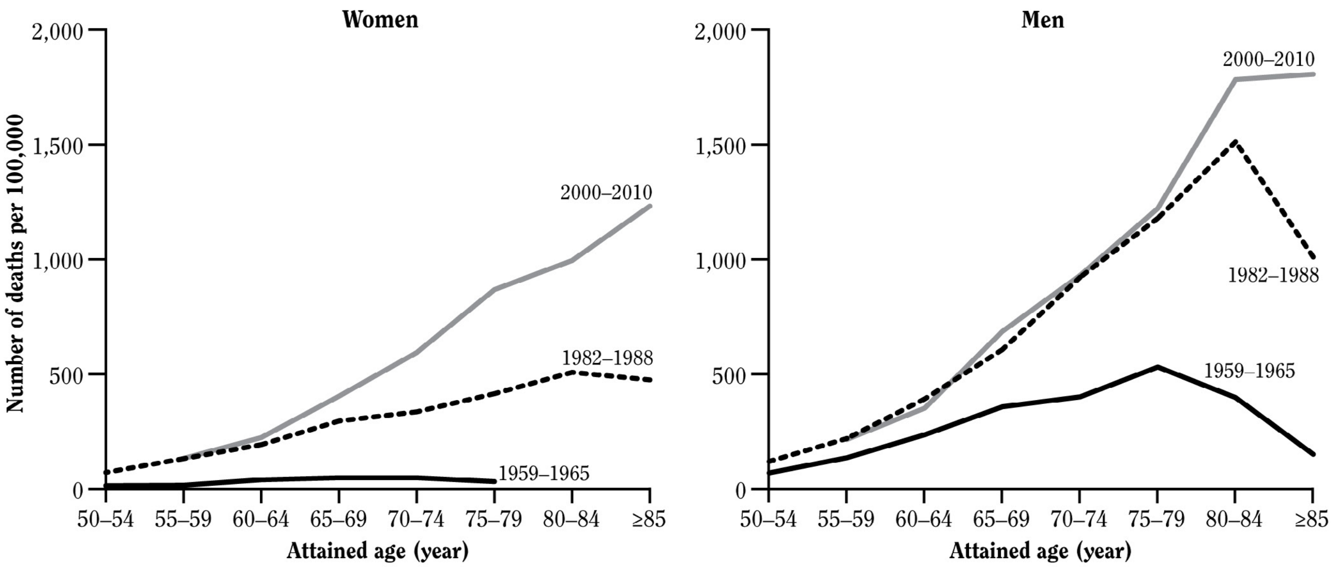
Thun and colleagues (2013) compared death rates and RRs in the pooled contemporary cohort with those from previous cohorts, CPS-I (1959–1965) and CPS-II (1982–1988), when both smoking prevalence and the background death rate among never smokers were higher. Among men, RRs for current smokers increased from the 1960s to the 1980s and then plateaued, with the exception of a continuing increase in smoking-related mortality from COPD. Among women, RRs for current smokers increased across all the time periods so that they are now equal to those of men. Death rates by age and gender for lung cancer and COPD increased markedly over time from each of these cohorts to the next (Figure 12.2). Generalizability of the pooled cohort samples to the full U.S. population is a potential concern. The study populations included higher percentages of Whites and highly educated persons than are found in the general population. However, estimated RRs for participants with only a high school education or less were generally similar to, or larger than, the estimates for those with a college education; thus, the overall RRs calculated by Thun and colleagues (2013) are likely to lead to some underestimation of SAM.

Another analysis of data from a large, contemporary cohort (Jha et al. 2013) similarly found that adjusting for race/ethnicity, educational level, alcohol consumption, and adiposity had little effect on risk estimates. Jha and colleagues (2013) matched data from the National Death Index (1986–2006) to records of participants, 25 years of age and older, in the NHIS from 1997–2004. In this study, the hazard ratio for death from any cause for current smokers versus nonsmokers was 3.0 for women and 2.8 for men. The lifespan of current smokers was 11–12 years shorter than that of nonsmokers.

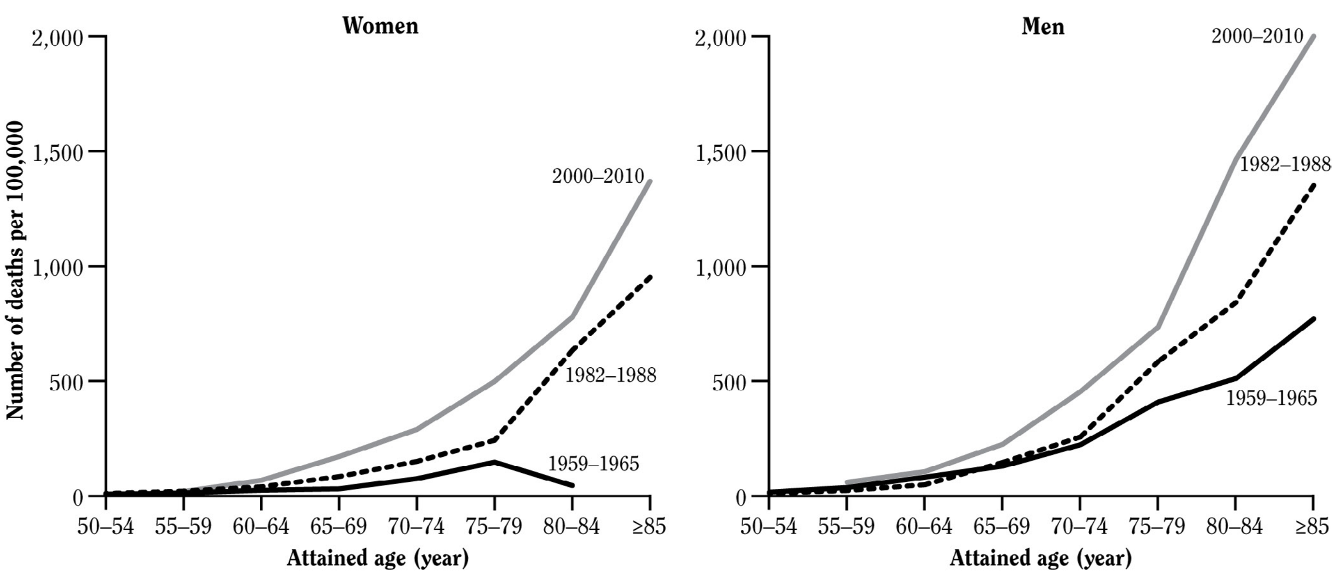
The analysis by Jha and colleagues (2013) also has limitations. In particular, NHIS participants are interviewed once only; thus, smoking histories are not updated in the interval between initial interview and death and

Figure 12.2 Changes over time in annual death rates from lung cancer and chronic obstructive pulmonary disease (COPD)

A. Lung cancer



B. COPD



Source: Thun et al. 2013. Reprinted with permission from Massachusetts Medical Society, © 2013.
Note: Data were obtained from the first Cancer Prevention Study for the period 1959–1965, from the second Cancer Prevention Study for the period 1982–1988, and from the contemporary cohort studies for the period 2000–2010.

transitions from current smoker status to former smoker status are not captured. To avoid using outdated smoking history data, which would inevitably misclassify some former smokers as current smokers at the time of death, Jha and colleagues (2013) limited their analysis to NHIS participants from 1997–2004.

Comparable results on changes in RRs over time were found in a large cohort study carried out in the United Kingdom. Pirie and colleagues (2013) used national mortality records through 2010 to assess mortality among a cohort of women who were 52 years of age or older when recruited in 1996–2001. Participants were resurveyed 3 years after recruitment. Those who were current smokers at baseline had a 2.76 mortality rate ratio compared to nonsmokers. Those who remained current smokers at the 3-year resurvey had a mortality rate ratio of 2.97, translating to a lifespan reduction of 11 years.

These studies by Thun and colleagues (2013), Jha and colleagues (2013), and Pirie and colleagues (2013) provide compelling evidence that RRs for smoking have increased over the past decades, particularly for women. Therefore, in 2013, CDC began using RRs derived from a contemporary pooled cohort of adults 55 years of age and older in SAMMEC. This cohort is based on the one created by Thun and colleagues (2013). The original published report from this pooled cohort (Thun et al. 2013) did not include RRs for the age-specific categories needed for SAMMEC calculations (age groups 55–64, 65–74, and ≥75) or for all smoking-related causes of death now included in SAMMEC. Therefore, the investigators responsible for the datasets represented in the pooled cohort provided the RRs shown in Table 12.3 to CDC's Office on Smoking and Health. These estimates include additional data not included in the original report (Thun et al. 2013) from 2 years of follow-up (2009–2010) that became available from the CPS-II Nutrition Cohort after the original publication, as well as updated outcome information from the WHI.

Also, in women 55 years and older, the RRs for "other" vascular conditions (atherosclerosis, aortic aneurysm, other vascular conditions) were modified to exclude data from the National Heart, Lung, and Blood Institute's (NHLBI's) WHI because WHI does not ascertain these conditions. In addition, RRs for the category of smoking-attributable cancers other than lung cancer (a category which includes acute myeloid leukemia, but not other types of leukemia) were calculated excluding all leukemias from WHI because WHI did not distinguish acute myeloid leukemia from other forms of leukemia.

Comparable estimates are not available for adults younger than 55 years of age. The NHIS study by Jha and colleagues (2013) included younger adults and used a nationally representative sample. However, in constraining the dataset to only the most recent years, the study had only a limited dataset that was not sufficiently large to provide stable disease-specific RR estimates for those younger than 55 years of age. Therefore, CDC elected to continue using CPS-II as the RR source for younger adults. Since the RR estimates for populations 55 years of age and older have remained high or increased in recent years (Thun et al. 2013), it is assumed that the CPS-II RR estimates for younger adults are conservative.

Additional Adult Disease Outcomes

The evidence is now sufficient to infer a causal relationship between smoking and five additional diseases in adults: age-related macular degeneration, diabetes mellitus, tuberculosis, liver cancer, and colorectal cancer (see Chapters 6, "Cancer"; 7, "Respiratory Disease"; and 10, "Other Specific Outcomes"). Accordingly, mortality RRs were calculated for the latter four conditions using the modified pooled contemporary cohort data. Because the number of smoking-attributable deaths from these conditions is relatively low compared to conditions such as lung cancer, particularly at younger ages, RRs were calculated for these conditions combined with others (i.e., diabetes mellitus was combined with cardiovascular diseases for the youngest age groups, tuberculosis was combined with other noncancer lung diseases, and liver and colorectal cancer were combined with other cancers). The combined RRs are more stable than individual RR estimates for these conditions. Although smoking is now thought to be related to decreased immune function and survival from cancer, RRs that are needed to estimate population-attributable burden of this effect are unavailable at present.

Infant RRs

In the past, SAMMEC calculated smoking-attributable infant deaths for short gestation/low birth weight, respiratory distress syndrome, other respiratory conditions, and sudden infant death syndrome (SIDS). The four RRs were based on pooled meta-analyses by Gavin and colleagues (2001) that summarize literature from the 1980s and early 1990s. More recently, Dietz and colleagues (2010) estimated associations for prenatal smoking and preterm deliveries, term low birth weight (<2,500 grams) deliveries, SIDS, and preterm-related deaths among 3,352,756 singleton, live births using the U.S. Linked Birth/Infant Death Data Set, 2002 Birth Cohort. This analysis used a newer method of defining preterm-related deaths that had been developed by Callaghan and colleagues (2006)—an expanded definition of death from preterm delivery,

Table 12.3 Relative risks by smoking status and age group, adults 35 years of age and older, United States

	Current smokers (years of age)				Former smokers (years of age)			
	35–54[a]	55–64[b]	65–74[b]	≥75[b]	35–54[a]	55–64[b]	65–74[b]	≥75[b]
Males								
Lung cancer	14.33	19.03	28.29	22.51	4.40	4.57	7.79	6.46
Other cancers[c]	1.74	1.86	2.35	2.18	1.36	1.31	1.49	1.46
Coronary heart disease	3.88	2.99	2.76	1.98	1.83	1.52	1.58	1.32
Other heart disease[d]			2.22	1.66			1.32	1.15
Cerebrovascular disease			2.17	1.48			1.23	1.12
Other vascular diseases[e]			7.25	4.93			2.20	1.72
Diabetes mellitus			1.50	1.00			1.53	1.06
Other cardiovascular diseases[f]	2.40	2.51			1.07	1.51		
Influenza, pneumonia, tuberculosis			2.58	1.62			1.62	1.42
Chronic obstructive pulmonary disease[g]			29.69	23.01			8.13	6.55
Influenza, pneumonia, tuberculosis, chronic obstructive pulmonary disease[h]	4.47	15.17			2.22	3.98		
All causes	2.55	2.97	3.02	2.40	1.33	1.47	1.57	1.41
Females								
Lung cancer	13.30	18.95	23.65	23.08	2.64	5.00	6.80	6.38
Other cancers[c]	1.28	2.08	2.06	1.93	1.24	1.28	1.26	1.27
Coronary heart disease	4.98	3.25	3.29	2.25	2.23	1.21	1.56	1.42
Other heart disease			1.85	1.75			1.29	1.32
Cerebrovascular disease			2.27	1.70			1.24	1.10
Other vascular diseases*[e]			6.81	5.77			2.26	2.02
Diabetes mellitus			1.54	1.10			1.29	1.06
Other cardiovascular diseases[f]	2.44	1.98			1.00	1.10		
Influenza, pneumonia, tuberculosis			1.75	2.06			1.28	1.21
Chronic obstructive pulmonary disease[g]			38.89	20.96			15.72	7.06
Influenza, pneumonia, tuberculosis, chronic obstructive pulmonary disease[h]	6.43	9.00			1.85	4.84		
All causes	1.79	2.63	2.87	2.47	1.22	1.34	1.53	1.43

Source: Analyses of Cancer Prevention Study II (CPS-II) and updated analyses of the pooled contemporary cohort population described in Thun et al. 2013 provided to the Centers for Disease Control and Prevention, National Center for Chronic Disease Prevention and Health Promotion, Office on Smoking and Health.

[a]Relative risks for 35–54 years of age, obtained from Cancer Prevention Study.

[b]Relative risks for 54–65 years of age, 65–74 years of age, and 75 years of age and older, obtained from merged contemporary cohorts (Thun et al 2012). Relative risks for women 55 years of age and older in diseases marked with * do not include data from the NHLBI Women's Health Initiative.

[c]Other cancers consist of cancers of the lip, pharynx and oral cavity, esophagus, stomach, pancreas, larynx, cervix uteri (women), kidney and renal pelvis, bladder, liver, colon and rectum, and acute myeloid leukemia.

[d]Other heart disease comprised of rheumatic heart disease, pulmonary heart disease, and other forms of heart disease.

[e]Other vascular diseases are comprised of atherosclerosis, aortic aneurysm, and other arterial diseases.

[f]For 35–54 years of age and ages 55–64 years of age, other cardiovascular diseases are comprised of other heart disease, cerebrovascular disease, other vascular diseases, and diabetes mellitus, analyzed and reported as category. A single relative risk based on combined conditions used to compute smoking-attributable mortality. Relative risk based on combined conditions used to compute smoking-attributable mortality in these age strata.

[g]Chronic obstructive pulmonary disease comprised of bronchitis, emphysema, and chronic airways obstruction.

[h]For 35–54 years of age and 55–64 years of age, influenza, pneumonia, tuberculosis, and chronic obstructive pulmonary disease analyzed and reported as 1 category. A single relative risk based on combined conditions was used to compute smoking attributable mortality.

as opposed to using only the ICD-10 codes for disorders related to short gestation and low birth weight. This newer construct includes the codes for premature rupture of membranes, placenta previa, and placental abruption and is now used by CDC to calculate national preterm-related death rates. In addition, the analysis by Dietz and colleagues (2010) restricts infant deaths to those for which prenatal smoking has an established causal effect; the 2004 Surgeon General's report found that prenatal smoking is causally associated with SIDS, premature rupture of membranes, placenta previa, placental abruption, preterm delivery, and fetal growth restriction/low birth weight (USDHHS 2004).

Using the findings of Dietz and colleagues (2010), the new RR for SIDS is estimated at 2.7, which is somewhat higher than the 2.29 estimated by Gavin and colleagues (2001). The new RR estimate for preterm-related deaths is 1.5 (Dietz et al. 2010). This estimate replaces the former RRs for short gestation/low birth weight (1.83), respiratory distress syndrome (1.30), and other perinatal respiratory conditions (1.41).

Deaths Attributable to Exposure to Secondhand Smoke

CDC's SAM totals include estimates of deaths from lung cancer and coronary heart disease deaths due to exposure to secondhand smoke (CDC 2002, 2005, 2008). For lung cancer, calculations have been based on a method developed by the U.S. Environmental Protection Agency ([USEPA] 1992) and used estimates of the RR published by Fontham and colleagues (1994) and estimates of prevalence of nonsmokers' exposure to secondhand smoke derived from unpublished data provided by CDC's National Center for Health Statistics. Estimates were developed for California and then extended to the U.S. population, since death rates for lung cancer in California in the late 1980s were comparable in other states and California represented 12% of the U.S. population (Pierce et al. 2010). For heart disease, calculations were based on the PAF approach, using RRs that ranged from 1.2–1.68 (California Environmental Protection Agency [Cal/EPA] 1997; Ciruzzi et al. 1998), and estimates of exposure to secondhand smoke in nonsmokers came from NHANES III (1988–1994) (Pirkle et al. 1996).

This approach has now been modified based on the work of Max and colleagues (2012). In their calculations for the United States for 2006, adult exposure to secondhand smoke was determined from biomarker (serum cotinine) data from the 2003–2006 NHANES. An RR estimate for CHD from exposure to secondhand smoke of 1.32 was used based on the studies by Whincup and colleagues (2004). For lung cancer, Max and colleagues (2012) used the lower bound of the range of RR estimates for lung cancer of 1.29 from Cal/EPA (2005). These methods have now been incorporated into SAMMEC in 2013.

Smoking-Attributable Mortality in Adults and Infants, United States, 2005–2009

This section provides the SAM estimates for the United States for the period 2005–2009. The general SAMMEC methodology has been modified as described above. The prevalence data for males and females 35 years of age and older came from NHIS for 1965–2011 (Table 12.2).

Table 12.4 provides average annual SAM for the United States for 2005–2009. The results indicate that cigarette smoking and exposure to tobacco smoke led to at least 480,000 premature deaths annually in the United States. Among adults 35 years of age and older, 163,700 smoking-attributable deaths were caused by cancer, 160,600 by cardiovascular and metabolic diseases, and 113,100 by pulmonary diseases (see Tables 12.4 and 12.5 for detailed results). Smoking during pregnancy resulted in an estimated 1,015 infant deaths annually during 2005–2009. Based on previously published estimates (Max et al. 2012), an estimated 7,330 (4.63%) lung cancer and 33,950 (8.23%) CHD deaths annually were attributable to exposure to secondhand smoke. The average annual SAM estimates also include 620 deaths from smoking-attributable residential fires based on data from the National Fire Protection Association (NFPA) and National Fire Incident Reporting System (Figure 12.3) (Hall 2012).

