Mortality of Smoking by Gender

Sam Gutterman, FSA, CERA, FCAS, MAAA

Presented at the Living to 100 Symposium

Orlando, Fla.

January 8–10, 2014

Mortality of Smoking by Gender, by Sam Gutterman, FSA, FCAS, CERA, HonFIA

2014 Living to 100 Symposium

Table of contents

Abstract

Exposure to cigarette smoke has had and will continue to have a huge effect on mortality. Significant differences in smoking prevalence rates by gender have contributed to varying levels and rates of improvement in mortality over the last several decades and are expected to continue to influence mortality improvement differently over the next several decades.

The combined effect of greater historical smoking prevalence rates by males and their corresponding earlier and larger reduction has in part been responsible for the recent improvement in mortality rates for males compared to that for females in the United States. Similar patterns are evident in almost all economically developed countries, although their timing and levels differ. The patterns in underdeveloped countries will likely follow similar patterns as concerns emerge about the effect of smoking on the mortality of their citizens.

The objective of this paper is to compare smoking prevalence and cessation by gender and the effect on smoking-attributable and, in turn, all-cause mortality. A summary of mortality attribution approaches used to enhance the evaluation of the effect of smoking and projections of mortality rates by gender is also provided.

Mortality of Smoking by Gender, by Sam Gutterman, FSA, FCAS, CERA, HonFIA

2014 Living to 100 Symposium

1. Background

As shown in figure 1, during the first half of the 20th century, American adult smoking prevalence increased, in large part as a result of product and technological changes (e.g., the introduction of and changes in cigarette blends, the safety match, curing and mass production processes, and cigarette distribution), as well as the liberalization of women's roles and behavior. Smoking peaked for adult males in the 1940s and 1950s, while it peaked for adult females in the 1960s.

Over the last half century, arguably the most important behavioral change affecting health has been the significant decrease in smoking prevalence. A dramatic decrease in male smoking prevalence and somewhat later a more modest decrease in female smoking prevalence have had a significant effect on mortality trends and will continue to do so over the next several decades.

The decrease in prevalence has been due to many factors, including a huge burst of adverse media publicity; continuous medical advice regarding smoking's adverse effects on health; regulatory constraints especially driven by a better understanding of the effect of secondhand smoke such as increasingly restrictive labeling, smoking in public places and advertising practices; increases in economic and social costs of smoking including taxes and peer pressure; and the aging of the population.

Nevertheless, peer pressure among many adolescents and the addictive nature of certain ingredients in cigarettes have offset to some extent these societal and intellectual pressures. Not only have many smokers continued their habit, it has been estimated that 3,800 American adolescents smoke their first cigarette every day, 1,000 of whom will become daily or even lifetime smokers.

Cigarette smoking[1] has had a significantly adverse effect on mortality over the last century and the early part of the 21st century. Decades of extensive medical and epidemiologic studies have shown smoking to be a leading cause of preventable deaths in the United States, as well as in other developed countries. Although a statistical relationship between smoking and mortality was first reported upon in the 1930s, only beginning in the 1950s and 1960s did supportable evidence point to a causative relationship.

In 1964 (50 years prior to the publication of this paper), the U.S. Surgeon General published a report titled "Smoking and Health" that, among things, concluded "cigarette smoking is causally related to lung cancer in men; the magnitude of the effect of cigarette smoking outweighs all other factors; and the risk of developing lung cancer increases with the duration of smoking and number of cigarettes smoked per day, and diminishes by discontinuing smoking." Subsequently, it has been found that smoking has also been causally linked to diseases of nearly all organs of the body and to harm fetuses of mothers who smoke.

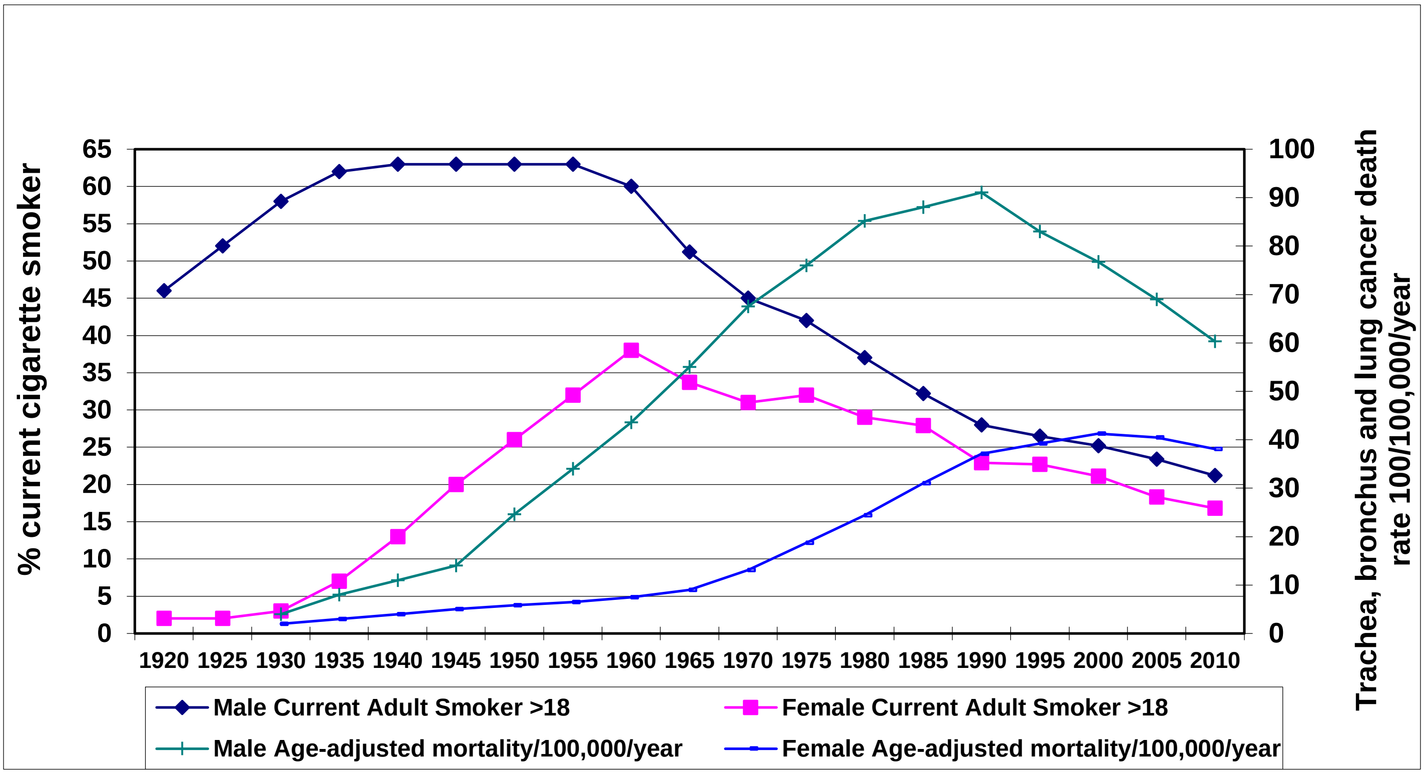
Although the 1964 surgeon general's report was far from the initial report or study dealing with this topic, and in fact its conclusions were based on numerous earlier studies, it had enormous effects on attitudes and behaviors. In 1986, "The Health Consequences of Involuntary Smoking," on the adverse consequences of secondhand smoke, was released. In the surgeon general's 1988 report, "The Health Consequences of Smoking—Nicotine Addiction," the use of tobacco was declared to be an addiction. It is now known that secondhand smoke can cause serious cardiovascular and respiratory diseases, strokes (especially in females), sudden death in infants and low birth weight babies of pregnant smokers. Children account for 28 percent of deaths attributable to secondhand smoke.