Smoking caused approximately 254,100 deaths in males (Table 12.5) and 183,300 deaths in females (Table 12.6), for a total of 437,400 deaths in the United States for each year from 2005–2009 from the new list of smoking-related diseases (i.e., the 19 diseases formerly used in the SAMMEC and the five diseases newly linked to smoking in

Table 12.4 Annual deaths and estimates of smoking-attributable mortality (SAM) for adults 35 years of age and older, total and by gender, United States, 2005–2009

	Males			Females			Total		
Disease	**Deaths**	**SAM**	**Attributable fraction (%)**	**Deaths**	**SAM**	**Attributable fraction (%)**	**Deaths**	**SAM**	**Attributable fraction (%)**
Lung cancer	88,730	74,300	83.74	69,800	56,359	80.74	158,530	130,659	82.42
Other cancers[a]	102,940	26,000	25.26	75,540	10,000	13.24	178,480	36,000	20.17
Total—Cancers	**191,670**	**100,300**	**52.33**	**145,340**	**63,400**	**43.62**	**337,010**	**163,700**	**48.57**
Coronary heart disease	218,870	61,800	28.24	193,720	37,500	19.36	412,590	99,300	24.07
Other heart disease[b]	75,670	13,400	17.71	96,200	12,100	12.58	171,870	25,500	14.84
Cerebrovascular disease[c]	53,610	8,200	15.30	81,300	7,100	8.73	134,920	15,300	11.34
Other vascular disease[d]	14,480	6,000	41.43	15,510	5,500	35.47	29,990	11,500	38.35
Diabetes mellitus	35,200	6,200	17.61	35,600	2,800	7.86	70,810	9,000	12.71
Total—Cardiovascular and metabolic diseases	**397,840**	**95,600**	**24.03**	**422,330**	**65,000**	**15.39**	**820,170**	**160,600**	**19.58**
Pneumonia, influenza, tuberculosis	25,300	7,800	30.83	30,290	4,700	15.52	55,590	12,500	22.49
COPD	61,430	50,400	82.04	66,300	50,200	75.71	127,740	100,600	78.76
Total—Pulmonary diseases[e]	**86,730**	**58,200**	**67.10**	**96,590**	**54,900**	**56.84**	**183,320**	**113,100**	**61.70**
Total—Cancers, cardiovascular and metabolic diseases, pulmonary diseases	**676,240**	**254,100**	**37.58**	**664,260**	**183,300**	**27.59**	**1,340,500**	**437,400**	**32.63**
Prenatal conditions[f]	5,970	346	5.80	4,620	267	5.78	10,590	613	5.79
Sudden infant death syndrome[g]	1,370	236	17.26	950	164	17.26	2,320	400	17.26
Perinatal conditions	**7,340**	**582**	**7.93**	**5,570**	**431**	**7.74**	**12,900**	**1,013**	**7.85**
Residential fires		**336**			**284**			**620**	**-**
Secondhand smoke									
Lung Cancer	88,730	4,370	4.93	69,800	2,960	4.24	158,530	7,330	4.63
Coronary heart disease	218,870	19,150	8.75	193,720	14,800	7.64	412,590	33,950	8.23
Total—Secondhand smoke	**307,600**	**23,530**	**7.65**	**263,520**	**17,760**	**6.74**	**571,120**	**41,280**	**7.23**
TOTAL Attributable deaths		**278,540**			**201,770**			**480,320**	

Source: Centers for Disease Control and Prevention, National Center for Chronic Disease Prevention and Health Promotion, Office on Smoking and Health, unpublished data.

Note: **COPD** = chronic obstructive pulmonary disease.

[a]Other cancers consist of cancers of the lip, pharynx and oral cavity, esophagus, stomach, pancreas, larynx, cervix uteri (women), kidney and renal pelvis, bladder, liver, colon and rectum, and acute myeloid leukemia.

[b]Other heart disease comprised of rheumatic heart disease, pulmonary heart disease, and other forms of heart disease.

[c]Other.

[d]Other vascular diseases are comprised of atherosclerosis, aortic aneurysm, and other arterial diseases.

[e]Pulmonary diseases consists of pneumonia, influenza, emphysema, bronchitis, and chronic airways obstruction.

[f]Prenatal conditions comprised of ICD-10 codes: K550, P000, P010, P011, P015, P020, P021, P027, P070–P073, P102, P220–P229, P250–P279, P280, P281, P360–P369, P520–P523, and P77 (Dietz et al. 2010).

[g]ICD-10 code R95.

Table 12.5 Average annual smoking-attributable mortality (SAM) for males 35 years of age and older, total and by age group, United States, 2005–2009

	35–64 years of age						65 years of age and older						≥35 years of age	
	35–54		55–64		Total[a]		65–74		≥75		Total[a]		Total[a]	
Disease	**Deaths**	**SAM**	**Deaths**	**SAM**	**Deaths**	**SAM**	**Deaths**	**SAM**	**Deaths**	**SAM**	**Deaths**	**SAM**	**Deaths**	**SAM**
Lung cancer	8,020	6,500	18,440	15,500	26,470	21,900	27,740	24,300	34,530	28,100	62,260	52,400	88,730	74,300
Other cancers[b]	13,370	2,800	22,540	5,400	35,900	8,200	26,380	7,900	40,660	10,300	67,040	18,200	102,940	26,000
Total—Cancers	**21,390**	**9,300**	**40,980**	**20,900**	**62,370**	**30,100**	**54,120**	**32,200**	**75,190**	**38,400**	**129,310**	**70,600**	**191,670**	**100,300**
Coronary heart disease	23,250	11,100	33,550	12,900	56,800	24,000	42,100	14,600	120,010	23,200	162,080	37,800	218,870	61,800
Other cardiovascular disease[c]	18,900	5,100	23,230	8,000	42,130	13,100								
Other heart disease[d]							12,310	3,000	45,950	5,000	58,260	8,100	75,670	13,400
Cerebrovascular disease[d]							9,390	2,000	33,800	3,000	43,190	5,000	53,610	8,200
Other vascular disease[d]							2,930	1,700	8,680	3,400	11,610	5,100	14,480	6,000
Diabetes mellitus							8,350	2,100	15,420	500	23,780	2,600	35,200	6,200
Total—Cardiovascular and metabolic diseases	**42,150**	**16,200**	**56,780**	**20,900**	**98,930**	**37,100**	**75,050**	**23,400**	**223,860**	**35,100**	**298,910**	**58,600**	**397,840**	**95,600**
Pneumonia, influenza, tuberculosis, COPD[e]	3,970	2,200	8,780	7,100	12,750	9,200								
Pneumonia, influenza, tuberculosis[f]							3,460	1,200	17,930	3,900	21,380	5,100	25,300	7,800
COPD[g]							15,040	13,300	37,560	30,600	52,600	43,900	61,430	50,400
Total—Pulmonary diseases	**3,970**	**2,200**	**8,780**	**7,100**	**12,750**	**9,200**	**18,490**	**14,500**	**55,490**	**34,500**	**73,980**	**49,000**	**86,730**	**58,200**
total—cancers, cardiovascular and metabolic diseases, pulmonary diseases	**67,500**	**27,700**	**106,540**	**48,900**	**174,050**	**76,400**	**147,660**	**70,100**	**354,540**	**108,000**	**502,190**	**178,200**	**676,240**	**254,100**
All causes	**164,750**	**52,300**	**174,350**	**64,400**	**339,100**	**116,700**	**222,100**	**79,400**	**573,910**	**134,600**	**796,010**	**214,100**	**1,135,110**	**330,800**

Source: Centers for Disease Control and Prevention, National Center for Chronic Disease Prevention and Health Promotion, Office on Smoking and Health, unpublished data.

Note: Estimation of SAM based on relative risks from updated analyses of the pooled contemporary cohorts described in Thun et al. 2013. **COPD** = chronic obstructive pulmonary disease; **CVD** = cardiovascular disease.

[a]Row and column totals may not add up exactly due to rounding.

[b]Cancers of the lip, pharynx and oral cavity, esophagus, stomach, pancreas, larynx, cervix uteri, kidney and renal pelvis, bladder, liver, colon and rectum, and acute myeloid leukemia were combined into 1 disease category for both analysis and presentation. A single relative risk for the combined conditions was used to compute SAM.

[c]Other cardiovascular disease consists of other heart disease, CVD, atherosclerosis, aortic aneurysm, other arterial diseases, and diabetes mellitus. For 35–54 and 55–64 years of age, the relative risk for the combined conditions was used to compute SAM. For 65–74 and ≥75 years of age, separate relative risks for other heart disease, CVD, and other vascular diseases were used to compute SAM.

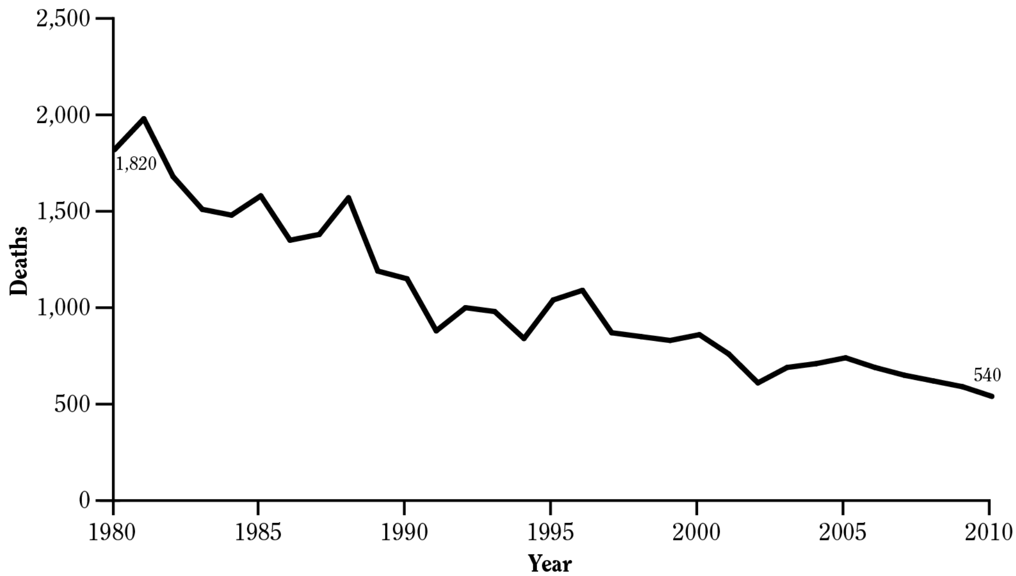
[d]For 65–74 and ≥75 years of age, other heart disease, CVD, other vascular disease, and diabetes mellitus also presented as separate conditions. Other vascular disease consists of atherosclerosis, aortic aneurysm, and other arterial diseases. Separate relative risks used to compute SAM for other heart disease, CVD, and diabetes mellitus. For other vascular disease, separate relative risks used to compute SAM for each condition before summing them for presentation.

[e]For 35–54 and 55–64 years, pneumonia, influenza, bronchitis, tuberculosis, and COPD were combined into 1 disease category for analysis and presentation. COPD consists of bronchitis, emphysema, and chronic airways obstruction. A single relative risk was used to compute SAM for the entire category.

[f]For 65–74 and ≥75 years of age, pneumonia/influenza/tuberculosis and COPD analyzed and presented as separate conditions. COPD consists of bronchitis, emphysema, and chronic airways obstruction. Separate relative risks were used to compute SAM for pneumonia/influenza/tuberculosis and for COPD.

[g]For ages 65–74 years and 75 years and older, pneumonia/influenza and COPD analyzed and presented as separate conditions. COPD consists of bronchitis, emphysema, and chronic airways obstruction. Separate relative risks were used to compute SAM for pneumonia/influenza and for COPD.

Figure 12.3 Trend in civilian deaths in smoking-material home fires, United States, 1980–2010



Source: Hall 2012. Reprinted with permission from NFPA's report, *"The Smoking-Material Fire Problem",* © 2013.
Note: NFPA = National Fire Protection Association.

this report). For men, 35 years of age and older, the counts of annual smoking-attributable deaths were 100,300 for cancers, 95,600 for cardiovascular and metabolic diseases, and 58,200 for pulmonary diseases (Table 12.5). For women, 35 years of age and older, the annual SAM was 63,400 for cancers, 65,000 for cardiovascular diseases, and 54,900 for pulmonary diseases (Table 12.6).

These results differ from those obtained for 2005–2009 using only CPS-II RRs for the 19 diseases included in the past (Table 12.7). Compared with CPS-II alone, the new RRs produce a higher lung cancer SAM estimate for women (53,400 vs. 48,200) and a lower lung cancer SAM estimate for men (74,300 vs. 77,200). SAM for other cancers is similar across the two methods for both men and women (36,000 with the new RRs vs. 36,900 for CPS-II alone for both genders combined). SAM for pulmonary diseases with the new RRs is also somewhat higher for both genders (113,100 vs. 108,100). The biggest difference is for cardiovascular diseases; SAM for both CHD and other cardiovascular disease SAMs are greatly increased with the new RRs. For men, cardiovascular and metabolic diseases SAM is estimated at 95,600 (vs. 70,300 with CPS-II RRs); for women, cardiovascular SAM is estimated at 65,000 (vs. 41,300 with CPS-II RRs). In total, for cancers, cardiovascular diseases, and pulmonary diseases with both genders combined, the overall annual average SAM estimate for 2005–2009 is 437,400, about 15% higher than would have been calculated using RRs from only CPS-II (382,000).

In previous infant SAMMEC calculations, the prevalence of prenatal smoking has been obtained from birth certificates. However, the 1989 version of the birth certificate and the 2003 revised birth certificate differ with respect to how smoking is ascertained. State uptake of the 2003 revised birth certificate has been gradual and it is expected that not all states will have implemented the revised birth certificate until 2014. Thus, birth certificate-based smoking data are not comparable across all states during the last decade. Therefore, for this report, the prevalence of prenatal smoking for 2005–2009 was calculated based on data from the Pregnancy Risk Assessment Monitoring System (PRAMS). PRAMS uses a self-administered questionnaire that is completed by women 2–6 months after delivering a live-born infant. Data from 34 states participating in PRAMS (Alaska, Arkansas, Colorado, Delaware, Florida, Georgia, Hawaii, Illinois, Maine, Maryland, Massachusetts, Michigan, Minnesota, Mississippi, Missouri, Nebraska, New Jersey, New Mexico, New York, North Carolina, Ohio, Oklahoma, Oregon, Pennsylvania, Rhode Island, South Carolina, Tennessee, Texas, Utah, Vermont, Washington, West Virginia, Wisconsin, and Wyoming) and New York City were included if the overall weighted response rate for a given state and year was at least 70%

Table 12.6 Average annual smoking attributable mortality (SAM) for females 35 years of age and older, total and by age group, United States, 2005–2009

	35–64 years of age						65 years of age and older						≥35 years of age	
	35–54		55–64		Total[a]		65–74		≥75		Total[a]		Total[a]	
Disease	**Deaths**	**SAM**	**Deaths**	**SAM**	**Deaths**	**SAM**	**Deaths**	**SAM**	**Deaths**	**SAM**	**Deaths**	**SAM**	**Deaths**	**SAM**
Lung cancer	6,390	4,800	12,690	10,100	19,080	14,900	20,510	16,700	30,210	21,800	50,720	38,500	69,800	53,400
Other cancers[b]	8,560	600	11,470	2,300	20,030	2,900	15,980	2,500	39,530	4,400	55,510	7,000	75,540	10,000
Total—Cancers	**14,950**	**5,400**	**24,160**	**12,400**	**39,110**	**17,800**	**36,490**	**19,200**	**69,740**	**26,200**	**106,230**	**45,500**	**145,340**	**63,400**
Coronary heart disease	7,480	3,900	12,920	3,800	20,400	7,600	23,090	7,000	150,230	22,900	173,320	29,900	193,720	37,500
Other cardiovascular disease[c]	12,320	2,900	15,800	2,400	28,120	5,300								
Other heart disease[d]							9,950	1,600	75,440	8,400	85,390	10,000	96,200	12,100
Cerebrovascular disease[d]							8,720	1,600	64,210	3,900	72,930	5,400	81,300	7,100
Other vascular disease[d]							1,900	1,000	12,270	4,200	14,160	5,200	15,510	5,500
Diabetes mellitus							7,020	900	20,990	400	28,010	1,400	35,600	2,800
Total—Cardiovascular and metabolic diseases	**19,800**	**6,800**	**28,720**	**6,200**	**48,520**	**12,900**	**50,680**	**12,100**	**323,130**	**39,800**	**373,810**	**51,900**	**422,330**	**65,000**
Pneumonia, influenza, tuberculosis, COPD[e]	3,320	1,900	7,460	5,200	10,790	7,100								
Pneumonia, influenza, tuberculosis[f]							2,780	400	24,690	2,500	27,470	2,900	30,290	4,700
COPD[f]							14,400	12,900	43,930	32,000	58,330	44,900	66,300	50,200
Total—Pulmonary diseases	**3,320**	**1,900**	**7,460**	**5,200**	**10,790**	**7,100**	**17,190**	**13,300**	**68,620**	**34,500**	**85,800**	**47,800**	**96,590**	**54,900**
Total—Cancers, cardiovascular and metabolic diseases, pulmonary diseases	**38,070**	**14,100**	**60,340**	**23,800**	**98,420**	**37,800**	**104,360**	**44,600**	**461,490**	**100,500**	**565,850**	**145,200**	**664,260**	**183,300**
All causes	**100,410**	**17,300**	**114,312**	**29,500**	**214,730**	**46,800**	**173,960**	**47,600**	**803,030**	**130,600**	**976,980**	**178,200**	**1,191,710**	**225,000**

Source: Centers for Disease Control and Prevention, National Center for Chronic Disease Prevention and Health Promotion, Office on Smoking and Health, unpublished data.

Note: Estimation of SAM based on relative risks from updated analyses of the pooled contemporary cohort described in Thun et al. 2013. **CVD** = cardiovascular disease; **COPD** = chronic obstructive pulmonary disease.

[a]Row and column totals may not add up exactly due to rounding.

[b]Cancers of the lip, pharynx and oral cavity, esophagus, stomach, pancreas, larynx, cervix uteri, kidney and renal pelvis, bladder, liver, colon and rectum, and acute myeloid leukemia were combined into 1 disease category for both analysis and presentation. A single relative risk for the combined conditions was used to compute SAM.

[c]Other cardiovascular disease consists of other heart disease, CVD, atherosclerosis, aortic aneurysm, other arterial diseases, and diabetes mellitus. For 35–54 and 55–64 years of age, the relative risk for the combined conditions was used to compute SAM. For 65–74 and ≥75 years of age, separate relative risks for other heart disease, CVD, and other vascular diseases were used to compute SAM.