Smoking remains the single leading cause of preventable mortality in the United States. In 2014, a further such report in the series, "The Health Consequences of Smoking—50 Years of Progress," continued to report on the adverse effects of smoking, identifying additional medical conditions that have and will continue to

[1] Although the focus of this paper is on cigarette smoking, other types of smoking, including that of cigars, pipes, smokeless tobacco, hookahs, e-cigarettes and e-hookahs, may also have adverse mortality implications. Most smoking-related mortality statistics and projections have ignored the effect of these other types of tobacco.

cause premature deaths in those exposed to smoking. It estimated that about 480,000 Americans annually die prematurely due to smoking. Based on recent mortality studies, it concluded that on average those who currently smoke experience worse relative mortality than that found in earlier studies (possibly 50 percent greater for females in the 2000s compared with that for females in the 1980s). This differential is, in part, due to the longer period during which current smokers have been active smokers.

Figure 1. Smoking prevalence and trachea/bronchus/lung cancer mortality rates



Sources: Weiss (1997), *Health, United States, 2012* and SEER Cancer Statistics Review 1975–2011

2. Smoking prevalence

According to Blackwell, Lucas and Clarke (2014), the 2012 National Health Interview Survey (NHIS) found that American adult smoking prevalence was 20.5 percent for males and 15.8 percent for females (18.1 percent overall). By age, prevalence was 17.3 percent for 18 to 24, 21.6 percent for 25 to 44, 19.5 percent for 45 to 64 and 8.9 percent for over 65. Between 2005 and 2012, the percent of ever-smokers who quit increased from 50.7 percent to 55.0 percent and the percent of daily smokers who smoked more than 30 cigarettes per day decreased from 12.6 percent to 7.0 percent and the number of cigarettes smoked per day by daily smokers decreased from 16.3 to 14.6. Among current and former smokers, 52.9 percent attempted to quit (defined as an attempt that lasts longer than one day at a time) during the year.

The extent of exposure to smoking has dramatically differed by population segment. Although the focus of attention in this paper is the difference by gender, it should be noted that prevalence also differs by age, location and cohort. Table 1 shows American adult smoking prevalence rates over the last 50 years through 2010 by age category, gender and year of death. This indicates the significant reduction in smoking prevalence for each attained age group over this period.

Table 1. Smoking prevalence of U.S. adults

Males	**1965**		**1974**	**1979**	**1985**	**1990**	**1995**	**2000**	**2005**	**2010**
18–24 years	54.1%		42.1%	35.0%	28.0%	26.6%	27.8%	28.1%	28.0%	22.8%
25–34 years	60.7		50.5	43.9	38.2	31.6	29.5	28.9	27.7	26.1
35–44 years	58.2		51.0	41.8	37.6	34.5	31.5	30.2	26.0	22.5
45–54 years	55.9		46.8	42.0	34.9	32.1	27.2	28.8	28.1	25.2
55–64 years	46.6		37.7	36.4	31.9	25.9	26.9	22.6	21.1	20.7
65+ years	28.5		24.8	20.9	19.6	14.6	14.9	10.2	8.9	9.7
All ages	51.2		42.8	37.0	32.2	28.0	26.5	25.2	23.4	21.2
Females	**1965**		**1974**	**1979**	**1985**	**1990**	**1995**	**2000**	**2005**	**2010**
18–24 years	38.1%		34.1%	33.8%	30.4%	22.5%	21.8%	24.9%	20.7%	17.4%
25–34 years	43.7		38.8	33.7	32.0	28.2	26.4	22.3	21.5	20.6
35–44 years	43.7		39.8	37.0	31.5	24.8	27.1	26.2	21.3	19.0
45–54 years	37.5		36.0	32.6	32.4	28.5	24.3	22.2	20.9	21.3
55–64 years	25.0		30.4	28.6	27.4	20.5	23.7	20.9	16.1	16.5
65+ years	9.6		12.0	13.2	13.5	11.5	11.5	9.3	8.3	9.3
All ages	33.7		32.2	30.1	27.9	22.9	22.7	21.1	18.3	17.5
Females/males	**1965**		**1974**	**1979**	**1985**	**1990**	**1995**	**2000**	**2005**	**2010**
18–44 years	72.7%		78.3%	85.9%	89.2%	81.5%	85.6%	83.9%	78.2%	79.9%
45–64 years	61.7		78.4	78.1	89.5	84.6	88.6	82.2	74.6	82.3
65+ years	33.7		48.4	63.2	68.9	78.8	77.2	91.2	93.3	95.9
All ages	65.8		75.2	81.4	86.6	81.8	85.7	83.7	78.2	82.5

Source: National Health Interview Surveys (NHIS)

Note that since the average attained age for females in the highest age category (65+ in this case) is higher than for males, a comparison of aggregate rates in this broad age group may be misleading and so should be viewed with caution.

Table 2 recasts the prevalence rates shown in table 1 by approximate birth cohort. Smoking prevalence has clearly decreased over time and age, the reductions most likely due to those who stopped smoking and the earlier death of those exposed to smoking. The ratio of smoking prevalence of females to that of males remained relatively constant until the 1961–70 birth cohort. However, due to the mix of cohorts in the overall population, overall trends have been different.

Table 2. Smoking prevalence trend by approximate birth cohort

Approximate birth cohort	**Calendar year**				
Males	**1965**	**1974**	**1985**	**1995**	**2005**
1921–30	54.1%	50.5%	37.6%	27.2%	21.1%
1931–40	60.7	51.0	34.9	26.9	8.9
1941–50	58.2	46.8	31.9	14.9	
1951–60	55.9	37.7	19.6		
1961–70	46.6	24.8			
Females	**1965**	**1974**	**1985**	**1995**	**2005**
1921–30	38.1%	38.8%	31.5%	24.3%	16.1%
1931–40	43.7	39.8	32.4	23.7	8.3
1941–50	43.7	36.0	27.4	11.5	
1951–60	37.5	30.4	13.5		
1961–70	25.0	12.0			
Females/males	**1965**	**1974**	**1985**	**1995**	**2005**
1921–30	70.4%	76.8%	83.8%	89.3%	76.3%
1931–40	72.0	78.0	92.8	88.1	93.3
1941–50	75.1	76.9	85.9	77.2	
1951–60	67.1	80.6	68.9		
1961–70	53.6	48.4			

Source: National Health Interview Surveys (NHIS)

Average daily cigarette consumption by smokers decreased from 20 in 1970 to 13 in 2012. To provide historical perspective, the average American adult averaged 1, 4 and 10 cigarettes per day in 1910, 1930 and 1950, respectively; this increase was followed by an increase in resulting deaths, as, according to Peto et al. (2012), tobacco caused about 12 percent of all U.S. deaths in middle age in 1950 and about 33 percent in 1990. Nearly 42 million American smokers struggle with a tobacco addiction that most want to quit, but, according to Schroeder and Koh (2014), only 3 to 5 percent annually are able to so unaided.

According to Ng et al. (2014), the global prevalence of smokers decreased from about 41.2 percent in 1980 to 31.1 percent for males in 2012, while it decreased for females from 10.6 percent to 6.2 percent. Prevalence rates decreased at a faster pace from 1996 to 2006 (1.7 percent annually) than for the period 2006 to 2012 (0.9 percent annually). Nevertheless, due to the increase in the total population and its age structure, there was an increase of 41 percent in the number of male smokers and a 7 percent increase in female smokers, or an increase in the number of daily smokers from 721 million in 1980 to about 967 million in 2012. In 2012, smokers in 34 countries experienced an average number of cigarettes of less than 10; in 78 countries, consumption was between 10 and 20 cigarettes per day; and in 75 countries, consumption was greater than 20 per day. Prevalence rates in males exceeded that in females in all countries other than Sweden, while nearly 80 percent of the more than 1 billion smokers worldwide now live in low- and middle-income countries. In addition, Giovino et al. (2012) estimated that about 30 million young adults begin smoking each year (about half of young males and about one-tenth of young females).

3. Methods of attributing deaths to smoking

The study of mortality by cause of death can be conducted at two levels. The more common approach is the use of the proximate cause of death, often recorded on death certificates. These causes include cancer, cardiovascular disease and accidents. Studies can also be conducted by underlying cause, for example, by genes, smoking, unhealthy nutrition, obesity, infection, pollution, occupation and high blood pressure. The first level is the more common basis for study, primarily because evidence of these causes is observable at the time of death. The second level consists of the basic drivers of the proximate cause, sometimes referred to as risk factors, without which the first level cause may not arise or would occur later. The second level can more often be controllable, measureable and serve as an early warning of what might come.

It is common that multiple causes can coexist (comorbidities), and it is often difficult to determine the relative contribution of each. In summary, the second level causes can in some cases provide a more effective basis for prevention and management. However, because the relationship is not as direct and lengthy lags can be involved (possibly 30 to 40 years for an individual who started smoking when young), it can be more challenging to quantify or estimate their consequential effects. Because of their more fundamental nature, their trends can prove useful in estimating future trends in mortality.

Various techniques have been used to estimate the number and rate of premature deaths attributable to smoking. The objective of most of these techniques is to determine smoking-attributable fractions that can be applied to the overall number of deaths or mortality rates (for example, by gender or causes of death) to determine the excess deaths that can be attributed to smoking. Many have used an indirect method because statistics regarding smoking as a cause of death are not normally available, as smoking is not usually considered to be the proximate cause of death.

There are many challenges in estimating smoking-attributable deaths, including the necessity to rely on self-reported smoking histories, projections of smoking prevalence and effects of smoking cessation, as well as overcoming inaccuracies in cause-of-death reporting, and treatment of occasional and short-term smokers. In addition, the time between exposure to smoking and different causes of death can vary widely. For example, even though lung cancer is usually thought of as the best base for extrapolating to all-cause mortality, typically there is a longer lag between exposure and death from lung cancer than for cardiovascular diseases; the lag between exposure and death due to chronic obstructive pulmonary disease (COPD) can be even longer.

The lag, whether taken to be between death and either initial exposure to smoking, average smoking prevalence or smoking cessation, is a significant assumption. The range of this assumption has usually varied between 25 years (Soneji and King 2012), 30 years (Janssen, van Wissen and Kunst 2013) and even longer in other studies. However, Preston et al. (2014) indicated that, using the Peto-Lopez method described below, the effect of substituting different disease lag-specific factors to the estimation of deaths attributable to smoking was only about 1.7 percent.

The methods described below have been grouped in several ways; the following is one categorization, generally corresponding to that described in Perez-Rios and Montes (2008). Researchers subsequent to the seminal papers that initially described each of these methods have introduced refinements to better achieve their purpose—either to be consistent with the result of other studies or to refine estimates. Those after the initial entry are indirect methods.