[d]For 65–74 and ≥75 years of age, other heart disease, CVD, other vascular disease, and diabetes mellitus also presented as separate conditions. Other vascular disease consists of atherosclerosis, aortic aneurysm, and other arterial diseases. Separate relative risks used to compute SAM for other heart disease, CVD and diabetes mellitus. For other vascular disease, separate relative risks used to compute SAM for each condition before summing them for presentation.

[e]For 35–54 and 55–64 years of age, pneumonia, influenza, bronchitis, tuberculosis and COPD were combined into 1 disease category for analysis and presentation. COPD consists of bronchitis, emphysema, and chronic airways obstruction. A single relative risk was used to compute SAM for the entire category.

[f]For 65–74 and ≥75 years of age, pneumonia/influenza/tuberculosis and COPD analyzed and presented as separate conditions. COPD consists of bronchitis, emphysema, and chronic airways obstruction. Separate relative risks were used to compute SAM for pneumonia/influenza/tuberculosis and for COPD.

Table 12.7 Average annual smoking-attributable mortality[a] (SAM) for adults 35 years of age and older, total and by gender, United States, 2005–2009: Cancer Prevention Study II (CPS-II) relative risks (RRs) vs. CPS-II/contemporary cohorts RRs

	Males		Females		Total	
Disease	**CPS-II[b]**	**CPS-II/ contemporary cohorts[c]**	**CPS-II[b]**	**CPS-II/ contemporary cohorts[c]**	**CPS-II[b]**	**CPS-II/ contemporary cohorts[c]**
Lung cancer	77,200	74,300	48,200	53,400	125,300	127,700
Other cancers[d]	27,300	26,000	9,700	10,000	36,900	36,000
Total—Cancers	**104,400**	**100,300**	**57,800**	**63,400**	**162,300**	**163,700**
Coronary heart disease	44,300	61,800	23,500	37,500	67,800	99,300
Other cardiovascular disease[e]	26,000	33,800	17,800	27,500	43,800	61,300
Total—Cardiovascular and metabolic diseases	**70,300**	**95,600**	**41,300**	**65,000**	**111,600**	**160,600**
Total—Pulmonary diseases[f]	**55,200**	**58,200**	**52,800**	**54,900**	**108,100**	**113,100**
Total—Cancers, cardiovascular and metabolic diseases, pulmonary diseases	**230,000**	**254,100**	**152,000**	**183,300**	**382,000**	**437,400**
All causes	**NA[g]**	**330,800**	**NA[g]**	**225,000**	**NA[g]**	**555,800**

Source: Centers for Disease Control and Prevention, National Center for Chronic Disease Prevention and Health Promotion, Office on Smoking and Health, unpublished data.

Note: **CVD** = cardiovascular disease; **NA** = not available.

[a]Row and column totals may not add up exactly due to rounding.

[b]SAM calculated using RRs from CPS-II; gender- and age-specific (35–64, ≥65 years of age) RRs and smoking status (current, former) prevalence used for estimates.

[c]SAM calculated using RRs from CPS-II for 35–54 years of age and RRs from contemporary cohorts (Thun et al. 2013) for ≥55 years of age; gender- and age-specific (35–54, 55–64, 65–74, ≥75 years of age) RRs and smoking status (current, former) used for estimates.

[d]Other cancers comprised of cancers of the lip, pharynx and oral cavity, esophagus, stomach, pancreas, larynx, cervix uteri, kidney and renal pelvis, bladder, and acute myeloid leukemia. Analysis for CPS-II and contemporary cohorts also includes cancers of liver and of colon and rectum.

[e]Other cardiovascular disease comprised of other heart disease, CVD, atherosclerosis, aortic aneurysm, and other arterial diseases. Analysis for CPS-II and contemporary cohorts also includes diabetes mellitus.

[f]Pulmonary diseases consists of pneumonia, influenza, emphysema, bronchitis, and chronic airways obstruction. Analysis for CPS-II and contemporary cohorts also includes tuberculosis.

[g]All-cause SAM not computed.

Table 12.8 Average annual perinatal deaths attributable to smoking, United States, 2005–2009

	Males		Females		Total	
Disease	**Deaths**	**SAM**	**Deaths**	**SAM**	**Deaths**	**SAM**
Prenatal conditions[a]	5,970	350	4,620	270	10,590	610
Sudden infant death syndrome[b]	1,370	240	950	160	2,320	400
Total	7,340	580	5,570	430	12,900	1,020

Source: Centers for Disease Control and Prevention, National Center for Chronic Disease Prevention and Health Promotion, Office on Smoking and Health, unpublished data.
Note: **ICD** = International Classification of Diseases; **SAM** = smoking-attributable mortality. Column may not sum exactly due to rounding.
[a]Prenatal conditions comprised of ICD-10 codes: K550, P000, P010, P011, P015, P020, P021, P027, P070–P073, P102, P220–P229, P250–P279, P280, P281, P360–P369, P520–P523, and P77 (Dietz et al. 2010).
[b]ICD-10 code R95.

for data collected during 2005–2006 and at least 65% for data collected starting in 2007. These PRAMS states represented 70% of live births in the United States in 2009 (Martin et al. 2011). Data from these states were pooled to estimate the national prevalence of smoking during the last 3 months of pregnancy. The average prevalence of prenatal smoking during 2005–2009 was estimated at 12.3% for the 34 PRAMS states and New York City, and this estimate was used as an approximation for the national prevalence of prenatal smoking. Using this source of prevalence data and the new RRs described previously, maternal smoking was estimated to result in 1,015 infant deaths annually in 2005–2009, 582 in males and 431 in females (Table 12.8). Of these, 614 were attributed to prenatal conditions and 401 to SIDS, which is causally related to both maternal smoking during pregnancy and exposure to secondhand smoke as an infant (USDHHS 2006).

Based on the results of Max and colleagues (2012), an estimated 33,951 CHD deaths and 7,333 lung cancer deaths were due to exposure to secondhand smoke among adults, 20 years of age and older, in 2006. Table 12.9 shows the estimated deaths attributable to exposure to secondhand smoke among U.S. adults, 20 years of age and older, for 2006. Although Max and colleagues (2012) also calculated the number of infant deaths attributable to exposure to secondhand smoke, those estimates are not included here because the relevant health conditions are encompassed in the SAMMEC calculations for infants.

CDC's national smoking-attributable burden totals have also typically included an estimate of smoking-attributable deaths from residential fires (CDC 2005, 2008). NFPA publishes estimates of the average annual number of civilian deaths attributed to smoking-material fires in the United States. These estimates are based on information reported to U.S. municipal fire departments and on information obtained from surveys from the NFPA and National Fire Incidence Reporting System. The average annual number of deaths attributed to smoking-material fires in homes between 2006–2010 was 620 (336 in males, 284 in females) (Hall 2012). These fires also caused an estimated 1,570 civilian injuries and $663 million in direct property damage. As the prevalence of smoking has decreased and requirements for fire-resistant mattresses and upholstery and for "fire-safe" cigarettes have been implemented, the number of smoking-material related fires and deaths has decreased. From 1980–2010, smoking-material fires decreased by 73% and civilian deaths in home structure fires decreased by 70% (Figure 12.3) (Hall 2012).

The average annual SAM for the United States for 2010–2014 (Table 12.15) is at least 480,000 premature deaths caused by cigarette smoking and exposure to secondhand smoke; however, this estimate does not include deaths caused by use of cigars, pipes, other forms of combusted tobacco (e.g., roll-your-own cigarettes, hookah pipes, bidis; see Chapter 13 for description of these various products), nor smokeless tobacco products. As discussed in Chapter 13, the use of these products has increased in recent years; while the methodology for estimating the current population burden from the use of these tobacco products remains under discussion, the number of deaths caused by these products is expected to be in the thousands per year (Shapiro et al. 2000). Also, the estimated burden due to the new causal conclusion that exposure

Table 12.9 Deaths, years of productive life lost, and value of lost productivity from coronary heart disease and lung cancer attributable to exposure to secondhand smoke among nonsmoking adults, 20 years of age and older, United States, 2006

Cause of death	Deaths attributable to exposure to secondhand smoke	Years of productive life lost	Value of lost productivity ($ in thousands)
Coronary heart disease			
Males	19,150	256,980	3,520,660
Females	14,800	164,960	1,106,850
Total	33,950	421,940	4,627,520
Lung cancer			
Males	4,370	62,810	741,450
Females	2,960	47,830	311,690
Total	7,330	110,640	1,053,150
Totals, coronary heart disease and lung cancer			
Males	23,530	319,790	4,262,110
Females	17,760	212,790	1,418,540
Total	41,280	532,580	5,680,670

Source: Max et al. 2012. Reprinted with permission from The Sheridan Press, © 2012.
Note: Column totals may not sum exactly due to rounding.

to secondhand smoke causes stroke (see Chapter 8) has not been published. However, based upon the methodology used to compute the CHD deaths caused by exposure to secondhand smoke (Max et al. 2012), over 8,000 stroke deaths annually may be attributable to secondhand smoke. Hence, the average annual total SAM for the United States due to smoking any combusted tobacco product or exposure to secondhand smoke is likely approaching 500,000 per year.

Projected Smoking-Related Deaths Among Youth, United States, 2012

Due to the slow decline in the prevalence of current smoking and initiation among youth and young adults (see Chapter 13, Table 13.19 and Figure 13.26), the annual burden of smoking-attributable mortality can be expected to remain at high levels for decades into the future. Although there is a trend of increasing success of quit attempts (see Chapter 13, Figure 13.17), the risks of premature death from smoking-related illness among former smokers and continuing smokers were higher in cohort study data from 2000–2012 than from earlier cohort studies (see Chapters 11 and 12).

In 1996, CDC projected the future impact of smoking on the health of children and teenagers based on the assumption that current tobacco use patterns would persist across the lives of this cohort of youth (CDC 1996). The future probability that a young adult smoker would die prematurely of a smoking-related cause was estimated to be 32% (CDC 1996). The methodology used to compute this probability of smoking-attributable mortality (PSAM) among young adult smokers is described in Appendix 12.2. The same CDC methodology was used to calculate updated estimates on the number of youth in the United States who will become future smokers and will die prematurely of a smoking-related illness (Tables 12.2.1 and 12.2.2). Because the prevalence of smoking in a birth cohort peaks during early adulthood (see Chapter 13), the average prevalence of smoking among adults 18–30 years of age in each state during 2011–2012 was used to estimate the future prevalence of smoking during early adulthood for the 0–17-years-of-age birth cohort in 2012. The number of persons 0–17 years of age in each state in 2012 was multiplied by the state-specific prevalence of smoking among those 18–30 years of age to calculate the number of youth expected to become regular smokers in each state. Overall, the estimated number of future smokers from the 0–17-years-of-age birth cohort in 2012 in the United States was 17,371,000 (ranging from 22,300 in the District of Columbia to 1,557,800 in Texas) (Table 12.2.1).

Based on the application of PSAM (0.32) to the state-specific estimates of potential smokers, the overall number of potential future smoking-attributable deaths among youth 0–17 years of age during 2012 in the United States was 5,557,000 (ranging from 7,000 in the District of Columbia to 498,000 in Texas) (Table 12.2.1). Based on the estimated PSAM variance and the state-specific sampling errors on estimates of smoking prevalence from the BRFSS, the estimated number of overall smoking-related deaths in the United States was predicted to vary on a statistical basis by less than or equal to 115,000 deaths. The CIs did not account for other sources of uncertainty, such as future changes in risk of dying from smoking or in quitting rate patterns.

These state-specific estimates were also used to calculate the proportion of youth, 0–17 years of age, who are projected to die prematurely from a smoking-related illness (Table 12.2.2). At the state level, estimates varied almost threefold, from 4.4% in Utah to 12.3% in West Virginia. Overall, 7.5% of youth from the 0–17-years-of-age birth cohort in 2012 in the United States are projected to die prematurely from a smoking-related illness if current rates of smoking and risk of disease associated with smoking persist. Therefore, an estimated 5.6 million youth currently aged 0–17 years of age will die prematurely of a smoking-related illness (Table 12.2.2).

Smoking-Attributable Morbidity Estimates

The most recent previous national estimate of smoking-attributable morbidity for the United States was published for the year 2000 (CDC 2003). For that prior report, the estimates of the prevalence of smoking-related medical conditions were obtained from NHANES III (1988–1994) for current, former, and never smokers to compute the SAFs of morbid conditions. Using the smoking prevalence estimates from BRFSS for the combined years of 1999–2001, it was estimated that 8.6 million (95% CI, 6.9–10.5 million) persons in the United States had 12.7 million (95% CI, 10.8–15.0 million) smoking-attributable serious medical conditions (CDC 2003). These estimates represent the numbers of people living with a smoking-caused disease at the time of the survey (Table 12.10). For diseases with a high mortality rate, such as lung cancer, the prevalence is low because there are few long-term survivors. For many of the conditions, the numbers of self-reported diseases were higher among former smokers than among current smokers. This pattern reflects the quitting of smoking by those who develop a smoking-caused disease, particularly later in life (USDHHS 2004).

In making these estimates, CDC noted that the self-reported data on the prevalence of the medical conditions probably substantially underestimate the true disease burden, particularly for COPD (CDC 2003). Additionally, it was noted that the scope of the medical conditions was limited to the diseases for which the NHANES had survey questions and those that previous Surgeon General's reports had concluded were caused by smoking. Finally, as reviewed in Chapter 11, smoking affects various additional acute and chronic conditions related to the quality of life, health status, and general morbidity.

In the present report, smoking and exposure to secondhand smoke have been causally linked to additional adverse health outcomes that were not considered in the 2003 estimates from CDC. These new causal associations for specific diseases link active smoking with diabetes, colorectal cancer, liver cancer, and tuberculosis, and exposure to secondhand smoke and stroke. For each of these diseases, there is an excess burden attributable to smoking and is potentially avoidable through tobacco control. Additionally, Chapter 11 reviews the evidence regarding the excess morbidity attributable to smoking as reflected

Table 12.10 Number and percentage of cigarette smoking-attributable conditions[a] among current and former smokers[b], by condition, United States[c], 2000

	Current smokers		Former smokers		Overall total	
Disease	Number	%	Number	%	Number	%
Chronic bronchitis	2,633,000	49	1,872,000	26	4,505,000	35
Emphysema	1,273,000	24	1,742,000	24	3,016,000	24
Heart attack	719,000	13	1,755,000	24	2,474,000	19
All cancer except lung cancer	358,000	7	1,154,000	16	1,512,000	12
Stroke	384,000	7	637,000	9	1,021,000	8
Lung cancer	46,000	1	138,000	2	184,000	1
Total[d]	5,412,000	100	7,299,000	100	12,711,000	100

Source: Centers for Disease Control and Prevention 2003.
[a]Cigarette smoking-attributable conditions considered are stroke, heart attack, emphysema, chronic bronchitis, and cancer of the lung, bladder, mouth/pharynx, esophagus, cervix (women), kidney, larynx, and pancreas.
[b]Current smokers were defined as persons who reported smoking ≥100 cigarettes during their lifetime and who now smoke some days or every day. Former smokers were defined as persons who reported having smoked ≥100 cigarettes during their lifetime but did not smoke at the time of the interview.
[c]Results are adjusted for age, race, gender, and state/area of residence and rounded to the nearest 1,000.
[d]Numbers might not add to total because of rounding.

in overall health status and general morbidity that may come from still unidentified associations between smoking and disease and through indirect pathways, such as diminished immune function. For the cancers, respiratory and cardiovascular diseases, and other adverse health outcomes, issues that merit attention in future updates of the estimates of smoking-attributable morbidity are outlined below.

Cancer

In this report, smoking has been causally linked to colorectal and liver cancer. Both of these cancer sites are among the most common for men and women (see Chapter 6). The previously reported estimates of 1,696,000 (1,512,000 + 184,000) persons in the year 2000 with a history of cancer due to current or past smoking were limited to lung, bladder, mouth/pharynx, esophagus, cervix, kidney, larynx, and pancreas sites. For cancer sites with a high mortality rate, such as the lung, the number of persons surviving is low because there are few long-term survivors. Although liver cancer has a low 5-year survival rate similar to lung cancer (i.e., 14% for liver and 16% for lung), the 5-year survival rate for persons with colorectal cancer is much higher (64%) (American Cancer Society 2013). Hence, an updated estimate of the number of persons surviving with cancer caused by smoking would be expected to increase with the inclusion of liver and colorectal cancer sites.

COPD

Previous Surgeon General's reports and Chapter 7 of this report document the very high level of risk for COPD due to active smoking. A very high proportion of COPD is attributable to current and past smoking (CDC 2008). Based on self-reports, 12–13 million U.S. adults report having COPD (American Lung Association 2013). However, self-reports of COPD likely substantially underestimate the true disease burden from smoking-attributable chronic respiratory diseases (CDC 2002, 2003). Analyses of data from NHANES III, which was the basis for the 2003 report from CDC, indicated that 63% of the respondents with a documented low level of lung function (forced expiratory volume in 1 second) <80% of the predicted value did not self-report a diagnosis of obstructive lung disease (CDC 2002). Using impaired lung function to estimate the prevalence of disease, approximately 24 million U.S. adults would be classified as having COPD (CDC 2002). Based on the estimate that 85–90% of these potential cases would be attributable to current or former smoking (USDHHS 2010), the total smoking-attributable burden of

COPD prevalence could be estimated to be between 20.4–21.6 million persons. This range of estimated prevalence of COPD is substantially higher than the 2003 estimate of 7,521,000 for chronic bronchitis and emphysema combined (CDC 2003).

Cardiovascular Diseases

In the United States, there is a high prevalence of persons living with a cardiovascular disease condition (see Table 8.4 in Chapter 8). In 2008, the estimated numbers of people in the United States with prevalent cardiovascular disease related to smoking were: history of acute myocardial infarction, 7.9 million; angina pectoris, 9 million; stroke, 7 million; heart failure, 5.7 million; atrial fibrillation, 2.2 million; and peripheral arterial disease (PAD), 8.3 million (NHLBI 2012). In 2000, it was estimated that among persons living with serious medical conditions, smoking caused approximately 2.5 million of the heart attacks and more than 1 million of the strokes (CDC 2003). Additionally, these estimates did not include the cardiovascular disease morbidity attributable to exposure to secondhand smoke.

However, in this and other reports (USDHHS 2004, 2010, 2012), the evidence has been reviewed showing that even brief exposures to tobacco smoke, from either smoking or exposure to secondhand smoke, can cause acute cardiovascular events and the progression of chronic vascular diseases. As reviewed in Chapter 8, the evidence is now sufficient to conclude that exposure to secondhand smoke causes stroke, and that the implementation of smokefree policies can reduce the incidence of acute coronary events. Additionally, the evidence reviewed in Chapter 10 leads to a conclusion that smoking causes diabetes. Since prior Surgeon General's reports have shown smoking causes PAD, the increasing evidence regarding the high RR of smoking in the development of symptomatic PAD (e.g., RR = 21 among women who smoked 15 or more cigarettes per day) (Conen et al. 2011) suggest that a high proportion of the prevalent PAD conditions could be attributable to smoking. Internationally, it has been estimated that approximately 15% of acute myocardial infarction events could be caused by exposure to secondhand smoke (Teo et al. 2006). Thus, the previous estimates of the cardiovascular disease morbidity burden attributable to smoking are most likely significant underestimates of the total, if these additional causes and the effects of secondhand smoke were to be included.

Additionally, the impact of smoking on progression of atherosclerotic disease may not have been adequately estimated in earlier estimates of SAM. Previous reports reviewed the evidence on the mechanisms by which smoking and exposure to secondhand smoke contribute to the early onset, progression, and severity of the atherosclerotic disease (USDHHS 2010, 2012). In 2010, the number of cardiovascular surgery procedures performed included: 1 million cardiac catheterizations, 500,000 balloon angioplasties or atherectomies, 454,000 insertions of coronary artery stent, and 395,000 coronary artery bypass graft procedures (CDC 2013). Thus, the prevalence of persons who have had such cardiovascular surgery procedures—which could have been due to the atherosclerotic disease caused by smoking—could be similar to the proportion of deaths from CHD caused by smoking (i.e., about 28% for men and almost 20% for women).

As the U.S. population ages, the number of persons who have been diagnosed with congestive heart failure (CHF) has increased (NHLBI 2012). In 2008, it was estimated that 5.7 million people have CHF in the United States. Evidence indicates that CHD is the underlying cause for approximately 65% of CHF cases and that smoking is a major contributing factor in the atherosclerotic disease process that leads to CHD (USDHHS 2004). According to the 19-year follow-up from the first NHANES Epidemiologic Follow-up Study, approximately 17.1% of the incident CHF could be attributed to tobacco smoking (He et al. 2001).

Thus, the previous estimate that about 3.5 million persons are living with a cardiovascular disease condition caused by smoking or exposure to secondhand smoke (CDC 2003) would appear to be a substantial underestimate of the total burden due to not only survivors of acute coronary events and strokes caused by smoking but also the number of persons with PAD, CHF, and a history of cardiovascular surgery procedures that could be attributed to smoking.

Diabetes

The present report concludes that smoking causes diabetes (see Chapter 10). As discussed in that chapter, the prevalence of diabetes in the United States has been increasing; in 2011, 25.6 million adults, 20 years of age and older, had diabetes. In the annual estimated smoking-attributable mortality for 2010–2014, approximately 13% of annual deaths due to diabetes were caused by current and former smoking (Table 12.4). Thus, the proportion of cases of diabetes attributable to smoking should be addressed when calculating smoking-attributable morbidity as well as mortality.

Summary

Approximately 8.6 million persons in the United States had an estimated 12.7 million smoking-attributable serious medical conditions in 2000 (CDC 2003). As noted previously, the updated evidence on diseases caused by smoking and exposure to secondhand smoke indicate that this estimate is likely a substantial underestimation of the true disease burden. Due to the increased burden of liver cancer and colorectal cancer, the various aspects of cardiovascular disease morbidity, which were not included in previous estimates, and the addition of diabetes cases attributed to smoking, the number of serious medical conditions caused by smoking could be much larger. For COPD alone, the updated estimate of the burden caused by smoking could be more than double the existing estimate.

Smoking-Attributable Economic Costs

This section covers smoking-attributable economic costs resulting from lost productivity and health care expenditures.

Loss of Productivity

The productivity losses calculated here only represent the present value of future earnings (PVFE) from paid labor and of foregone future imputed earnings from unpaid household work that is unrealized as a consequence of early mortality. Past estimations of PVFE values to use for productivity loss calculations were based on values for the United States in 2000 (Haddix et al. 2003) and an assumed 1% productivity rate and 3% discount rate. Estimates of PVFE for later years were estimated by applying annual changes in the non-seasonally-adjusted employment cost index for total compensation for civilian workers (U.S. Bureau of Labor Statistics n.d.). Male-specific PVFEs were used for both males and females, to account for historical gender bias in compensation.

Productivity losses were estimated by multiplying age-specific YPLL by age-specific PVFE, with total productivity determined by adding subtotals across age and disease categories. Estimates are based on deaths in adults 35–79 years of age.

YPLLs are calculated by multiplying age-specific SAM for each disease category by age group-specific years of life remaining. Years of life remaining are based on U.S. life table data published by the National Center for Health Statistics at CDC. For this report, U.S. life tables were current through 2008; for these calculations, years of life remaining for 2009 were considered equal to those for 2008. Total YPLL is determined by adding subtotals across age and disease categories.

Grosse and colleagues (2009) published updated estimates of PVFE for the United States for 2007. PVFEs for total production for both genders combined were used for estimating productivity losses for 2005–2009, with 2007 values serving as the baseline and values for earlier and later years estimated by annual change in the employment cost index. Due to the use of different assumptions and parameters, the PVFE values published by Grosse and colleagues (2009) were conservative compared to the PVFE estimates published by Haddix and colleagues (2003).

Table 12.11 lists estimated average annual smoking-attributable productivity loss by disease category and gender for the United States from 2005–2009. For 2005–2009, the value of lost productivity attributable to premature death from smoking, based on the 19 diseases used in prior SAMMEC estimates (CDC 2008), was $107.6 billion—$69.6 billion in men and $38 billion in women. Cancers accounted for $44.5 billion of lost productivity costs, and cardiovascular and metabolic diseases accounted for $44.7 billion, and pulmonary diseases accounted for $18.4 billion. Using all-cause mortality, the value of lost SAM would be $150.7 billion—$105.6 billion in men and $45.1 billion in women. Additionally, the value of lost productivity due to premature deaths caused by exposure to secondhand smoke was estimated to be $5.7 billion (Table 12.9). Because these figures account only for lost productivity due to premature mortality and not for lost productivity due to morbidity they significantly underestimate the full value of lost productivity costs due to smoking.

Updated Estimates of Smoking-Attributable Health Care Expenditures

The smoking-attributable health care expenditure is one important component of smoking-attributable economic costs. Although the prevalence of smoking continues to decline in the United States, smoking-related health care expenditures still account for an estimated 5–14% of the total health care expenditures in the United States (Levy and Newhouse 2011; Congressional Budget Office [CBO] 2012). The analytical approaches used to estimate attributable expenditures vary depending on the methodology adopted and the time horizon considered in the analysis. In terms of the former, some studies use a

Table 12.11 Average annual value of lost productivity attributable to death from cigarette smoking, adults 35–79 years of age, United States, 2005–2009

	Value of lost productivity ($ in thousands)[a]		
Disease	**Males**	**Females**	**Total**
Lung cancer	20,326,794	14,084,073	34,410,868
Other cancers[b]	7,434,058	2,614,451	10,048,509
Total—Cancers	**27,760,852**	**16,698,524**	**44,459,376**
Coronary heart disease	20,646,966	7,420,262	28,067,228
Other cardiovascular disease[c]	11,209,038	5,454,808	16,663,845
Total—Cardiovascular and metabolic diseases	**31,856,004**	**12,875,069**	**44,731,073**
Total—Pulmonary diseases[d]	**9,963,054**	**8,402,054**	**18,365,108**
Total—Cancers, cardiovascular and metabolic diseases, pulmonary diseases	**69,579,910**	**37,975,647**	**107,555,557**
Total—All causes	**105,641,174**	**45,085,339**	**150,726,514**

Source: Centers for Diease Control and Prevention, National Center for Chronic Disease Prevention and Health Promotion, Office on Smoking and Health, unpublished data.
[a]Value of lost productivity calculated based on potential value of future earnings in the United States in 2007, published by Grosse et al. 2009.
[b]Other cancers comprised of cancers of the lip, pharynx and oral cavity, esophagus, stomach, pancreas, larynx, cervix uteri, kidney and renal pelvis, bladder, colon and rectum, liver, and acute myeloid leukemia.
[c]Other cardiovascular disease comprised of other heart disease, cardiovascular disease, atherosclerosis, aortic aneurysm, other arterial diseases, and diabetes mellitus.
[d]Pulmonary diseases consist of pneumonia, influenza, tuberculosis, emphysema, bronchitis, and chronic airways obstruction.

disease-specific approach, in which the attributable expenditure for each major smoking-related disease is estimated as the product of the total health care expenditure for the disease and the share of attributable expenditure. The sum of these disease-specific attributable expenditures provides the total health care expenditure that is attributable to smoking. Other studies take a regression approach, in which health care expenditures are compared by smoking status while controlling for other factors that may differ among current, never, and former smokers. In terms of time horizons, most previous studies on smoking-attributable health care expenditures have taken a cross-sectional approach, in which attributable expenditures were calculated for a point in time. A few took a lifetime approach, in which the attributable expenditures were considered over an individual's life expectancy (Manning et al. 1991; Sloan et al. 2004).

In order to account for the methodologic differences and to provide a reasonable range of smoking-attributable health care expenditures, this section presents estimated attributable expenditures obtained from three different approaches: (1) updated estimates by type of medical services based on the expenditure SAFs in the SAMMEC, (2) updated estimates by age and gender based on an approach originated by Solberg and colleagues (2006), and (3) national estimates by source of fund from a regression analysis using the data from the Medical Expenditure Panel Survey (MEPS) (Xu et al. in press). Although these approaches are not the only ways to estimate the smoking-attributable health care expenditures, they are commonly used. To be consistent with SAM, all of these estimates are cross-sectional. Use of these approaches explores the sensitivity of estimates to the method selected.

Smoking-Attributable Health Care Expenditures by Type of Medical Services

The approach published by Miller and colleagues (1999) involves estimation of expenditure smoking-attributable fractions for five categories of personal health care expenditures—ambulatory care, hospital care, prescriptions, nursing home care, and other care (including home health care, durable and nondurable medical equipment, and other professional services) while accounting for potential confounders. The expenditure SAFs are calculated based on a 2-stage econometric model. Estimates of smoking-attributable health care expenditures are for adults 19 years of age and older and exclude dental expenditures. Values for category-specific health care expenditures are based on data from the Centers for Medicare & Medicaid Services ([CMS] 2012c).

Based on this approach, smoking-attributable medical expenditures were estimated to be $75.5 billion for 1998 (CDC 2002), and $96 billion for 2004 (CDC 2008). Updated estimates for the United States in 2009 were produced based on this approach, using expenditure SAFs for 2004 (CDC n.d.). Expenditures for persons 19 years of age and younger were excluded using 2004 age-specific expenditure data published by CMS (2012a). Updated overall and category-specific expenditure estimates are presented in Table 12.12. Overall, an estimated $132.5 billion of health care expenditures in adults 19 years of age and older were attributable to smoking in 2009, an approximate 38% increase over the 2004 figure. This accounts for 7.6% of all health care expenditures (excluding dental expenditures) in adults ages 19 years and older, consistent with the 6–8% range reported by Warner and colleagues (1999). This figure excludes costs attributable to exposure to secondhand smoke.

Table 12.12 Aggregate health care expenditures attributable to cigarette smoking by type of service among adults, 19 years of age and older, United States, 2009

Type of service	Smoking attributable fraction (%)[a]	Expenditures ($ in billions)
Hospitals	10.3	67.0
Ambulatory care	4.9	21.0
Nursing home care	7.9	10.6
Prescription drugs	9.5	25.5
Other services[b]	3.3	8.2
Total	7.6	132.5[c]

Source: Centers for Disease Control and Prevention, National Center for Chronic Disease Prevention and Health Promotion, Office on Smoking and Health, unpublished data.
Note: Based on the approach by Miller and colleagues 1999. Expenses are presented in 2009 dollars.
[a]Smoking-attributable fractions for 2004 in the United States are available at https://apps.nccd.cdc.gov/sammec/exp_comp.asp.
[b]Other expenditures include home health care, durable and nondurable medical equipment, and other professional services.
[c]Sum of individual categories does not equal the total due to rounding.

Smoking-Attributable Health Care Expenditures by Age and Gender

This approach, using the latest evidence-based RRs of smoking-related disease events, presents an option to distribute smoking-attributable health care expenditures by age, gender, and smoking status. The major advantage of this approach is that it can create estimates closely reflecting the known epidemiologic risks of smoking and benefits of cessation by age and gender. In this approach, per capita health care expenditures by smoking status are first estimated based on the projected 2012 per capita personal health care expenditures for 19 years of age and older from CMS (2012b) and relative cost ratios of health care expenditures for current and former smokers compared to never smokers. These cost ratios are calculated from per-person relative health care costs by smoking status reported by Musich and colleagues (2003). In that study, costs were calculated controlling for age, gender, and the presence of chronic diseases (Musich et al. 2003). With the estimated per capita health care expenditures by smoking status, the national smoking-attributable health care expenditures and expenditure SAFs can be obtained using national prevalence figures for current, former, and never smokers. The national smoking-attributable health care expenditures are then apportioned by age and gender group according to the distribution of hospitalization days for smoking-related diseases.

Specifically, for each smoking-related disease *h*, age group *i*, and gender *j*, hospitalization days are distributed by smoking status using algebraic manipulation of the formula:

$$DAYST_{h,i,j} = \sum_{k \varepsilon S} DAYSN_{h,i,j,k} * RR_{h,i,j,k}$$

where DAYST and DAYSN are the number of hospitalization days for all smokers, including both current and former smokers, and never smokers, respectively, and the smoking status *s* is defined by three values for *k* representing never, current, and former smokers. $RR_{h,i,j,k}$ is the RR of hospitalization for smoking status *k*, age group *i,* and gender *j* relative to never smokers from the same demographic group (RR = 1.0 for never smokers). After solving for DAYSN, RRs are used to calculate days of hospitalization for current and former smokers. The portion of days across all smoking-related diseases for each age, gender, and smoking status group ($PD_{i,j,k}$) is then:

$$PD_{i,j,k} = \frac{\Sigma_h DAYSN_{h,i,j,k} * RR_{h,i,j,k}}{\Sigma_h \Sigma k \varepsilon s \; DAYSN_{h,i,j,k} * RR_{h,i,j,k}}$$

In practice, the RR for hospitalizations is replaced by the proxy, the RR of mortality. Finally, the resulting proportions can be applied along with estimates of smoking prevalence and national smoking-attributable health care expenditures to estimate the distribution of expenditures by age, gender, and smoking status that reflect relative disease risk.

The number of hospitalization days comes from the 2010 National Hospital Discharge Survey. Hospitalization days are weighted to a nationally representative sample and standard errors on counts and percentages are tabulated using the generalized variance curves provided by the National Hospital Discharge Survey (NHDS) in the public use data set. The prevalence figures for current smokers, former smoker and never smokers are estimated from the 2012 NHIS.

Results from this approach suggest that smoking accounted for 8.66% of total annual health care expenditures in the United States in 2012. The projected personal health care expenditure is $2,031.2 billion in 2013, after excluding dental expenditures and expenditures for persons 19 years of age or younger based on 2004 age specific expenditure data published by CMS (2012a,b). Consequently, the smoking-attributable health care expenditure in 2013 is estimated around $175.9 billion. Of the total, $94.2 billion was contributed by current smokers and $81.7 billion was contributed by former smokers. Table 12.13 presents smoking-attributable health care expenditures by age and gender.

Smoking-Attributable Health Care Expenditures by Source of Funds

This regression approach is based on a two-part model to calibrate the impact of smoking independently from the impact of other factors that are correlated with smoking and may affect health care expenditures. The data used in the analysis come from the MEPS. The MEPS is a nationally representative survey of the civilian noninstitutionalized U.S. population that provides detailed information on health care use and medical expenditures. MEPS respondents can be directly linked to the NHIS, as they are drawn from the NHIS household samples within the preceding 2 years. The NHIS, designed to be a major source of information on the health of the civilian noninstitutionalized U.S. population, collects detailed smoking history information from respondents. Therefore, respondents' smoking status in the analysis comes from the NHIS. The final data set contains approximately 41,000 observations from the 2006–2010 MEPS that are linked to the 2004–2009 NHIS.

The two-part model, a standard statistical technique for analyzing health care spending data (Finkelstein et

Table 12.13 Aggregate health care expenditures ($ in billions) attributable to cigarette smoking among adults, 35 years of age and older, by age group and gender, United States, 2012

	Former smokers			Current smokers			Total
Age group	Males	Females	Subtotal	Males	Females	Subtotal	
35–44 years	0.5	0.3	0.8	3.0	2.4	5.4	6.2
45–54 years	2.9	1.1	4.0	10.7	8.8	19.4	23.4
55–64 years	8.6	5.5	14.1	17.4	12.8	30.2	44.3
65–74 years	15.4	11.2	26.7	15.0	10.0	25.0	51.7
≥75 years	18.6	17.6	36.2	5.9	8.3	14.2	50.4
All ages	46.0	35.7	81.7	52.0	42.2	94.2	175.9

Source: Centers for Disease Control and Prevention, National Center for Chronic Disease Prevention and Health Promotion, Office on Smoking and Health, unpublished data.
Note: Based on the approach by Solberg and colleagues 2006. Expenditures presented in 2013 dollars. Since relative risks of mortality of smoking-related diseases do not differ by smoking status for those between 19 and 34 years of age, the approach assigns no smoking-attributable health care expenditures to that particular age group.

al. 2009; CBO 2012), separately estimates the probability of having any medical expenditure in the first part and then estimates annual medical expenditure conditional on having positive expenditures in the second part. The estimates from each part are then combined to estimate annual smoking-attributable health care expenditures.

In each component of the model, health care expenditures excluding dental are considered as a function of the respondent's smoking status and individual sociodemographic and health characteristics. Each respondent in the analysis was categorized as a current smoker, a recent quitter (quit smoking within the last 5 years), a long-term quitter (quit smoking for more than 5 years), or a never smoker. Studies have found that former smokers, and particularly recent quitters, might have higher expenditures than continuing smokers (Fishman et al. 2003, 2006; Hockenberry et al. 2012), as quits are often prompted by symptoms of disease that continue to cause care utilization in the years following quitting. This issue has been addressed in different ways in the existing literature, by excluding recent quitters (Solberg et al. 2006), categorizing recent quitters as current smokers (Sloan et al. 2004; Jha et al. 2013), or mathematically smoothing over expenditure increases in the period after successfully quitting in a way that effectively excludes recent quitters from the analysis of spending (CBO 2012). This analysis includes an independent group of recent quitters to address this issue.