- Direct method. Cohort studies of current smokers with self-reported smoking histories have been conducted in some countries. However, as smoking-related deaths are not well documented, such comparisons may require the heroic assumption that other contributing factors to health and death are similar between the current, previous and never-smoker populations. If smoking-attributable deaths were accurately available, this would likely be the best approach; however, accurate data of this type is rarely available or is onerous to develop. As a result, further discussion of this method is not pursued here.

- Prevalence-based indirect analysis. These methods are based upon mortality of population subgroups. This approach uses subgroup data, including cohorts, age groups, gender and usually direct cause of deaths (e.g., in categories such as lung cancer, cardiovascular disease and accidents). It uses lung cancer mortality rates as a base because (1) lung cancer is usually coded as a cause of death accurately and is closely tied to smoking as a behavioral risk factor and (2) these rates can provide a reasonable measure of exposure to smoking prevalence.

  - Peto-Lopez. This method was originally described in a paper by Peto et al. (1992). It is based on the assumption that overall smoking mortality can be estimated by focusing on lung cancer mortality, and using age- and gender-related mortality risks of smokers relative to those of nonsmokers by cause of death, as well as corresponding total mortality rate of nonsmokers. Its advantage is that the extrapolation uses those relationships and does not require data on lifetime exposure to smoking.

    It is conducted in a two-step process utilizing lung cancer deaths as a surrogate for mortality. The first step is to determine the excess of lung cancer mortality rates in the national (smoker and nonsmoker) population compared to corresponding lung cancer mortality among nonsmokers. The second step is to estimate smoking exposures and the relative risks of smoking to calculate fractions of mortality from other smoking-related causes. Findings of the American Cancer Society's Cancer Prevention Study II (CPS-II), the largest such study, are used to compare lung cancer deaths for smokers and nonsmokers, as well as other deaths similarly split. As Peto assumed that smokers are self-selected, some of the differential found was viewed as being attributable to confounding with other risk factors, and as a result (they halved[2] the CPS-II excess risks for causes other than lung cancer (the fraction was estimated by judgment; Preston, Glei and Wilmoth 2010b described this choice as arbitrary). Peto et al. (1992) also assumed that the smoking-attributable fractions of death by cause for those age 75–79 were also applicable to those over those ages.

    - Rostron and Wilmoth (2011) modified this method by using more refined age intervals and a more recent baseline level of lung cancer mortality.

    - Oza et al. (2011) also accounted for declining hazard ratios by disease type by cohort due to the widespread reduction in smoking prevalence. Oza used three methods in the development of projections: (1) the Peto-Lopez approach, (2) the Peto-Lopez approach modified to reflect lower hazard ratios for many diseases in former smokers, and (3) the population attributable fraction method, similar to one applied by the U.S. Centers for Disease Control and Prevention (CDC) described below.

  - Preston-Glei-Wilmoth (PGW). First described in Preston, Glei and Wilmoth 2010b, this method builds on the concepts underlying the Peto-Lopez method. The PGW method uses a macro-level statistical association (based on studies from 21 countries relating to the period between 1950 and 2006) between lung cancer mortality and all-cause mortality, without relying on specific estimates of smoker to all-cause mortality by cause of death (thus not requiring the assumption that relativities between risks by cause will continue). It applies negative binomial regression to

[2] Malarcher et al. (2000) estimated the effect of confounding that varies by immediate cause of death and gender. For example, for lung cancer for males, the fraction attributable to smoking was on a fully adjusted basis 0.91, for COPD 0.88, for ischemic heart disease 0.24 and for cardiovascular disease 0.10; for females, the corresponding fractions were 0.77 for lung cancer, 0.68 for COPD, 0.10 for ischemic heart disease and 0.09 for cardiovascular disease.

estimate mortality due to smoking for all causes other than lung cancer from mortality due to lung cancer (attributable to smokers). The resulting factor multiplied by lung cancer mortality rates due to smoking (that is, the difference between observed mortality rates for smokers and expected mortality rates for nonsmokers) applied to all-cause mortality results in an estimated number of deaths attributable to smoking. Its underlying assumption is that lung cancer mortality is a reliable proxy for the effect of smoking on mortality due to other causes, after adjusting for gender and age. They estimated that 24 percent of deaths of those older than 50 can be attributed to smoking.

- PGW-Rostron (PGW-R). This modification of the PGW method incorporates an age group-year interaction term, with the objective of improving estimates of certain population groups, as Rostron (2010) found that the attributable fraction differs considerably by age group. This was particularly true of older women, for which the PGW method did not appear to accurately project attributable deaths. To validate his results, Rostron applied the Peto-Lopez method based on NHIS results rather than those of CPS-II (he believed NHIS was more nationally representative and not overrepresented by university-educated white Americans as was CPS-II), and applied a Cox proportional hazard model, controlling for factors including education, income and body mass index (BMI) for all-cause mortality.

- Excess mortality by class. An example of this method is given in Rogers et al. (2005), in which mortality risks for seven smoker groups (heavy current, moderate current, light current, heavy former, moderate former, light former and never-smoker) by gender, based on a nationally representative sample (the NHIS 1990 supplement). They estimated relative mortality risks by smoking status, controlling for various demographic variables and other possibly confounding risk factors. Some commentators (e.g., Fenelon and Preston [2012]) believe that estimates of Rogers et al. (and those of the CDC) suffer because they don't reflect changes in smoking status that occur during their follow-up study period.

- Survival analysis. Rostron (2011) conducted a survival analysis of data from adults in the 1997–2004 National Health Interview Survey, followed through the end of 2006. They used a finer age stratification structure and looked at light, medium and heavy smokers, as well as a variety of possible confounding risk factors that were controlled for in a cohort analysis.

- Predictive. This method considers multiple variables, including causes or effects. An application has included a Dutch study in 1988, the Prevent model. These have not yet been developed sufficiently to address here.

The CDC develops estimates of smoking-attributable mortality (SAM) for the United States by taking a five-year rolling average of estimates of mortality for 19 disease categories by four age groups, two genders and smoking history. To these they added a relatively small number of deaths due to secondhand smoke and residential fires caused by smoking.

Because of the lack of regularly reported mortality statistics by smoking characteristics, indirect methods have been used extensively, usually relying on data from a large population survey, such as the CSP-II of 1982–88, in which rates of lung cancer mortality by smoking habit are developed (at least one set of researchers, Thun et al. [2013], has used the findings of more recent studies—see table 9). Their mortality projections used additional assumptions, including the effect of smoking cessation of former smokers, which tend to converge toward the never-smoker level after a number of years (see section 5).

Although estimates of U.S. premature deaths attributable to smoking have varied considerably, they usually run between 300,000 and 600,000 per year. Table 3, from Rostron and Wilmoth (2011), shows estimates by cause of death from the CDC and an adjusted (for age) Peto-Lopez method described in Rostron and Wilmoth

(2011). Some of the differences are the result of alternative assumptions regarding the extent that certain relationships are maintained over time and over the study period. This table shows that total smoking-attributable deaths are just a little less than four times the number of lung cancer deaths attributable to smoking.

Table 3. Estimated average annual number of smoking-attributable deaths, 1997–2001

Cause of death	Smoking attributable deaths				Percent of total smoking attributable deaths			
	Females		Males		Females		Males	
	CDC	Modified Peto-Lopez with adjust	CDC	Modified Peto-Lopez with adjust	CDC	Modified Peto-Lopez with adjust	CDC	Modified Peto-Lopez with adjust
Cancers	54,310	48,916	104,219	96,922	30.4%	43.1%	40.2%	51.6%
Lung cancer	44,810	43,743	79,026	76,513	25.1%	38.5%	30.5%	40.7%
Other cancers	9,500	5,173	25,193	20,409	5.3%	4.6%	9.7%	10.9%
Circulatory diseases	53,612	21,872	84,367	43,339	30.1%	19.3%	32.5%	23.1%
Cardiovascular	44,719	17,906	75,824	37,815	25.1%	15.8%	29.2%	20.1%
Cerebrovascular	8,893	3,966	8,543	5,524	5.0%	3.5%	3.3%	2.9%
Respiratory	47,135	25,282	54,319	31,788	26.4%	22.3%	20.9%	16.9%
Other	23,351	17,487	16,589	15,854	13.1%	15.4%	6.4%	8.4%
All causes	178,408	113,557	259,494	187,904	100.0%	100.0%	100.0%	100.0%

Source: Rostron and Wilmoth (2011)

Fenelon and Preston (2012) gathered the smoking-attributable fractions shown in table 4, relating to mortality attributable smoking fractions in the United States.

Table 4. Mortality attributable to smoking in American adults

Method	Ages	Females		Males	
		2000	2004	2000	2004
PGW (2010)	50–84	0.19	0.20	0.23	0.22
PGW-R (2010)	50+	0.14	—	0.22	—
Peto-Lopez	50+	0.21	—	0.24	—
CDC	35+	—	0.15	—	0.23
Rogers	35+	0.13	—	0.21	—

Source: Fenelon and Preston (2012)
Notes: according to Preston, Glei and Wilmoth 2010b, females: 1955: 0.00, 1980: 0.07, 2003: 0.24; males: 1955: 0.09, 1988: 0.24, 2003: 0.24

Mehta and Chang (2011), based on NHIS data, found that the risk of death for a smoker compared with that of a never-smoker increased by 25.4 percent from 1987 to 2006. Mehta and Chang's further analysis of data from National Health and Nutrition Examination Surveys (NHANES) between 1971 and 2006 showed an even faster annual increase in the relative risk of death for current smokers. Former smokers also showed an increasing relative risk of death, although the increase was slower than for current smokers and not always statistically significant. One factor that might serve as a contributing reason for this is the increase in the cumulative time that an individual spends in an unhealthy state.

For example, Thun et al. (1997) found that, between 1959 and 1982, the mean duration of smoking for male current smokers rose modestly, but increased from nine to 12 years in female current smokers. Smokers at a later date may have inhaled more deeply, possibly to compensate for reductions in cigarettes' tar and nicotine content or that the years of lifetime smoking may have been distributed in a more damaging manner. Mehta and Preston (2012) found that these trends have continued, albeit at a slower pace, with a 1.0 year increase in mean duration of smoking among female smokers between ages 50 and 74 between 1987–92 and 1997–2003, with a very small increase for males. In summary, although the prevalence of smoking has declined, for those currently smoking, the average duration of smoking has increased.

Several factors adversely affect comparisons of smoking-attributable mortality between countries, including variations in definitions of smoking and lung cancer, changes over time in diagnosis and treatment of lung cancer, lack of national representativeness of some studies, and regional variations in the type of tobacco and ingredients used (Lee and Forey 2013). Note that these factors are only applicable to territories with a relatively mature smoking population.

Fenelon and Preston (2012) used the PGW method to assess the percentage of difference in mortality rates in 2004 among regions of the United States. Their paper indicated that among females, smoking-related mortality is responsible for 23 percent of the South's disadvantage as to mortality relative to the rest of the country and 35 percent of its excess mortality relative to the Mountain region. For males, differences in smoking explained 50 percent of its excess mortality relative to the rest of the United States and 60 percent of the disparity with that of the Mountain region.

4. Mortality

Exposure to cigarette smoke has been shown to increase mortality on a lagged basis (except for certain relatively infrequent causes of death such as property fires). That is, a period of years pass between exposure to smoking and death, the duration of which depends upon such factors as when exposure to smoking began, the length of exposure, the type of cigarettes used including their filtration and tar content, and the intensity of smoking, including the degree of inhalation, as well as comorbidities. This lag between exposure to smoking and consequential death can be two or five decades. Exposure can either be directly from smoking itself or from secondary inhalation of others' smoking.

The trends and lags by a major cause of death which is in turn caused by smoking can be seen in figure 1 in a comparison between overall rates of smoking prevalence and mortality due to trachea, bronchus and lung (TBL) cancers. One reason to compare smoking prevalence with these types of death is that a large percentage of these cancers are due to smoking and these causes of death are relatively accurately recorded. However, it is difficult to discern the precise lag until death from figure 1, since it does not follow individual cohorts, as the lag can differ significantly by the individual's type, level and duration of smoking. Thus, a study of the relation between current smoking prevalence and mortality can be misleading when changes in smoking prevalence or patterns occur and sufficient lags are not reported on.