In order to account for differences in sociodemographic and health characteristics by smoking status, all of the regressions included controls for age (18–24 years of age, 25–44 years of age, 45–64 years of age, 65–74 years of age, and 75 years of age and older), gender, race/ethnicity (Whites, Blacks, Hispanics, Others), education (less than high school, high school, some college, college and above), marital status (married or cohabitating, never married, not cohabitating, divorced/separated/widowed), family income as percent of federal poverty level (<100%, 100–124%, 125–200%, 200–399%, 400% and above), indicators of alcohol consumption (excessive drinkers, nonexcessive drinkers, and nonusers), indicators of body weight (underweight, normal weight, overweight, and obese), an indicator of health insurance coverage (when applicable), the receipt of flu shots, use of seatbelt, taking more risks than average person, and belief in own ability to overcome illness without medical help (yes vs. no), and geographic location (four census regions), and the year fixed effect.

A linear probability model was used for the first part. Based on the specification tests, a generalized linear model with a log link and gamma distribution was used in the second part (Manning and Mullahy 2001). In addition to the total health care expenditure, separate two-part models were also performed by source of fund (out-of-pocket, private, Medicaid, and Medicare, other federal, and others). In all analyses, bootstrapped standard errors were obtained.

Smoking-attributable fractions of health care expenditures are estimated using the following formula:

$$SAFE_{ij} = \frac{EXPS_{ij} - EXPNS_i}{EXPNS_i}$$

where $EXPS_{ij}$ is the predicted level of expenditures given individual *i*'s smoking status *j* (current smokers, recent quitters, or long term quitters), whereas $EXPNS_i$ is the predicted level of expenditures if individual *i* had never been a smoker and $SAFE_{ij}$ represents the various attributable fractions. Specifically, using the estimated model, each individual's $EXPS_{ij}$ is obtained as the product of the predicted probability of having an expenditure given the smoking status and the predicted expenditure conditional on the expenditure being positive. The calculation for $EXPNS_i$ is the same except that the smoking indicator is set to never smoking. The $SAFE_{ij}$ of the population is obtained by averaging over the population for each current or former smoker.

One limitation, however, is that the MEPS expenditure estimates have been shown to be 38% lower than comparable estimates from the Personal Health Care Expenditures reported by CMS, since the MEPS sample is limited to noninstitutionalized civilians and it does not include costs for some services such as long-term care stays longer than 45 days (Sing et al. 2006).

Therefore, the annual expenditures presented are estimated based on the 2010 National Health Expenditures by health insurance enrollment from CMS (2012b) and SAFs by source of fund estimated from the MEPS. Specifically, these expenditures are calculated as the product of SAFs estimated via MEPS by total health care expenditures for the corresponding category reported.

The estimates from the NHIS-linked MEPS data suggest that 8.7% of total health care expenditure was attributable to cigarette smoking between 2006–2010. Based on the 2010 Personal Health Care Expenditures report by CMS, smoking contributed to more than $170 billion in health care expenditures in total (Table 12.14). In particular, roughly 3.4% of out-of-pocket health care expenditure (approximately $8.5 billion), 4.4% of private health insurance expenditure (approximately $33.7 billion), 15.2% of Medicaid expenditure (approximately $40.1) billion, or 9.6% of Medicare expenditure (approximately $45 billion) was smoking attributable. In other words, more than 60% of annual health care expenditures associated with smoking in the United States were reimbursed by public funds, either Medicaid, Medicare, or other federal funds.

Table 12.14 Smoking-attributable fraction (SAF) and aggregate health care expenditures attributable to cigarette smoking by source of fund, National Health Expenditure Accounts (NHEA), United States, 2010

	SAF (%)		Expense ($ in billions)	
Source of fund	**Estimated SAF**	**95% CI**	**NHEA**	**95% CI**
Self-paid	3.4	0.6–6.0	8.5	1.5–15.2
Private insurance	5.4	1.0–9.9	33.7	6.4–61.3
Medicaid	15.2	6.2–27.4	40.1	16.7–66.3
Medicare	9.6	4.4–15.6	45.0	20.5–73.1
Other federal	32.8	21.3–46.3	24.5	15.9–34.6
Others	11.8	0.0–23.9	17.9	0.0–36.2
Total	8.7	5.1–12.6	170.6	92.9–228.2

Source: Xu et al., in press.
Note: Expenditures presented in 2010 dollars. Expenditures associated with dental services are excluded from the total national health expenditures by source of fund. Expenditures for persons under 19 years of age were also excluded using 2004 age-specific expenditure data published by the Centers for Medicare & Medicaid Services. The sum of individual categories does not equal the total due to rounding. **CI** = confidence interval.

Synthesis of Findings

In the preceding sections, smoking-attributable health care expenditures have been estimated based on three different approaches providing a range of figures. None of the total smoking-attributable health care expenditures estimated from these approaches is dependent on a list of specific smoking-attributable conditions. Annual smoking-attributable estimated health care expenditures are between $132.5 billion in 2009 to $175.9 billion in 2013. These estimates are far higher than the $95.9 billion estimate for 2004 by CDC (2008). In comparison, if the CDC estimate for 2004 had been simply adjusted using the Consumer Price Index (all items and medical care-specific) to 2012, the resulting estimates would have been $116.56 billion (all items) or $128.32 billion (medical care-specific).

These estimated attributable expenditures also suggest that smoking has accounted for approximately 7–9% of total annual health care spending in the United States during recent years. In addition to total smoking-attributable health care expenditures, each approach provides specific estimates for different subpopulations in the United States. Results in Table 12.13 suggest that annual attributable health care expenditures may vary by age, from $6.2 billion for those between 35–44 years of age to approximately $50 billion for both those between 65–74 years of age and those 75 years of age and above, while estimates in Table 12.14 imply that more than 60% of the attributable health care expenditures are likely paid by public funds. Based on expenditure SAFs in the SAMMEC, Table 12.12 indicates that smoking contributes $67 billion in expenditures for hospitals, $21 billion in ambulatory care, $10.6 billion in nursing home care, $25.5 billion in prescription drugs, and $8.2 billion in other services.

These three approaches each have their own limitations. The updated SAMMEC approach depends on SAFs for expenditures estimated in 2004 and the data used for the estimation comes from the 2000–2004 MEPS. These attributable fractions are likely outdated and thus may cause an underestimation of smoking-attributable health care expenditures.

Although the second approach originated by Solberg and colleagues (2006) can closely reflect the known epidemiologic risks of smoking and the benefits of cessation by age and gender, the estimated attributable expenditures depend on the relative cost ratios of health care expenditures for current and former smokers compared to never smokers. In addition, the use of mortality RRs as a proxy for the RR of hospitalizations implicitly assumes that the event-fatality rate is constant across smoking status. If instead, for example, current smokers have a lower event-fatality rate than former smokers for a particular smoking-related disease, then the RRs of death for former smokers compared to current smokers would be higher than the RR of events. Consequently, the calculations might overestimate the economic benefits of quitting. Second, if there are differences in case-events by smoking status and those differences are not constant with respect to age, then the distribution of expenditures by age group could also be impacted by using mortality RRs as a proxy. Differences in disease cases by smoking status have not been systematically studied in detail and, therefore, it is difficult to predict the direction and extent of any biases introduced to those estimates.

Finally, although a two-part model is commonly used to model health expenditures, the robustness of the estimates depends on the extent to which all of the factors of health care spending and mortality are accounted for. For example, in an analysis using a similar approach, the CBO (2012) concluded that differences in demographic characteristics account for $130 (12%) of the gap in annual expenditures between current or former smokers and nonsmokers who otherwise resemble smokers in the 45–64 age group, $380 (26%) of the gap in the 65–74 age group, and $460 (26%) of the gap in the 75-and-over age group. In the regression approach, an extensive set of factors are included, in addition to the regional fixed effects. After controlling for similar factors, Jha and colleagues (2013) concluded that additional adjustments did not materially affect their estimated smoking impacts on hazard ratios of mortality. This finding provides indirect evidence to support the specification used in the analysis.

Summary

The estimated SAFs of health care expenditures from all three approaches (7.6%, 8.7%, and 8.7%) are within the range of findings from existing cross-sectional studies which extend from 6.54% in Miller and colleagues (1999) to 14% in Warner and colleagues (1999). Particularly, these estimates are very close to the most recent estimated SAFs reported in the CBO's report (2012), which concluded that 7% of total annual spending on health care in the United States between 2002–2008 was attributable to cigarette smoking. Thus, the various estimates, coming from different data sets and methodologies, are consistent in showing that smoking has continued to cause a significant portion of health care expenditures in the United States.

Total Smoking-Attributable Mortality, 1965–2014

Table 12.15 provides the estimated smoking-attributable mortality for the period 1965–2014. The 2004 Surgeon General's report provided an estimated cumulative total for SAM for 1965–1999 (USDHHS 2004, Chapter 7 and Appendix). The total SAM estimates for 1965–1999 were derived from annual population-attributable risk estimates for the period beginning with the publication of the first Surgeon General's report on the health consequences of smoking in 1964.

Specific details on the methodology used to compute the population-attributable risk estimates for 1965–1999 were provided in the 2004 Surgeon General's report (USDHHS 2004, Chapter 7 and Appendix). Deaths from cigar smoking, pipe smoking, and smokeless tobacco use were not included in these estimates, nor were deaths from fires and exposure to secondhand smoke for the period of 1965–1999. The mortality RR estimates for the 19 disease categories among adults causally associated with smoking were obtained from data from CPS-I and CPS-II: CPS-I data (1959–1965) were used for 1965–1971; CPS-II data (1982–1988) for 1982–1999; and the midpoint RRs between CPS-I and CPS-II were used for 1972–1981.

The average annual SAM estimates for the United States from 2000–2004 have been published (CDC 2008) and briefly described above. For the period 2000–2004, CDC estimated the annual SAM for 19 disease categories based on the mortality RR estimates from CPS-II (1982–1988). Annual estimates of smoking-attributable premature deaths for four health outcomes in infants, deaths from residential fires caused by smoking, and deaths from lung cancer and CHD attributed to exposure to secondhand smoke also were published (CDC 2008).

The 2013 update to SAMMEC methodology was discussed earlier in this chapter. Estimates for 2005–2009 for men and women are shown in Tables 12.5 and 12.6. Updated estimates of infant deaths and deaths attributable to exposure to secondhand smoke for 2005–2009 are shown in Tables 12.8 and 12.9. The average annual SAM for the United States for 2005–2009 are provided in Table 12.7.

From 1965–2009, smoking caused an estimated 5.8 million cancer deaths, 7.0 million cardiovascular and metabolic disease deaths, 3.2 million respiratory disease deaths, and 103,355 infant deaths (Table 12.15). Since

Table 12.15 Smoking-attributable mortality,[a] total and by gender, United States, 1965–2014

	Males				Females				Total				Total	Total
Disease	**1965–1999**	**2000–2004**	**2005–2009**	**2010–2014**	**1965–1999**	**2000–2004**	**2005–2009**	**2010–2014**	**1965–1999**	**2000–2004**	**2005–2009**	**2010–2014**	**1965–2009**	**1965–2014**
Lung cancer	2,286,800	393,400	371,500	371,500	812,000	234,210	267,000	267,000	3,099,000	627,610	638,500	638,500	4,365,110	5,004,000
Other cancers[b]	804,800	128,960	130,000	130,000	241,500	47,670	50,000	50,000	1,046,400	176,630	180,000	180,000	1,403,030	1,583,000
Total—Cancers	**3,091,600**	**522,360**	**501,500**	**501,500**	**1,053,700**	**281,880**	**317,000**	**317,000**	**4,145,400**	**804,240**	**818,500**	**818,500**	**5,768,140**	**6,587,000**
Coronary heart disease	2,517,200	254,420	309,000	309,000	981,800	145,610	187,500	187,500	3,499,000	400,030	496,500	496,500	4,395,530	4,892,000
Other cardiovascular disease[c]	1,336,000	141,280	169,000	169,000	704,000	101,190	137,500	137,500	2,040,000	242,460	306,500	306,500	2,588,960	2,895,000
Total—Cardiovascular and metabolic diseases	**3,853,200**	**395,700**	**478,000**	**478,000**	**1,685,800**	**246,790**	**325,000**	**325,000**	**5,539,000**	**642,490**	**803,000**	**803,000**	**6,984,490**	**7,787,000**
Total—Pulmonary diseases[d]	**1,440,700**	**268,980**	**291,000**	**291,000**	**715,800**	**247,720**	**274,500**	**274,500**	**2,156,500**	**516,690**	**565,500**	**565,500**	**3,238,690**	**3,804,000**
Total—Cancers, cardiovascular and metabolic diseases, pulmonary diseases	**8,385,500**	**1,187,030**	**1,270,500**	**1,270,500**	**3,455,300**	**776,390**	**916,500**	**916,500**	**11,840,900**	**1,963,420**	**2,187,000**	**2,187,000**	**15,991,320**	**18,178,000**
Perinatal conditions[e]	**54,200**	**2,230**	**2,910**	**2,910**	**40,200**	**1,660**	**2,160**	**2,160**	**94,400**	**3,880**	**5,080**	**5,080**	**103,360**	**108,000**
Residential fires[f]	**41,930**	**2,080**	**1,680[f]**	**1,680[f]**	**33,820**	**1,600**	**1,420[f]**	**1,420[f]**	**75,750**	**3,680**	**3,100**	**3,100**	**82,530**	**86,000**
Secondhand smoke														
Lung cancer	74,590	10,660	21,870	21,870	44,410	6,350	14,800	14,800	172,670	17,000	36,670	36,670	172,670	263,000
Coronary heart disease	779,100	146,280	95,760	95,760	445,900	83,720	74,000	74,000	1,624,760	230,000	169,760	169,760	1,624,760	2,194,000
Total—Secondhand smoke	**853,690**	**156,940**	**117,630**	**117,630**	**490,310**	**90,060**	**88,790**	**88,790**	**1,797,420**	**247,000**	**206,420**	**206,420**	**1,797,420**	**2,457,000**
TOTAL—Attributable deaths	**8,439,700**	**1,348,280**	**1,407,840**	**1,407,840**	**3,495,500**	**869,700**	**1,021,650**	**1,021,650**	**13,808,470**	**2,217,980**	**2,401,600**	**2,401,600**	**17,974,620**	**20,830,000**

Source: Centers for Disease Control and Prevention, National Center for Chronic Disease Prevention and Health Promotion, Office on Smoking and Health, unpublished data.

Note: **CPS** = Cancer Prevention Study; **ICD** = International Classification of Diseases; **RR** = relative risk; **SAM** = smoking-attributable mortality. SAM calculated using RRs from CPS-II; gender- and age-specific (35–64, ≥65 years of age) RRs and smoking status (current, former) prevalence used for estimates. SAM calculated using RRs from CPS-II for adults 35–54 years of age and RRs from contemporary cohorts (Thun et al. 2013) for adults 55 years of age and older; gender- and age-specific (35–54, 55–64, 65–74, ≥75 years of age) RRs and smoking status (current, former) used for estimates. All-cause SAM not computed.

[a]Row and column totals may not add up exactly due to rounding.

[b]Other cancers comprised of cancers of the lip, pharynx and oral cavity, esophagus, stomach, pancreas, larynx, cervix uteri (women), kidney and renal pelvis, bladder and acute myeloid leukemia. Data for 2005–2009 also include cancers of liver and of colon and rectum.

[c]Other cardiovascular disease comprised of other heart disease cardiovascular disease, atherosclerosis, aortic aneurysm, and other arterial diseases. Data for 2005–2009 also include diabetes mellitus.

[d]Pulmonary diseases consists of pneumonia, influenza, emphysema, bronchitis and chronic airways obstruction. Data for 2005–2009 also includes tuberculosis.

[e]Prenatal conditions comprised of ICD-10 codes: K550, P000, P010, P011, P015, P020, P021, P027, P070–P073, P102, P220–229, P250–P279, P280, P281, P360–P369, P520–P523, and P77 (Dietz et al. 2010).

[f]Based on average annual deaths, 2006–2010, reported by Hall 2012.

1980, there have been an estimated 32,530 smoking-attributable residential fire-related deaths (Figure 12.3). Since Hall (2012) reports that smoking-material fires dropped by more than one-half when smoke detectors became more widely used in the late 1970s, it can be conservatively estimated that the number of residential fire deaths from 1965–1979 was at least 50,000 (e.g., 2,000 per year). Thus, for the period 1965–2009, the total number of smoking-attributable residential fire-related deaths can be estimated to be about 82,530 (50,000 + 32,530). Deaths attributable to exposure to secondhand smoke have not been estimated for 1965–1990; however, since 1990 the total number of deaths attributable to exposure to secondhand smoke is estimated to be about 3,400 annually for lung cancer and 35,000 for CHD (Steenland 1992; USEPA 1992; CDC 2005, 2008). Since exposures to secondhand smoke were much higher in nonsmokers in earlier decades (USDHHS 2006), it can be estimated that the deaths attributable to exposure to secondhand smoke back to 1965 could be estimated to be about at similar rates for the 35-year period (1965–1999). Thus, for the period 1965–2009, the total number of premature deaths attributable to exposure to secondhand smoke can be estimated to be about 1.8 million. Hence, for 1965–2009, the total estimated deaths attributable to smoking and exposure to secondhand smoke was about 18.0 million.

From 2010–2014, the number of deaths caused by smoking and exposure to secondhand smoke is estimated to continue at levels similar to that from 2005–2009—namely, about 480,000 per year. Therefore, the estimated total for the years 2010–2014 would be approximately 2.4 million additional deaths caused by smoking and exposure to secondhand smoke, and the total estimate for the 50-year period, from 1965–2014, would be approximately 20.4 million deaths caused by smoking and exposure to secondhand smoke.

Summary

Cigarette smoking remains the single leading cause of preventable mortality in the United States and causes a high morbidity burden. The costs of health care are substantial. This chapter reviewed various methods for assessing the disease burden of smoking-related illnesses, including epidemiologic calculations, indirect estimates, and model-based approaches for assessing SAM. These estimates are not strongly biased by potential confounding factors, even though smokers and nonsmokers tend to have different profiles for a number of lifestyle-related risk factors for disease. Economic disease burden estimates assess the costs of smoking to governments and society in general. Both types of assessments provide compelling evidence that programs and policies are needed to continue the progress toward ending the tobacco epidemic.

Conclusions

1. Since the first Surgeon General's report on smoking and health in 1964, there have been more than 20 million premature deaths attributable to smoking and exposure to secondhand smoke. Smoking remains the leading preventable cause of premature death in the United States.

2. Despite declines in the prevalence of current smoking, the annual burden of smoking-attributable mortality in the United States has remained above 400,000 for more than a decade and currently is estimated to be about 480,000, with millions more living with smoking-related diseases.

3. Due to the slow decline in the prevalence of current smoking, the annual burden of smoking-attributable mortality can be expected to remain at high levels for decades into the future, with 5.6 million youth currently 0 to 17 years of age projected to die prematurely from a smoking-related illness.

4. Annual smoking-attributable economic costs in the United States estimated for the years 2009–2012 were between $289–332.5 billion, including $132.5–175.9 billion for direct medical care of adults, $151 billion for lost productivity due to premature death estimated from 2005–2009, and $5.6 billion (in 2006) for lost productivity due to exposure to secondhand smoke.

Implications

Estimates of the attributable burden of disease from smoking have value for policy formulation and decision-making. They may be useful for motivating action and for assigning priorities. For smoking, the enormity of the estimates is a powerful impetus for action. In addition, economic cost-of-illness studies on tobacco-related diseases can help inform policymakers about the economic benefits of supporting comprehensive tobacco use prevention and control programs, and implementing effective policies and regulations to reduce tobacco use in the United States. The estimates of expenditures are essential for cost-effectiveness and cost-benefit analyses. Uniformly, such analyses provide a strong basis for implementing effective tobacco control strategies. Additionally, these estimates may be useful in estimating SAM in other countries (Appendix 12.1).

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Appended Table 12.2 Annual prevalence of current smoking and former smoking among adults, 35 years of age and older, for selected years; NHIS, United States, 1965–2011

A. Men

Year	35–54 years of age: % CS	35–54 years of age: % FS	55–64 years of age: % CS	55–64 years of age: % FS	65–74 years of age: % CS	65–74 years of age: % FS	75 years of age and older: % CS	75 years of age and older: % FS
1965	57.1	21.2	46.6	27.1	33.1	30.1	19.3	24.2
1970	48.7	28.6	41.1	34.9	27.1	41.5	15.7	36.3
1974	48.8	30.2	37.7	40.0	29.2	43.0	15.9	38.7
1977	46.5	29.5	37.0	36.4	26.7	44.6	15.9	41.6
1980	42.7	30.9	38.5	39.4	22.2	48.0	9.0	46.3
1983	40.1	30.7	32.6	45.4	26.7	46.6	12.2	51.2
1985	36.5	34.2	31.9	47.2	21.9	53.2	15.0	51.1
1987	35.4	32.2	30.3	45.2	20.6	55.1	11.4	52.4
1988	35.6	30.9	28.0	48.4	21.4	53.9	11.4	54.5
1990	33.5	31.8	25.9	45.8	18.3	53.0	7.6	59.5
1992	34.0	31.1	25.4	45.7	19.6	53.1	10.7	52.0
1994	32.2	30.7	24.7	47.5	16.1	57.1	8.4	60.3
1995	29.7	28.1	26.9	43.3	18.1	51.5	9.6	55.2
1997[a]	31.1	26.1	24.1	45.2	16.2	56.1	7.7	56.4
1998	30.1	25.9	24.2	44.4	13.3	58.2	6.2	59.0
1999	29.1	25.2	22.3	44.8	12.6	57.8	7.5	58.1
2000	29.6	22.1	22.6	45.0	13.7	53.9	5.4	58.6
2001	27.5	23.5	24.2	44.1	14.5	55.6	7.4	55.8
2002	28.4	23.5	20.7	44.3	12.4	55.1	7.0	58.3
2003	27.0	22.1	21.2	41.8	13.3	52.8	5.9	54.1
2004	26.6	21.1	22.7	40.3	12.8	52.7	5.9	55.5
2005	27.0	19.8	21.1	41.7	11.4	52.5	5.7	56.8
2006	25.7	20.7	21.5	41.1	17.4	45.4	6.2	59.0
2007	24.0	20.6	19.6	38.6	12.5	51.8	5.1	58.3
2008	25.4	20.8	22.6	34.5	14.6	51.3	5.1	59.0
2009	26.4	20.3	20.8	40.3	12.5	52.5	5.5	56.2
2010	23.9	21.7	20.7	35.6	12.6	50.4	5.5	55.5
2011	24.2	20.5	21.4	36.1	11.7	49.9	5.0	54.9

Appended Table 12.2 Continued

B. Women

Year	35–54 years of age: % CS	35–54 years of age: % FS	55–64 years of age: % CS	55–64 years of age: % FS	65–74 years of age: % CS	65–74 years of age: % FS	75 years of age and older: % CS	75 years of age and older: %FS
1965	40.8	9.4	25.0	7.6	12.4	5.1	4.5	3.6
1970	37.9	13.3	28.5	12.1	14.4	9.0	5.6	5.5
1974	37.9	14.1	30.4	16.0	16.0	12.5	5.8	7.6
1977	37.5	14.9	32.4	16.0	17.5	13.4	6.6	10.2
1980	34.3	17.9	27.9	17.6	21.8	17.6	8.9	8.8
1983	33.9	17.2	28.0	19.7	17.6	22.6	6.3	12.8
1985	31.9	20.1	27.4	22.2	17.9	23.5	7.0	17.9
1987	30.2	19.8	25.6	23.6	18.9	21.4	7.2	14.8
1988	28.3	21.0	26.2	24.4	16.7	23.8	7.3	16.3
1990	26.3	22.1	20.5	24.3	15.6	25.9	5.8	19.6
1992	27.8	20.9	22.6	23.9	14.9	23.3	7.5	24.2
1994	25.8	21.7	20.7	29.5	13.4	30.9	8.2	21.7
1995	25.9	21.2	23.7	24.4	14.4	29.7	7.9	23.1
1997[a]	25.4	20.6	19.0	27.6	15.3	28.3	7.0	22.9
1998	25.4	19.6	20.1	26.7	15.3	30.3	6.5	23.3
1999	25.0	19.4	17.7	29.5	14.0	29.6	7.1	25.9
2000	24.4	19.8	20.8	28.3	12.2	28.8	6.2	23.8
2001	24.2	18.2	19.8	27.2	12.8	28.6	5.3	25.6
2002	23.2	18.7	18.8	28.1	11.4	31.2	5.8	25.7
2003	22.9	17.6	18.2	26.4	11.0	32.4	5.6	27.9
2004	21.2	18.2	18.6	26.1	11.2	28.9	5.0	28.3
2005	21.1	17.5	16.1	26.5	10.8	30.2	5.9	26.7
2006	21.5	16.9	14.9	26.1	11.2	29.8	5.4	25.9
2007	20.9	17.0	16.2	25.1	11.9	30.2	3.2	26.0
2008	22.3	18.2	16.3	24.7	10.5	31.6	6.1	29.8
2009	21.7	16.7	16.1	26.6	12.5	33.1	6.3	25.8
2010	20.2	16.6	16.5	25.2	13.3	30.2	4.8	28.4
2011	20.8	17.0	15.0	25.5	9.9	34.6	4.0	30.6

Sources: National Center for Health Statistics, public use data sets, 1965, 1970, 1974, 1977, 1980, 1983, 1985, 1987–1988, 1990, 1992, 1994–1995, 1997–2011. The NHIS sample is representative of the civilian, noninstitutionalized population of the United States.
Notes: **CS** = Current smokers, defined as having smoked at least 100 cigarettes and currently smoking every day or some days (the some days condition was added in 1992); **FS** = former smokers, defined as having smoked at least 100 cigarettes but not currently smoking; **NHIS** = National Health Interview Survey.
[a]A questionnaire redesign of NHIS was implemented in 1997. Data preceding this year may not be directly comparable with data from 1997 and later.

Appended Table 12.3 Relative risks by smoking status and age group, adults 35 years of age and older, United States

A. Males

	Current smokers (years of age)				Former smokers (years of age)			
	35–54[a]	**55–64[b]**	**65–74[b]**	**≥75[b]**	**35–54[a]**	**55–64[b]**	**65–74[b]**	**≥75[b]**
Lung cancer	14.33	19.03	28.29	22.51	4.40	4.57	7.79	6.46
Other cancers[c]	1.74	1.86	2.35	2.18	1.36	1.31	1.49	1.46
Coronary heart disease	3.88	2.99	2.76	1.98	1.83	1.52	1.58	1.32
Other heart disease[d]			2.22	1.66			1.32	1.15
Cerebrovascular disease			2.17	1.48			1.23	1.12
Other vascular diseases[e]			7.25	4.93			2.20	1.72
Diabetes mellitus			1.50	1.00			1.53	1.06
Other cardiovascular diseases[f]	2.40	2.51			1.07	1.51		
Influenza, pneumonia, tuberculosis			2.58	1.62			1.62	1.42
Chronic obstructive pulmonary disease[g]			29.69	23.01			8.13	6.55
Influenza, pneumonia, tuberculosis, chronic obstructive pulmonary disease[h]	4.47	15.17			2.22	3.98		
All causes	2.55	2.97	3.02	2.40	1.33	1.47	1.57	1.41

B. Females

	Current smokers (years of age)				Former smokers (years of age)			
	35–54[a]	**55–64[b]**	**65–74[b]**	**≥75[b]**	**35–54[a]**	**55–64[b]**	**65–74[b]**	**≥75[b]**
Lung cancer	13.30	18.95	23.65	23.08	2.64	5.00	6.80	6.38
Other cancers[c]	1.28	2.08	2.06	1.93	1.24	1.28	1.26	1.27
Coronary heart disease	4.98	3.25	3.29	2.25	2.23	1.21	1.56	1.42
Other heart disease			1.85	1.75			1.29	1.32
Cerebrovascular disease			2.27	1.70			1.24	1.10
Other vascular diseases*[e]			6.81	5.77			2.26	2.02
Diabetes mellitus			1.54	1.10			1.29	1.06
Other cardiovascular diseases[f]	2.44	1.98			1.00	1.10		
Influenza, pneumonia, tuberculosis			1.75	2.06			1.28	1.21
Chronic obstructive pulmonary disease[g]			38.89	20.96			15.72	7.06
Influenza, pneumonia, tuberculosis, chronic obstructive pulmonary disease[h]	6.43	9.00			1.85	4.84		
All causes	1.79	2.63	2.87	2.47	1.22	1.34	1.53	1.43

Source: Analyses of Cancer Prevention Study II (CPS-II) and updated analyses of the pooled contemporary cohort population described in Thun et al. 2013 provided to the Centers for Disease Control and Prevention, National Center for Chronic Disease Prevention and Health Promotion, Office on Smoking and Health.

[a]Relative risks for 35–54 years of age, obtained from Cancer Prevention Study.

[b]Relative risks for 54–65 years of age, 65–74 years of age, and 75 years of age and older, obtained from merged contemporary cohorts (Thun et al 2012). Relative risks for women 55 years of age and older in diseases marked with * do not include data from the NHLBI Women's Health Initiative.

[c]Other cancers consist of cancers of the lip, pharynx and oral cavity, esophagus, stomach, pancreas, larynx, cervix uteri (women), kidney and renal pelvis, bladder, liver, colon and rectum, and acute myeloid leukemia.

[d]Other heart disease comprised of rheumatic heart disease, pulmonary heart disease, and other forms of heart disease.

[e]Other vascular diseases are comprised of atherosclerosis, aortic aneurysm, and other arterial diseases.

Appended Table 12.3 Continued

[f]For 35–54 years of age and ages 55–64 years of age, other cardiovascular diseases are comprised of other heart disease, cerebrovascular disease, other vascular diseases, and diabetes mellitus, analyzed and reported as category. A single relative risk based on combined conditions used to compute smoking-attributable mortality. Relative risk based on combined conditions used to compute smoking-attributable mortality in these age strata.
[g]Chronic obstructive pulmonary disease comprised of bronchitis, emphysema, and chronic airways obstruction.
[h]For 35–54 years of age and 55–64 years of age, influenza, pneumonia, tuberculosis, and chronic obstructive pulmonary disease analyzed and reported as 1 category. A single relative risk based on combined conditions was used to compute smoking attributable mortality.

Table 12.5 Average annual smoking-attributable mortality (SAM) for males 35 years of age and older, total and by age group, United States, 2005–2009

Disease	35–54 years of age		55–64 years of age		35–64 years of age: Total[a]		65–74 years of age		≥75 years of age		65 years of age and older: Total[a]		≥35 years of age : Total[a]	
	Deaths	SAM	Deaths	SAM	Deaths	SAM	Deaths	SAM	Deaths	SAM	Deaths	SAM	Deaths	SAM
Lung cancer	8,020	6,500	18,440	15,500	26,470	21,900	27,740	24,300	34,530	28,100	62,260	52,400	88,730	74,300
Other cancers[b]	13,370	2,800	22,540	5,400	35,900	8,200	26,380	7,900	40,660	10,300	67,040	18,200	102,940	26,000
Total—Cancers	**21,390**	**9,300**	**40,980**	**20,900**	**62,370**	**30,100**	**54,120**	**32,200**	**75,190**	**38,400**	**129,310**	**70,600**	**191,670**	**100,300**
Coronary heart disease	23,250	11,100	33,550	12,900	56,800	24,000	42,100	14,600	120,010	23,200	162,080	37,800	218,870	61,800
Other cardiovascular disease[c]	18,900	5,100	23,230	8,000	42,130	13,100								
Other heart disease[d]							12,310	3,000	45,950	5,000	58,260	8,100	75,670	13,400
Cerebrovascular disease[d]							9,390	2,000	33,800	3,000	43,190	5,000	53,610	8,200
Other vascular disease[d]							2,930	1,700	8,680	3,400	11,610	5,100	14,480	6,000
Diabetes mellitus							8,350	2,100	15,420	500	23,780	2,600	35,200	6,200
Total—Cardiovascular and metabolic diseases	**42,150**	**16,200**	**56,780**	**20,900**	**98,930**	**37,100**	**75,050**	**23,400**	**223,860**	**35,100**	**298,910**	**58,600**	**397,840**	**95,600**
Pneumonia, influenza, tuberculosis, COPD[e]	3,970	2,200	8,780	7,100	12,750	9,200								
Pneumonia, influenza, tuberculosis[f]							3,460	1,200	17,930	3,900	21,380	5,100	25,300	7,800
COPD[g]							15,040	13,300	37,560	30,600	52,600	43,900	61,430	50,400
Total—Pulmonary diseases	**3,970**	**2,200**	**8,780**	**7,100**	**12,750**	**9,200**	**18,490**	**14,500**	**55,490**	**34,500**	**73,980**	**49,000**	**86,730**	**58,200**
total—cancers, cardiovascular and metabolic diseases, pulmonary diseases	**67,500**	**27,700**	**106,540**	**48,900**	**174,050**	**76,400**	**147,660**	**70,100**	**354,540**	**108,000**	**502,190**	**178,200**	**676,240**	**254,100**
All causes	**164,750**	**52,300**	**174,350**	**64,400**	**339,100**	**116,700**	**222,100**	**79,400**	**573,910**	**134,600**	**796,010**	**214,100**	**1,135,110**	**330,800**

Source: Centers for Disease Control and Prevention, National Center for Chronic Disease Prevention and Health Promotion, Office on Smoking and Health, unpublished data.
Note: Estimation of SAM based on relative risks from updated analyses of the pooled contemporary cohorts described in Thun et al. 2013. **COPD** = chronic obstructive pulmonary disease; **CVD** = cardiovascular disease.
[a]Row and column totals may not add up exactly due to rounding.
[b]Cancers of the lip, pharynx and oral cavity, esophagus, stomach, pancreas, larynx, cervix uteri, kidney and renal pelvis, bladder, liver, colon and rectum, and acute myeloid leukemia were combined into 1 disease category for both analysis and presentation. A single relative risk for the combined conditions was used to compute SAM.
[c]Other cardiovascular disease consists of other heart disease, CVD, atherosclerosis, aortic aneurysm, other arterial diseases, and diabetes mellitus. For 35–54 and 55–64 years of age, the relative risk for the combined conditions was used to compute SAM. For 65–74 and ≥75 years of age, separate relative risks for other heart disease, CVD, and other vascular diseases were used to compute SAM.
[d]For 65–74 and ≥75 years of age, other heart disease, CVD, other vascular disease, and diabetes mellitus also presented as separate conditions. Other vascular disease consists of atherosclerosis, aortic aneurysm, and other arterial diseases. Separate relative risks used to compute SAM for other heart disease, CVD, and diabetes mellitus. For other vascular disease, separate relative risks used to compute SAM for each condition before summing them for presentation.
[e]For 35–54 and 55–64 years, pneumonia, influenza, bronchitis, tuberculosis, and COPD were combined into 1 disease category for analysis and presentation. COPD consists of bronchitis, emphysema, and chronic airways obstruction. A single relative risk was used to compute SAM for the entire category.
[f]For 65–74 and ≥75 years of age, pneumonia/influenza/tuberculosis and COPD analyzed and presented as separate conditions. COPD consists of bronchitis, emphysema, and chronic airways obstruction. Separate relative risks were used to compute SAM for pneumonia/influenza/tuberculosis and for COPD.
[g]For ages 65–74 years and 75 years and older, pneumonia/influenza and COPD analyzed and presented as separate conditions. COPD consists of bronchitis, emphysema, and chronic airways obstruction. Separate relative risks were used to compute SAM for pneumonia/influenza and for COPD.