With findings from NHIS' interviews between 1997 and 2004 (followed through December 2006), Jha et al. (2013) calculated that all-cause mortality for current smokers between ages 25 and 75 was three times the corresponding mortality of the never-smoked (3.0 hazard ratio for females and 2.8 for males). This is shown in table 5. The probability of surviving from age 25 to 75 was twice as great for never-smokers (70 percent to 38 percent for females and 61 percent to 36 percent for males). Another way of expressing this is that life expectancy was 10 years longer for never-smokers when compared with that of current-smokers.

Table 5 also shows, based on NHIS, the relative mortality between current and never-smokers by major direct cause of death, as given in Jha et al. (2013), with hazard ratios adjusted for age, educational level, alcohol consumption and BMI. Table 5 also provides for these direct causes of death for smokers the percentage attributable to smoking; these percentages are similar to those found in Kenfield et al. (2008), which showed that 64 percent of all deaths of current smokers were attributable to smoking.

Table 5. Adjusted mortality hazard rates by cause of death (ages 25 through 79)

	Females		**Males**	
	Hazard ratios: current to never-smokers	**Percent of deaths attributable to smoking among smokers**	**Hazard ratios: current to never-smokers**	**Percent of deaths attributable to smoking among smokers**
Lung cancer	17.8	94%	14.6	93%
Other cancers	1.7	41	2.2	55
Respiratory diseases	8.5	88	9.0	89
Ischemic heart disease	3.5	72	3.2	69
Strokes	3.2	69	1.7	40
Other vascular diseases (excl. ischemic, strokes)	3.1	68	2.1	52
Other medical conditions	3.0	66	2.9	65
Accidents and injuries	3.9	0	2.1	0
All causes	3.0	62	2.8	60

Source: Jha et al. (2013)

Significant adverse health effects of smoking include lung cancer, other cancers, cardiovascular disease and respiratory diseases including COPD, emphysema and tuberculosis. Peto et al. (2012) calculated that of an estimated 512,000 American adults who died in 2000 as a result of smoking, 185,000 died due to cancer, 144,000 died due to vascular diseases (including heart disease, stroke and other diseases of the arteries and veins), 108,000 died due to respiratory-related diseases and 75,000 died due to other causes. Of the 185,000 who died due to cancer, about 138,000 of the total 155,000 lung cancer deaths (the third most common cancer in the United States) died due to smoking.

The surgeon general's report (2014) expanded on prior reports by indicating that recent studies showed additional causes of death and health problems could be attributed to smoking. These include: liver and colorectal cancers, rheumatoid arthritis, diabetes, tuberculosis, age-related macular degeneration, immune system impairment, worsening asthma, cleft lips and palates in fetuses, and erectile dysfunction. The report indicated it was suggestive, but not definitive, that smoking can lead to breast cancer, but there was sufficient evidence that mechanisms exist through which cigarette smoking may cause breast cancer. The report found suggestive evidence that there was a higher risk of death from prostate cancer if one smokes, although causation has not been demonstrated. Bladder and cervical cancer had been added as being caused by smoking in earlier surgeon general reports. It also made the point that while smoking causes most cases of lung cancer (a current smoker is 25 times as likely to develop lung cancer as a nonsmoker), a current smoker is only about 1.5 times as likely to develop liver cancer as a nonsmoker.

The 2014 report also pointed out that today's smokers have a much higher risk for lung cancer and COPD than did smokers in 1964, despite smoking fewer cigarettes. This is in part because current smokers are likely to have been smoking for a longer period of time and because of changes in the design and composition of cigarettes, including the use of filters that can lead to more puffing of noxious materials and the use of blended tobaccos that contain carcinogenic nitrosamines.

Based on the Nurses Health Study reported on by Kenfield et al. (2008), the risk for all major causes of death except for cerebrovascular deaths increases significantly as the number of cigarettes smoked per day and pack-years of smoking increases. The strongest association by cause of death for those who smoked more than 35 cigarettes per day is for COPD (hazard ratio of 114.5) and for lung cancer (hazard ratio of 39.9). For current smokers, hazard ratios for other cancers were 10.18 for cervix cancer, 7.03 for esophagus cancer, 6.01 for pharynx cancer, 4.72 for lip and mouth cancers, 2.97 for bladder and kidney cancer, 2.84 for pancreas cancer, 1.72 for acute myeloid leukemia, 1.63 for colorectal cancers, 1.59 for stomach cancer and 1.20 for ovarian cancer. In addition, this study indicated all-cause mortality was 22 percent greater for current smokers who started smoking younger than age 18 (hazard ratio of 2.93) than for those starting after age 25 (hazard ratio of 2.40), at least partially due to differences in the duration of smoking.

In spite of the adverse trends resulting from past exposure to smoking, all-cause mortality globally has significantly improved for a very long time due to a wide range of factors. The annual number of premature deaths due to smoking, including the effect of secondhand smoke, was estimated by Jha (2009) to be more than 5 million in 2010 and is expected to be more than 10 million by 2030, of which 7 million will be from less developed countries. Oberg et al. (2011), based on a study of secondhand smoke in 2004 covering 192 countries, estimated that globally 33 percent of nonsmoking males, 35 percent of nonsmoking females and 40 percent of children have been exposed to secondhand smoke, resulting in about 603,000 annual deaths. The distribution of these estimated deaths was 47 percent adult females, 26 percent adult males and 28 percent children.

Unless smoking trends dramatically shift in the near future, cancer and total deaths due to smoking will inevitably increase, especially in developing countries. Most smokers worldwide are now between the ages of 20 and 40, while premature (smoking-attributable) deaths don't occur until somewhat later in life.

Over the last few decades, male mortality has improved at a faster rate than for females in many countries, in part due to the effect of significant decreases in male smoking prevalence. As the (lagged) effect of this trend gradually wears off over time, the differential rate of mortality improvement will likely reduce and may converge to that of females.

Tables 6 and 7 show trends in mortality attributed to lung and closely related (trachea and bronchus) cancers, for which a high percent is due to smoking, for three recent years (1999, 2003 and 2007) for adult American males and females, respectively, by attained age group. These tables also indicate the relationship between TBL cancers and all-cause mortality for the same demographic categories. Table 8 directly compares the values of the prior two tables for males and females.

For the eight-year period that spans experience in tables 6 to 8, both all-cause and TBL cancer mortality rates decreased for all ages for males, while for females, all-cause mortality increased at age group 45–49. TBL cancer mortality rates for females also increased in the 45–49 age group, as well as in the age 75+ categories. As a percent of all-cause mortality rates, TBL cancer mortality rates for males have decreased for ages through 64 and increased for age groups beginning at age 70, as those in this older birth cohort continue to suffer from TBL cancer due to exposure to smoking. As a percentage of all-cause mortality, TBL cancer mortality rates for females increased for age groups beginning at age 65, while it has decreased for those in their 50s, where females have begun to experience more favorable TBL cancer trends as the smoking prevalence for these cohorts has decreased. Expectations are that these patterns by age and gender will continue to change over time as the effect of differences in smoking prevalence among birth cohorts continues to be felt.

Note that a majority of deaths attributed to smoking are not due to TBL cancers, so the ratios indicated in relation to TBL do not represent the total effect of smoking. Also note that the decrease in TBL cancer mortality rates in the oldest age category are certainly due to multiple causes (comorbidities) of death that can result in underreporting of the contribution of TBL cancer to deaths.

Table 6. Trend in U.S. malignant neoplasms of trachea, bronchus and lung compared with all-cause mortality rates (per 100,000) for male adults

	40-44	45-49	50-54	55-59	60-64	65-69	70-74	75-79	80-84	85+
TBL Cancer mortality rates										
2007	6.7	20.3	45.1	85.0	156.0	265.6	368.1	475.3	530.8	453.0
2003	9.5	24.8	50.0	101.3	183.7	292.1	411.0	514.2	541.5	475.1
1999	10.4	24.7	56.3	120.7	212.3	327.1	442.8	505.8	547.7	509.2
Average	9.1	23.5	50.5	101.6	185.3	294.6	411.0	504.6	542.3	482.8
All-cause mortality rates										
2007	276.8	423.8	646.6	922.2	1,328.4	2,002.2	3,046.9	4,817.2	7,758.7	14,006.4
2003	304.1	457.9	660.8	942.3	1,462.2	2,216.6	3,428.7	5,400.3	8,513.7	15,794.0
1999	302.9	455.8	654.6	1,026.1	1,595.9	2,479.5	3,816.5	5,719.8	9,156.8	16,931.3
Average	296.6	447.5	654.1	951.5	1,454.4	2,210.1	3,416.9	5,330.9	8,469.8	15,718.0
TBL Cancer mortality as % All-cause mortality										
2007	2.4%	4.8%	7.0%	9.2%	11.7%	13.3%	12.1%	9.9%	6.8%	3.2%
2003	3.1%	5.4%	7.6%	10.8%	12.6%	13.2%	12.0%	9.5%	6.4%	3.0%
1999	3.4%	5.4%	8.6%	11.8%	13.3%	13.2%	11.6%	8.8%	6.0%	3.0%
Average	3.1%	5.2%	7.7%	10.7%	12.7%	13.3%	12.0%	9.5%	6.4%	3.1%
Change in TBL Cancer mortality rates										
Average Annual	-5.22%	-2.34%	-2.72%	-4.28%	-3.76%	-2.56%	-2.27%	-0.76%	-0.37%	-1.43%
2007/1999	-35.6%	-17.8%	-19.9%	-29.6%	-26.5%	-18.8%	-16.9%	-6.0%	-3.1%	-11.0%
Change in All-cause mortality rates										
Average Annual	-1.10%	-0.90%	-0.15%	-1.31%	-2.26%	-2.63%	-2.77%	-2.12%	-2.04%	-2.31%
2007/1999	-8.6%	-7.0%	-1.2%	-10.1%	-16.8%	-19.2%	-20.2%	-15.8%	-15.3%	-17.3%
Change in All-cause (other than TBL cancer) mortality rates										
Average Annual	-0.97%	-0.82%	0.08%	-0.96%	-2.04%	-2.64%	-2.83%	-2.26%	-2.16%	-2.34%
2007/1999	-7.7%	-6.4%	0.5%	-7.5%	-15.3%	-19.3%	-20.6%	-16.7%	-16.0%	-17.5%
Females/Males										
TBL Cancer mortality rates										
2007	104.5%	87.7%	72.1%	64.0%	66.1%	63.3%	62.9%	59.0%	54.2%	50.1%
2003	78.9%	71.8%	63.8%	62.7%	63.9%	60.3%	57.4%	54.0%	52.0%	46.5%
1999	77.9%	64.4%	63.4%	58.2%	56.3%	54.1%	52.9%	51.3%	47.2%	40.3%
Average	86.1%	74.0%	64.8%	62.3%	61.6%	59.2%	57.2%	54.3%	50.7%	45.4%

Source: CDC (December 2013)

Table 7. Trend in U.S. malignant neoplasms of trachea, bronchus and lung compared with all-cause mortality rates (per 100,000) for female adults