Appended Table 12.6 Average annual smoking-attributable mortality (SAM) for females 35 years of age and older, total and by age group, United States, 2005–2009

A. 35–64 years of age

Disease	35–54 years of age: Deaths	35–54 years of age: SAM	55–64 years of age: Deaths	55–64 years of age: SAM	35–64 years of age: Total[a] Deaths	35–64 years of age: Total[a] SAM
Lung cancer	6,390	4,800	12,690	10,100	19,080	14,900
Other cancers[b]	8,560	600	11,470	2,300	20,030	2,900
Total—Cancers	**14,950**	**5,400**	**24,160**	**12,400**	**39,110**	**17,800**
Coronary heart disease	7,480	3,900	12,920	3,800	20,400	7,600
Other cardiovascular disease[c]	12,320	2,900	15,800	2,400	28,120	5,300
Other heart disease[d]						
Cerebrovascular disease[d]						
Other vascular disease[d]						
Diabetes mellitus						
Total—Cardiovascular and metabolic diseases	**19,800**	**6,800**	**28,720**	**6,200**	**48,520**	**12,900**
Pneumonia, influenza, tuberculosis, COPD[e]	3,320	1,900	7,460	5,200	10,790	7,100
Pneumonia, influenza, tuberculosis[f]						
COPD[g]						
Total—Pulmonary diseases	**3,320**	**1,900**	**7,460**	**5,200**	**10,790**	**7,100**
Total—Cancers, cardiovascular and metabolic diseases, pulmonary diseases	**38,070**	**14,100**	**60,340**	**23,800**	**98,420**	**37,800**
All causes	**100,410**	**17,300**	**114,312**	**29,500**	**214,730**	**46,800**

Appended Table 12.6 Continued
B. 65 years of age and older

Disease	65–74 years of age: Deaths	65–74 years of age: SAM	75 years of age and older: Deaths	75 years of age and older: SAM	65 years of age and older: Total[a] Deaths	65 years of age and older: Total[a] SAM
Lung cancer	20,510	16,700	30,210	21,800	50,720	38,500
Other cancers[b]	15,980	2,500	39,530	4,400	55,510	7,000
Total—Cancers	**36,490**	**19,200**	**69,740**	**26,200**	**106,230**	**45,500**
Coronary heart disease	23,090	7,000	150,230	22,900	173,320	29,900
Other cardiovascular disease[c]						
Other heart disease[d]	9,950	1,600	75,440	8,400	85,390	10,000
Cerebrovascular disease[d]	8,720	1,600	64,210	3,900	72,930	5,400
Other vascular disease[d]	1,900	1,000	12,270	4,200	14,160	5,200
Diabetes mellitus	7,020	900	20,990	400	28,010	1,400
Total—Cardiovascular and metabolic diseases	**50,680**	**12,100**	**323,130**	**39,800**	**373,810**	**51,900**
Pneumonia, influenza, tuberculosis, COPD[e]						
Pneumonia, influenza, tuberculosis[f]	2,780	400	24,690	2,500	27,470	2,900
COPDg	14,400	12,900	43,930	32,000	58,330	44,900
Total—Pulmonary diseases	**17,190**	**13,300**	**68,620**	**34,500**	**85,800**	**47,800**
Total—Cancers, cardiovascular and metabolic diseases, pulmonary diseases	**104,360**	**44,600**	**461,490**	**100,500**	**565,850**	**145,200**
All causes	**173,960**	**47,600**	**803,030**	**130,600**	**976,980**	**178,200**

Appended Table 12.6 Continued

C. Total: 35 years of age and older

Disease	Deaths	SAM
Lung cancer	69,800	53,400
Other cancers[b]	75,540	10,000
Total—Cancers	**145,340**	**63,400**
Coronary heart disease	193,720	37,500
Other cardiovascular disease[c]		
Other heart disease[d]	96,200	12,100
Cerebrovascular disease[d]	81,300	7,100
Other vascular disease[d]	15,510	5,500
Diabetes mellitus	35,600	2,800
Total—Cardiovascular and metabolic diseases	**422,330**	**65,000**
Pneumonia, influenza, tuberculosis, COPD[e]		
Pneumonia, influenza, tuberculosis[f]	30,290	4,700
COPD[g]	66,300	50,200
Total—Pulmonary diseases	**96,590**	**54,900**
Total—Cancers, cardiovascular and metabolic diseases, pulmonary diseases	**664,260**	**183,300**
All causes	**1,191,710**	**225,000**

Source: Centers for Disease Control and Prevention, National Center for Chronic Disease Prevention and Health Promotion, Office on Smoking and Health, unpublished data.

Note: Estimation of SAM based on relative risks from updated analyses of the pooled contemporary cohort described in Thun et al. 2013. **CVD** = cardiovascular disease; **COPD** = chronic obstructive pulmonary disease.

[a]Row and column totals may not add up exactly due to rounding.

[b]Cancers of the lip, pharynx and oral cavity, esophagus, stomach, pancreas, larynx, cervix uteri, kidney and renal pelvis, bladder, liver, colon and rectum, and acute myeloid leukemia were combined into 1 disease category for both analysis and presentation. A single relative risk for the combined conditions was used to compute SAM.

[c]Other cardiovascular disease consists of other heart disease, CVD, atherosclerosis, aortic aneurysm, other arterial diseases, and diabetes mellitus. For 35–54 and 55–64 years of age, the relative risk for the combined conditions was used to compute SAM. For 65–74 and ≥75 years of age, separate relative risks for other heart disease, CVD, and other vascular diseases were used to compute SAM.

[d]For 65–74 and ≥75 years of age, other heart disease, CVD, other vascular disease, and diabetes mellitus also presented as separate conditions. Other vascular disease consists of atherosclerosis, aortic aneurysm, and other arterial diseases. Separate relative risks used to compute SAM for other heart disease, CVD and diabetes mellitus. For other vascular disease, separate relative risks used to compute SAM for each condition before summing them for presentation.

[e]For 35–54 and 55–64 years of age, pneumonia, influenza, bronchitis, tuberculosis and COPD were combined into 1 disease category for analysis and presentation. COPD consists of bronchitis, emphysema, and chronic airways obstruction. A single relative risk was used to compute SAM for the entire category.

[f]For 65–74 and ≥75 years of age, pneumonia/influenza/tuberculosis and COPD analyzed and presented as separate conditions. COPD consists of bronchitis, emphysema, and chronic airways obstruction. Separate relative risks were used to compute SAM for pneumonia/influenza/tuberculosis and for COPD.

Chapter 12 Appendices

Appendix 12.1

Other Methods Used to Calculate Smoking-Attributable Mortality

Several alternative methods have been developed for estimating the number of deaths attributable to smoking. The indirect method developed by Peto and colleagues (1992, 1994), often referred to as the "Peto-Lopez approach," has been used in countries where the data needed to estimate the population-attributable fraction (PAF) directly are not available. This approach uses the death rate for lung cancer in the country of interest as an indirect indicator of the cumulative risk of smoking. It calculates a smoking impact ratio that represents the absolute excess of lung cancer mortality in a population relative to the lung cancer mortality rate in a known group of nonsmokers, specifically the population from the Cancer Prevention Study II (CPS-II). This method does not require data on the prevalence of current or former smoking in the country of interest; this is inferred from the lung cancer mortality excess using the country-specific death rates for lung cancer and the age- and gender-specific death rates for lung cancer among never smokers in CPS-II. Because age-specific death rates among smokers in CPS-II tended to be twice those of nonsmokers, excess risks for all other diseases considered causally related to tobacco use are halved to produce conservative estimations for non-U.S. settings, and the smoking impact ratio is applied to these deaths to estimate the total smoking-attributable mortality (SAM).

Other researchers (Sterling et al. 1993; Malarcher et al. 2000; Thun et al. 2000a) have used model-based approaches to compute PAF. These approaches essentially expand the formula for PAF to include adjustments for potential confounding factors, including education, alcohol consumption, hypertension, diabetes, occupational risk factors, and income. These approaches were developed in part in response to methodologic concerns raised about possible confounding by differences in risk factors for tobacco-caused disease other than cigarettes across smoking groups (Sterling et al. 1993). However, the work by Malarcher and colleagues (2000) and Thun and colleagues (2000b) indicated that confounding affects SAM estimates only slightly (<1% difference in SAM with and without confounder adjustment) in the United States.

Leistikow (2004) and colleagues (2005, 2006, 2008) proposed estimating SAM based on the correlation between the trend in the national lung cancer mortality rate and the corresponding trend in mortality from all other cancers combined. To estimate SAM, this approach uses linear regression, age-adjusted rates from the Surveillance, Epidemiology, and End Results database, and the following formula:

$$\textit{Smoking-attributable fraction} = 1 - \frac{\textit{rate in the unexposed}}{\textit{rate in the exposed}}$$

This approach attributes any change in the total rate of cancer to tobacco use and ignores co-temporal changes in other factors. Therefore, the approach may not accurately reflect the number of deaths from all types of cancers attributable to smoking.

Preston and colleagues (2010) developed a model-based approach to estimate SAM in high income countries. Like Peto and colleagues (1992, 1994), they used the lung cancer mortality rate as an indicator of the impact of smoking on the mortality from all other causes. But instead of applying relative risks (RRs) for lung cancer and other diseases from a previous study, such as CPS-II, they modeled the relationship between mortality from causes other than lung cancer as a function of lung cancer mortality and other variables within a macro-level statistical model, allowing the data to determine the lung-cancer mortality/all other cause mortality relationship for each country. Model outputs were used to compute SAFs for all-cause mortality. With one exception (Japan), the estimates of smoking-attributable fractions (SAFs) for the 20 countries studied were consistent with the findings of Peto and colleagues (1992, 1994). Rostron (2010) proposed refining this model with the addition of an interaction term for age and calendar year to better reflect mortality changes over time in causes other than lung cancer and produce female-specific results closer to those of Peto and colleagues (1992, 1994). Rostron (2010) also compared findings from the modified model-based method to findings computed using a modified Peto-Lopez indirect approach in which adjusted RRs based on mortality follow-up for participants from 1997–2003. Although RRs from the National Health Interview Survey (NHIS) Linked Mortality Files were used in place of RRs from CPS-II, the study found that the modified approaches produced comparable findings for the 20 countries studied.

Rostron (2011) also proposed a new method that considers potential confounding and uses finer age stratification than that of smoking-attributable mortality, morbidity, economic costs (SAMMEC). With this method, hazard ratios for all-cause mortality stratified by smoking status are derived by matching NHIS participant records to the National Death Index. Smoking status is defined per responses to the NHIS, with current smokers categorized as light, medium, or heavy smokers based on the number of cigarette packs smoked per day (<1 pack, 1–1.9 packs, ≥2 packs). Hazard ratios are computed for 10-year age groups using a Cox proportional hazards model, fitting both unadjusted models and adjusted models that control for race, Hispanic ethnicity, marital status, education, family income, alcohol consumption, and body mass index.

Oza and colleagues (2011) proposed another method to compute SAM. The method is based on the indirect method developed by Peto and colleagues (1992) but also accounts for declining RRs due to widespread reduction in tobacco use. Declining RRs in former smokers produced somewhat smaller estimates than the indirect method. However, both approaches produced larger SAM estimates than those produced by the PAF approach.

Recent Estimates of Smoking-Attributable Mortality in the United States

Estimates by CDC (2008, 2009)

The Centers for Disease Control and Prevention ([CDC] 2008) published updated calculations of SAM and years of potential life lost (YPLL) calculations, covering the period 2000–2004. CDC estimated approximately 393,000 annual deaths from the 19 disease categories among adults and the four adverse infant health outcomes for which there was sufficient evidence to infer a causal relationship with smoking (National Cancer Institute 1999; U.S. Department of Health and Human Services [USDHHS] 2004). The 19 adult diseases included neoplasms (of the lip, oral cavity, and pharynx; esophagus; stomach; pancreas; larynx; trachea, bronchus, and lung; cervix; bladder; kidney and other urinary tract; and acute myeloid leukemia), cardiovascular diseases (coronary heart disease, other heart disease, cerebrovascular disease, atherosclerosis, aortic aneurysm, and other arterial disease), and respiratory diseases (pneumonia and influenza, bronchitis and emphysema, and chronic airways obstruction). The perinatal conditions included short gestation and low birth weight, respiratory distress syndrome, other respiratory conditions in newborns, and sudden infant death syndrome.

Calculations of SAFs and SAMs were based on RRs for smoking-related diseases and smoking prevalence estimates for current and former smokers, 35 years of age and older, and for maternal smokers. Age-adjusted RR data were obtained from CPS-II (1982–1988); gender-specific smoking prevalence data for adults, 35 years of age and older, were obtained from NHIS. RR estimates for the death of infants whose mothers smoked during pregnancy were obtained from studies by McIntosh (1984) and Gavin and colleagues (2001). Data on the prevalence of maternal smoking were obtained from birth certificates for most states for 2000–2004 (National Center for Health Statistics [NCHS] n.d.). Age- and gender-specific mortality data were also obtained from the NCHS (Minino et al. 2007). YPLL for persons 35 years of age and older were calculated using remaining life expectancy—that is, life expectancy at any given age of death minus age at death and for infants, from birth.

Based on these data, annual SAM for men 35 years of age and older was approximately 104,500 for cancers, 79,100 for cardiovascular diseases, and 53,800 for respiratory diseases. For women 35 years of age and older, the annual SAM was 56,400 for cancers, 49,400 for cardiovascular diseases, and 49,500 for respiratory diseases. The largest numbers of smoking-attributable deaths were from lung cancer, coronary heart disease, and chronic obstructive pulmonary disease (COPD) (124,800, 82,000, and 64,700, respectively, for men and women combined). SAM based on these 19 conditions was responsible for the total annual YPLL of 3,319,000 for males and 2,152,600 for females. Smoking during pregnancy was estimated to result in 560 deaths in infant males and 410 deaths in infant females annually.

CDC also estimated that approximately 740 deaths are attributable to residential fires caused by smoking (Hall 2012) and 49,400 deaths in adults from lung cancer and coronary heart disease due to exposure to secondhand smoke (California Environmental Protection Agency 2005), for an overall total of approximately 444,000 premature deaths annually from active smoking and exposure to tobacco smoke.

CDC also published state-based SAM calculations for 2000–2004 (CDC 2009). The average annual number of smoking-attributable deaths ranged from 492 (Alaska) to 36,687 (California), with a median of 5,534. In all states, the number of smoking-attributable deaths was higher for males than females. SAM rates per 100,000 population were lowest in Utah (138.3), Hawaii (167.6), and Minnesota (215.1) and highest in Kentucky (370.6), West Virginia (344.3), and Nevada (343.7). The median average annual SAM rate for 2000–2004 was 263.3 deaths per 100,000. These rates reflect differences in smoking prevalence and in population and mortality distributions among states. In general, lower SAM rates were observed in states with lower prevalence of smoking.

Estimates by Rogers (2005)

Rogers and colleagues (2005) estimated excess deaths attributable to cigarette smoking in the United States in 2000 by using discrete-time hazard models and life tables with covariates to take into account smoking status and multiple demographic and lifestyle covariates. Data regarding baseline smoking and demographic and lifestyle variables were obtained from the Health Promotion and Disease Prevention supplement to the 1990 NHIS. Death rates were based on mortality follow-up for 1990–1997 in the linked NHIS-Multiple Cause of Death files. Categorization of smoking was based on both status (current, former, and never) and amount smoked daily by current smokers and former smokers before they quit. Covariates in the models included age, gender, race, marital status, family income, employment status, education, drinking status, seatbelt use, stress, physical activity, and body mass index. Rogers and colleagues (2005) estimated that 338,000 deaths attributable to smoking could have been averted in the United States in 2000 if current and former smokers had the same mortality experience as never smokers. They estimated about 57,000 fewer smoking-attributable deaths than reported by CDC for 2001 (CDC 2002), a gap they attributed to differences in methods, time periods, subpopulations, and assumptions. They also noted that controlling confounding factors had a modest impact on the relationship between smoking and mortality, which was consistent with previous studies (Malarcher et al. 2000; Thun et al. 2000b).

Estimates by Danaei and Colleagues (2009)

Danaei and colleagues (2009) estimated mortality attributable to 12 modifiable dietary, lifestyle, and metabolic risk factors in the United States. These risk factors included high blood glucose, low-density lipoprotein, cholesterol, blood pressure, overweight-obesity, high dietary trans fatty acid intake, dietary salt intake, low dietary polyunsaturated fatty acid intake, omega-3 fatty acid intake, fruit and vegetable intake, physical activity, alcohol use, and smoking. The study used the smoking impact ratio (Peto et al. 1992) as the metric for tobacco exposure and incorporated 18 diseases and conditions having a smoking-attributable component. These diseases and conditions corresponded closely to the conditions used in SAMMEC, but Danaei and colleagues (2009) also included diabetes mellitus, colorectal cancer, tuberculosis, and hypertensive disease. RRs for most smoking-attributable conditions were derived primarily from CPS-II, but RRs for diabetes and tuberculosis were obtained from meta-analyses of large prospective cohorts (for diabetes) or cohort, case-control, and cross-sectional studies (for tuberculosis). According to Danaei and colleagues, tobacco smoking accounted for an estimated 467,000 deaths (95% confidence interval, 436,000–500,000) in the United States in 2005.

Estimates by Preston and Colleagues (2010) and Rostron (2010)

Using their model-based approach, Preston and colleagues (2010) estimated that 24% of deaths among persons 50 years of age and older in the United States were attributable to smoking in 2003. This result translates to about 26,000 fewer smoking-attributable deaths in males and about 97,000 more smoking-attributable deaths in females in the United States in 2003 than that estimated by CDC for adults, 35 years of age and older (CDC 2008). Rostron (2010)—noting differences in both the totals and the age distribution of smoking-attributable deaths for females when comparing the approach of Peto and colleagues (1992, 1994) with that of Preston and colleagues (2010)—modified the model-based approach by adding an age-by-year interaction term. Results for females using the modified approach (166,000 smoking-attributable deaths in 2003 among women 50 years of age and older) were more consistent with the results from CDC (174,000 smoking-attributable deaths per year in 2000–2004 among women 35 years of age and older).

Estimates by Rostron (2011, 2013)

Rostron (2011) used a survival analysis approach to compute adult SAM for 2002–2006 in the United States. The RR estimates were based on mortality follow-up of adults in the NHIS from 1997–2004 to 2006. Overall, the study estimated that 291,000 men and 229,000 women died annually from 2002–2006 as a result of smoking. This approach avoided the issue of changing RRs over time by using RRs based on observations of smoking behavior made in a cohort that was followed during the period for which SAM was estimated. This approach produced somewhat higher estimates of SAM than those published in 2008 using SAMMEC, particularly for women, which the author postulated was due to using a more recent data source for estimating smoking exposure. In a subsequent study, Rostron (2013) used CDC's SAMMEC methodology with RRs derived from mortality follow-up using public use data from 1997–2004 from NHIS Linked Mortality Files. The public use files contained perturbed data, in which date and underlying cause of death are replaced with synthetic data for selected decedents to reduce the risk of respondent identification. Although this technique is considered unlikely to cause large changes in results, caution should be used when interpreting results for specific causes of death. Rostron (2011) used these data to calculate RRs adjusted for race/ethnicity, educational attainment, alcohol consumption, and body mass index. Deaths related to exposure to secondhand smoke were not included. With this approach, Rostron estimated about 380,000 smoking-attributable adult deaths in the United States in 2004.

Estimates by Oza and Colleagues (2011)

Oza and colleagues (2011) performed a comparative analysis of methods to compute SAM for the United States in 2005. They used three methods: (1) the Peto-Lopez approach; (2) the Peto-Lopez approach modified to account for lower RRs for many diseases in former smokers; and (3) the PAF method. RRs for smoking-attributable diseases were obtained from CPS-II. For the PAF method, current and former smoking prevalence was computed using data from the National Health and Nutrition Examination Survey for 2003–2004 and 2005–2006. Based on the unmodified Peto-Lopez method, smoking-attributable estimates of deaths reported by Oza and colleagues (2011) were 254,700 and 227,000 for males and females, respectively. Accounting for lower RRs for many diseases in former smokers produced a small reduction in the number of smoking-attributable deaths: 251,900 and 221,100, respectively. The PAF method produced the smallest estimates of SAM, with estimates of 225,800 for males and 163,700 for females.

The four sets of estimates share PAF as the common conceptual base. However, differing methods were used to develop the RRs used for the calculations. Rostron (2011, 2013) used estimates obtained from the NHIS follow-up from 1997–2004, and other estimates were directly (CDC 2008) or indirectly (Danaei and colleagues 2009; Oza and colleagues 2011) from CPS-II. Nonetheless, the resulting estimates spanned a relatively narrow range from about 440,000–500,000.

Recent Estimates of Smoking-Attributable Mortality in Other Countries

The World Health Organization (WHO 2012) published a global report regarding mortality attributable to tobacco. WHO reported that in 2004, about 5 million deaths attributable to tobacco use (combustible and noncombustible) occurred in adults, 30 years of age and older, worldwide, or 1 death about every 6 seconds. These 5 million deaths represented about 12% of global deaths in this age range, with 16% of deaths in men and 7% of deaths in women being attributable to tobacco use. The Americas and European WHO regions had the highest proportion of deaths attributable to tobacco use (16% for both), while the Eastern Mediterranean (7%) and African (3%) regions had the lowest proportion of deaths (WHO 2012). Worldwide, 5% of deaths from communicable diseases and 14% of deaths from noncommunicable diseases are attributable to tobacco use. Within communicable diseases, lower respiratory infections and tuberculosis have the highest proportions of deaths attributable to tobacco use (12% and 7%, respectively). Noncommunicable diseases with the highest proportions of deaths attributable to tobacco use are respiratory diseases (36%), cancers (22%), and cardiovascular diseases (10%). Globally, 71% of deaths from lung cancer and 42% of deaths from COPD are attributable to tobacco use (WHO 2012).

Lim and colleagues (2012) systematically reviewed and synthesized published and unpublished data to estimate deaths and disability-adjusted life years (DALYs) attributable to the independent effects of 67 risk factors and clusters of risk factors for 21 regions in 1990 and 2010. The Peto-Lopez approach was used to estimate the burden from smoking. In this comprehensive study, tobacco smoking, including exposure to secondhand smoke, was among the top three contributors to global disease burden in both years, accounting for more than 5 million deaths in 1990 and more than 6 million in 2010, and above 150 million DALYs in both years. In 2010, tobacco smoking accounted for 8.4% of the global disease burden among men and was the leading risk factor, and accounted for 3.7% of disease burden among women (fourth highest risk factor); it was the second leading cause of disease for both genders combined (Lim et al. 2012).

Őberg and colleagues (2011) examined burden of disease from exposure to secondhand smoke in 2004 for 192 counties, computing attributable deaths and DALYs for children and nonsmoking adults. They estimated that globally, 33% of nonsmoking males, 35% of nonsmoking females, and 40% of children were exposed to secondhand smoke. They reported that about 603,000 deaths, or 1% of global mortality, were attributable to exposure to secondhand smoke—with 47% of deaths occurring in women, 26% in men, and 28% in children. The most common causes of death worldwide attributable to exposure to secondhand smoke were coronary heart disease, lower respiratory infections, asthma, and lung cancer. In addition, about 10.9 million DALYs (0.7% of global burden of disease in DALYS) were attributable to exposure to secondhand smoke. Of these DALYs, 61% were in children; the highest burdens of disease were for lower respiratory infections (children <5 years of age), coronary heart disease (adults), and asthma (adults and children).

Thun and colleagues (2013) published estimates of mortality attributable to tobacco for 41 medium and high resource countries for 1950 through the most recent time for which data were available (typically 2005–2009). This was done in context of a four-stage model, as first proposed by Lopez and colleagues (1994), that was developed to describe the tobacco epidemic and explain the lengthy delay between widespread adoption of smoking by a population and the full effects on mortality. The analysis was undertaken in part to examine predictions derived from the model in light of recent past declines in smoking prevalence. They reported that over the past two decades, SAM for males, which had peaked in the 1960s to 1980s in many of the counties examined, was level or declining in most of the countries. The largest declines were observed in Finland and England, but not much of a decline was observed in Bulgaria, Greece, Hungary, Japan, Norway, Portugal, Romania, and Spain. However, during that same time, SAM in females was increasing or plateauing, and even increasing rapidly in some countries (e.g., The Netherlands). Projecting the model to 2025, the authors expect both the prevalence of smoking and SAM to decline in parallel in most developed countries. They also noted that the four-stage model seemed generalizable to men in developing countries, but not women, particularly in predicting widespread uptake of smoking—suggesting that developing gender-specific models may be more appropriate for these countries (Thun et al. 2013).

Appendix 12.2

Methodology

In 1996, the Centers for Disease Control and Prevention (CDC) projected the future impact of smoking on the health of children and teenagers if then current tobacco use patterns persisted across the lives of this cohort of youth. Among the 68.7 million youth 0–17 years of age in 1995, CDC estimated that 16.6 million of them would become smokers as young adults and that 5.3 million of them would die prematurely from a smoking-related illness. For this model in 1996, the number of future adult smokers was calculated by projecting the future number of smokers from this cohort that would continue to smoke throughout their lives. The future total of smoking-related deaths among youth smokers was calculated by estimating the number of future adult smokers from the 68.7 million youth. The model then applied estimates of premature death attributable to smoking among continuing smokers (Peto and Lopez 1994) and among those who quit smoking after the age of 35 years (Mattson et al. 1987). Based on data from the 1986 National Mortality Followback Survey, 55% (95% confidence interval [CI] ± 1%) of persons who had ever smoked at least 100 cigarettes during their lifetimes continued to smoke until 1 year before their deaths, and 45% (95% CI ± 1%) quit smoking earlier in their adult lives (CDC, unpublished data). Based on data from long-term cohort studies, an estimated 50% of deaths among continuing smokers were attributable to smoking (Peto and Lopez 1994). Although estimates of the number of smoking-attributable deaths among former smokers ranged from 10% to 37%, a conservative estimate of 10% was used in the 1996 analysis (Mattson et al. 1987; CDC 1996; CDC unpublished data). The future probability of smoking-attributable mortality (PSAM) among youth was computed to be 0.32 ([0.55 x 0.5] + [0.45 x 0.1]). Estimates for the variance of the two smoking-attributable fractions (50% and 10%) within the PSAM were computed from the American Cancer Society's Cancer Prevention Study II (Thun et al. 1995). These two variances were combined with the variances for the probabilities of continued smoking or quitting smoking using a Taylor Series approximation method, which yielded an estimate of 0.00422 for the relative error of the PSAM. To reflect the uncertainty of the multiple assumptions about future smoking and mortality patterns, this error estimate for the PSAM was increased by a factor of 2.5, yielding an estimated standard error of 0.0106.

However, as reviewed in this report, input data have changed since this model was used in 1996. For example, the relative risks for major diseases caused by smoking—including lung cancer and chronic obstructive pulmonary disease (see Chapter 12, particularly Table 12.3)—were higher for 2000–2012 than those obtained from the two cohort studies from the American Cancer Society, which examined data from 1959 to 1986 (see Chapters 11 and 12). As reviewed in Chapter 13, patterns of quitting smoking are improving in the United States (see Figure 13.17). Furthermore, in 2012, approximately 40% of adult smokers quit smoking before 45 years of age and approximately 57% did so before 65 years of age (see Table 13.9). However, about 60% of adult smokers continue to smoke beyond 40 years of age. Although data indicate benefits to quitting smoking even later in life, the proportion of the excess risk that can be prevented declines with age

(Jha et al. 2013; Thun et al. 2013). Approximately one in six young adult smokers who do not quit until 40 years of age still may die prematurely from a smoking-related disease, but the excess risk more than doubles among former smokers who do not quit before 55 years of age (Jha et al. 2013). Among continuing smokers in the United States, an estimated 60% of premature deaths are attributable to smoking (Jha et al. 2013). An updated estimate of the PSAM based on these recent patterns of quitting and new risks reviewed in this report has not been computed. This uncertainty is not reflected in the CI.

Findings

Although the patterns of quitting smoking are improving, the risk of premature death from smoking-related illness among former smokers and continuing smokers is higher than that calculated in 1996. The model used by CDC in 1996 was used to calculate updated estimates on the number of youth in the United States who will become future smokers and will die prematurely of a smoking-related illness (Tables 12.1.1 and 12.1.2). State-specific data on the prevalence of current smoking among adults, 18–30 years of age, in each state and the District of Columbia, were obtained from the Behavioral Risk Factor Surveillance System (BRFSS) for 2011–2012. Current smokers were respondents who reported having smoked at least 100 cigarettes during their lifetimes and who reported currently smoking. Because the prevalence of smoking in a birth cohort peaks during early adulthood (see Chapter 13), the average prevalence of smoking among adults 18–30 years of age in each state during 2011–2012 was used to estimate the future prevalence of smoking during early adulthood for the 0–17-years-of-age birth cohort in 2012. The number of persons 0–17 years of age in each state in 2012 was obtained from the National Center for Health Statistics (2013). This figure was multiplied by the state-specific prevalence of smoking among those 18–30 years of age to calculate the number of youth anticipated to become regular smokers in each state. Overall, the estimated number of future smokers from the 0–17-years-of-age birth cohort in 2012 in the United States was 17,371,000 (ranging from 22,300 in the District of Columbia to 1,557,800 in Texas) (Table 12.2.1).

Based on the application of PSAM (0.32) to the state-specific estimates of potential smokers, the overall number of potential future smoking-attributable deaths among youth 0–17 years of age during 2012 in the United States was 5,557,000 (ranging from 7,000 in the District of Columbia to 498,000 in Texas) (Table 12.2.1). Based on the estimated PSAM variance and the state-specific sampling errors on estimates of smoking prevalence from the BRFSS, the estimated number of overall smoking-related deaths in the United States was predicted to vary on a statistical basis by less than or equal to 115,000 deaths. The CIs did not account for other sources of uncertainty, such as future changes in risk of dying from smoking or a greater quitting rate earlier in life in the future.

These state-specific estimates were also used to calculate the proportion of youth, 0–17 years of age, who are projected to die prematurely from a smoking-related illness (Table 12.2.2). At the state level, estimates varied almost threefold, from 4.4% in Utah to 12.3% in West Virginia. Overall, 7.5% of youth from the 0–17-years-of-age birth cohort in 2012 in the United States are projected to die prematurely from a smoking-related illness if current rates of smoking and risk of disease associated with smoking persist.

Table 12.2.1 Prevalence of current smoking among adults, 18–30 years of age,[a] and projected number of persons, 0–17 years of age, who will become smokers and die prematurely as adults because of a smoking-related illness, by state—United States, 2012

State	Prevalence (%) of current smoking 18–30 years of age (± 95% CI)	Population, 0–17 years of age[b]	Projected number of smokers 0–17 years of age (± 95% CI)	Projected number of deaths 0–17 years of age
Alabama	29.9 (2.9)	1,124,406	336,200 (303,600–368,800)	108,000
Alaska	23.3 (3.1)	187,100	43,600 (37,800–49,400)	14,000
Arizona	22.2 (3.5)	1,620,894	359,800 (303,100–416,600)	115,000
Arkansas	30.2 (4.0)	710,881	214,700 (186,300–242,400)	69,000
California	14.9 (1.3)	9,240,219	1,376,800 (1,256,700–1,496,900)	441,000
Colorado	23.0 (2.0)	1,231,358	283,200 (258,600–307,800)	91,000
Connecticut	22.1 (2.8)	793,558	175,400 (153,200–197,600)	56,000
Delaware	26.2 (3.4)	205,050	53,700 (46,800–60,700)	17,000
District of Columbia	20.4 (3.7)	109,480	22,300 (18,300–26,400)	7,000
Florida	21.1 (2.6)	4,002,480	844,500 (740,500–944,600)	270,000
Georgia	25.6 (2.7)	2,490,125	637,500 (570,200–704,700)	204,000
Hawaii	22.1 (2.7)	303,011	67,000 (58,800–74,800)	21,000
Idaho	22.1 (3.5)	426,653	94,300 (79,400–108,800)	30,000
Illinois	23.5 (3.3)	3,064,065	720,100 (618,900–818,100)	230,000
Indiana	29.6 (2.5)	1,591,477	471,100 (431,300–509,300)	151,000
Iowa	23.8 (2.5)	722,953	172,100 (154,000–189,400)	55,000
Kansas	26.4 (1.7)	724,304	191,200 (178,900–204,300)	61,000
Kentucky	36.5 (2.8)	1,018,238	371,700 (343,100–401,200)	119,000

Table 12.2.1 Continued

State	Prevalence (%) of current smoking 18–30 years of age (± 95% CI)	Population, 0–17 years of age[b]	Projected number of smokers 0–17 years of age (± 95% CI)	Projected number of deaths 0–17 years of age
Louisiana	27.5 (2.8)	1,117,803	307,400 (276,100–338,700)	98,000
Maine	31.7 (2.5)	265,918	84,300 (77,600–91,200)	27,000
Maryland	21.5 (2.7)	1,343,800	288,900 (252,600–325,200)	92,000
Massachusetts	23.0 (1.8)	1,401,415	322,300 (297,100–349,000)	103,000
Michigan	29.4 (2.5)	2,266,870	666,500 (609,800–723,100)	213,000
Minnesota	25.0 (2.0)	1,276,148	319,000 (293,500–343,300)	102,000
Mississippi	28.7 (2.6)	745,333	213,900 (194,500–234,000)	68,000
Missouri	28.4 (2.9)	1,403,475	398,600 (357,900–440,700)	128,000
Montana	26.6 (2.4)	221,980	59,000 (53,700–64,200)	19,000
Nebraska	25.6 (1.5)	463,405	118,600 (111,700–125,600)	38,000
Nevada	19.4 (2.9)	663,583	128,700 (109,500–147,300)	41,000
New Hampshire	24.7 (3.3)	274,840	67,900 (58,800–77,000)	22,000
New Jersey	22.0 (2.1)	2,026,384	445,800 (403,300–486,300)	143,000
New Mexico	24.2 (2.2)	514,442	124,500 (113,200–135,300)	40,000
New York	20.5 (2.4)	4,263,154	873,900 (771,600–976,300)	280,000
North Carolina	24.6 (2.2)	2,286,528	562,500 (512,200–612,800)	180,000
North Dakota	28.1 (3.1)	154,608	43,400 (38,700–48,200)	14,000
Ohio	30.4 (2.5)	2,663,674	809,800 (743,200–876,300)	259,000
Oklahoma	29.4 (2.6)	937,363	275,600 (251,200–300,900)	88,000

Table 12.2.1 Continued

State	Prevalence (%) of current smoking 18–30 years of age (± 95% CI)	Population, 0–17 years of age[b]	Projected number of smokers 0–17 years of age (± 95% CI)	Projected number of deaths 0–17 years of age
Oregon	24.8 (3.0)	860,624	213,400 (187,600–239,300)	68,000
Pennsylvania	27.8 (2.1)	2,739,386	761,500 (704,000–821,800)	244,000
Rhode Island	22.5 (3.1)	216,474	48,700 (42,000–55,400)	16,000
South Carolina	29.9 (2.3)	1,080,090	322,900 (298,100–347,800)	103,000
South Dakota	32.2 (3.2)	204,169	65,700 (59,200–72,500)	21,000
Tennessee	26.2 (4.1)	1,494,016	391,400 (330,200–452,700)	125,000
Texas	22.3 (2.1)	6,985,639	1,557,800 (1,411,100–1,704,500)	498,000
Utah	13.6 (1.4)	887,972	120,800 (108,300–132,300)	39,000
Vermont	25.4 (3.1)	123,951	31,500 (27,600–35,200)	10,000
Virginia	25.3 (2.8)	1,856,737	469,800 (417,800–521,700)	150,000
Washington	20.5 (1.9)	1,584,967	324,900 (294,800–356,600)	104,000
West Virginia	38.5 (3.4)	384,041	147,900 (134,800–160,500)	47,000
Wisconsin	25.2 (3.2)	1,317,557	332,000 (289,900–374,200)	106,000
Wyoming	27.9 (3.2)	135,490	37,800 (33,500–42,100)	12,000
Total		73,728,088	17,371,900 (15,604,600–19,133,800)	5,557,000

Source: Centers for Disease Control and Prevention, National Center for Chronic Disease Prevention and Health Promotion, Office on Smoking and Health, unpublished data.
Note: **CI** = confidence interval.
[a]Prevalance data were obtained from the Behavioral Risk Factor Surveillance System.
[b]Population estimates were obtained from the National Center for Health Statistics 2013.

Table 12.2.2 Proportion (%) of persons, 0–17 years of age, who are projected to become smokers and die prematurely as adults because of smoking-related illness, by state—United States, 2012

State	Population, 0–17 years of age[a]	Projected number of deaths	Proportion (%) of population projected to die prematurely
Alabama	1,124,406	108,000	9.6
Alaska	187,100	14,000	7.5
Arizona	1,620,894	115,000	7.1
Arkansas	710,881	69,000	9.7
California	9,240,219	441,000	4.8
Colorado	1,231,358	91,000	7.4
Connecticut	793,558	56,000	7.1
Delaware	205,050	17,000	8.4
District of Columbia	109,480	7,000	6.5
Florida	4,002,480	270,000	6.8
Georgia	2,490,125	204,000	8.2
Hawaii	303,011	21,000	7.1
Idaho	426,653	30,000	7.1
Illinois	3,064,065	230,000	7.5
Indiana	1,591,477	151,000	9.5
Iowa	722,953	55,000	7.6
Kansas	724,304	61,000	8.4
Kentucky	1,018,238	119,000	11.7
Louisiana	1,117,803	98,000	8.8
Maine	265,918	27,000	10.1
Maryland	1,343,800	92,000	6.9
Massachusetts	1,401,415	103,000	7.4
Michigan	2,266,870	213,000	9.4
Minnesota	1,276,148	102,000	8.0
Mississippi	745,333	68,000	9.2
Missouri	1,403,475	128,000	9.1
Montana	221,980	19,000	8.5
Nebraska	463,405	38,000	8.2
Nevada	663,583	41,000	6.2
New Hampshire	274,840	22,000	7.9
New Jersey	2,026,384	143,000	7.0
New Mexico	514,442	40,000	7.7
New York	4,263,154	280,000	6.6
North Carolina	2,286,528	180,000	7.9

Table 12.2.2 Continued

State	Population, 0–17 years of age[a]	Projected number of deaths	Proportion (%) of population projected to die prematurely
North Dakota	154,608	14,000	9.0
Ohio	2,663,674	259,000	9.7
Oklahoma	937,363	88,000	9.4
Oregon	860,624	68,000	7.9
Pennsylvania	2,739,386	244,000	8.9
Rhode Island	216,474	16,000	7.2
South Carolina	1,080,090	103,000	9.6
South Dakota	204,169	21,000	10.3
Tennessee	1,494,016	125,000	8.4
Texas	6,985,639	498,000	7.1
Utah	887,972	39,000	4.4
Vermont	123,951	10,000	8.1
Virginia	1,856,737	150,000	8.1
Washington	1,584,967	104,000	6.6
West Virginia	384,041	47,000	12.3
Wisconsin	1,317,557	106,000	8.1
Wyoming	135,490	12,000	8.9
Total	73,728,088	5,557,000	7.5

Source: Centers for Disease Control and Prevention, National Center for Chronic Disease Prevention and Health Promotion, Office on Smoking and Health, unpublished data.
[a]Population estimates were obtained from the National Center for Health Statistics 2013.

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