	40-44	45-49	50-54	55-59	60-64	65-69	70-74	75-79	80-84	85+
TBL Cancer mortality rates										
2007	7.0	17.8	32.5	54.4	103.1	168.1	231.5	280.6	287.7	227.0
2003	7.5	17.8	31.9	63.5	117.4	176.2	236.1	277.9	281.4	221.0
1999	8.1	15.9	35.7	70.2	119.6	177.1	234.4	259.7	258.7	205.3
Average	7.9	17.4	32.7	63.3	114.2	174.3	235.0	274.1	275.2	219.2
All-cause mortality rates										
2007	166.7	258.1	376.8	541.8	829.7	1,299.4	2,037.2	3,304.0	5,511.7	12,442.3
2003	179.2	263.2	380.9	579.7	928.8	1,427.1	2,256.6	3,625.3	6,036.0	14,062.5
1999	169.3	251.8	384.7	619.2	988.3	1,549.1	2,414.2	3,826.7	6,464.2	14,861.2
Average	174.2	259.3	379.9	578.2	916.6	1,422.6	2,234.7	3,582.7	5,991.3	13,784.6
TBL Cancer mortality as % All-cause mortality										
2007	4.2%	6.9%	8.6%	10.0%	12.4%	12.9%	11.4%	8.5%	5.2%	1.8%
2003	4.2%	6.8%	8.4%	11.0%	12.6%	12.3%	10.5%	7.7%	4.7%	1.6%
1999	4.8%	6.3%	9.3%	11.3%	12.1%	11.4%	9.7%	6.8%	4.0%	1.4%
Average	4.5%	6.7%	8.6%	10.9%	12.5%	12.3%	10.5%	7.7%	4.6%	1.6%
Change in TBL Cancer mortality rates										
Average Annual	-1.50%	1.44%	-1.14%	-3.12%	-1.82%	-0.64%	-0.15%	0.98%	1.35%	1.27%
2007/1999	-13.6%	11.9%	-9.0%	-22.5%	-13.8%	-5.1%	-1.2%	8.0%	11.2%	10.6%
Change in All-cause mortality rates										
Average Annual	-0.17%	0.32%	-0.25%	-1.65%	-2.15%	-2.17%	-2.10%	-1.81%	-1.97%	-2.18%
2007/1999	-1.5%	2.5%	-2.1%	-12.5%	-16.0%	-16.1%	-15.6%	-13.7%	-14.7%	-16.3%
Change in All-cause (other than TBL cancer) mortality rates										
Average Annual	-0.09%	0.24%	-0.16%	-1.47%	-2.20%	-2.38%	-2.32%	-2.04%	-2.12%	-2.24%
2007/1999	-0.9%	1.9%	-1.3%	-11.2%	-16.4%	-17.5%	-17.2%	-15.2%	-15.8%	-16.7%
Females/Males										
All-cause mortality rates										
2007	60.2%	60.9%	58.3%	58.8%	62.5%	64.9%	66.9%	68.6%	71.0%	88.8%
2003	58.9%	57.5%	57.6%	61.5%	63.5%	64.4%	65.8%	67.1%	70.9%	89.0%
1999	55.9%	55.2%	58.8%	60.3%	61.9%	62.5%	63.3%	66.9%	70.6%	87.8%
Average	58.7%	58.0%	58.1%	60.8%	63.0%	64.4%	65.4%	67.2%	70.7%	87.7%

Source: CDC (Dec 2013)

The increasing trend in the ratio of female-to-male TBL cancer mortality rates is evident in table 8. Because the lag between exposure to smoking and mortality by cause differs (for example, the lag between exposure to smoking and consequential cardiovascular disease tends to be generally longer than the lag with respect to TBL cancer, and between exposure to smoking and respiratory-related diseases tends to be shorter), it is important to recognize these differences in projecting future differences. At younger ages (that is, earlier than age 45), the risk of dying from smoking due to lung disease is now at least as great for females as for males.

Table 8. Female to male trends in U.S. malignant neoplasms of trachea, bronchus and lung (TBL) compared with total mortality

	40-44	45-49	50-54	55-59	60-64	65-69	70-74	75-79	80-84	85+
TBL Cancer mortality rates										
2007	104.5%	87.7%	72.1%	64.0%	66.1%	63.3%	62.9%	59.0%	54.2%	50.1%
2003	78.9%	71.8%	63.8%	62.7%	63.9%	60.3%	57.4%	54.0%	52.0%	46.5%
1999	77.9%	64.4%	63.4%	58.2%	56.3%	54.1%	52.9%	51.3%	47.2%	40.3%
Average	86.1%	74.0%	64.8%	62.3%	61.6%	59.2%	57.2%	54.3%	50.7%	45.4%
All-cause mortality rates										
2007	60.2%	60.9%	58.3%	58.8%	62.5%	64.9%	66.9%	68.6%	71.0%	88.8%
2003	58.9%	57.5%	57.6%	61.5%	63.5%	64.4%	65.8%	67.1%	70.9%	89.0%
1999	55.9%	55.2%	58.8%	60.3%	61.9%	62.5%	63.3%	66.9%	70.6%	87.8%
Average	58.7%	58.0%	58.1%	60.8%	63.0%	64.4%	65.4%	67.2%	70.7%	87.7%
TBL Cancer mortality as % All-cause mortality										
2007	173.5%	144.0%	123.7%	108.9%	105.8%	97.5%	94.1%	86.1%	76.3%	56.4%
2003	134.0%	124.9%	110.7%	101.9%	100.6%	93.7%	87.3%	80.5%	73.3%	52.2%
1999	139.3%	116.5%	107.9%	96.4%	91.0%	86.7%	83.7%	76.7%	66.9%	45.9%
Average	147.1%	127.7%	111.6%	102.5%	98.0%	92.1%	87.6%	80.9%	71.8%	51.9%
Change in TBL Cancer mortality rates : males - females										
Average Annual	-3.7%	-3.8%	-1.6%	-1.2%	-1.9%	-1.9%	-2.1%	-1.7%	-1.7%	-2.7%
2007/1999	-22.0%	-29.8%	-10.9%	-7.1%	-12.7%	-13.7%	-15.6%	-14.1%	-14.3%	-21.6%
Change in All-cause mortality rates : males - females										
Average Annual	-0.9%	-1.2%	0.1%	0.3%	-0.1%	-0.5%	-0.7%	-0.3%	-0.1%	-0.1%
2007/1999	-7.1%	-9.5%	0.8%	2.4%	-0.7%	-3.1%	-4.5%	-2.1%	-0.5%	-1.0%
Change in All-cause (other than TBL cancer) mortality rates : males - females										
Average Annual	-0.9%	-1.1%	0.2%	0.5%	0.2%	-0.3%	-0.5%	-0.2%	0.0%	-0.1%
2007/1999	-6.7%	-8.3%	1.9%	3.7%	1.1%	-1.8%	-3.4%	-1.5%	-0.2%	-0.8%

Source: CDC (Dec 2013)

Table 9 shows ratios of current and former smokers to never-smokers, with age-adjusted hazard ratios (not multivariable-adjusted) as given in Thun et al. (2013). The sources of the data underlying this table are from the large-scale American Cancer Society's Cancer Prevention Study II, while the contemporary set of studies includes the combined experience of five more recent studies (the National Institutes of Health/AARP Diet and Health Study, CPS-II Nutrition Cohort, the Women's Health Initiative, the Nurses Health Study and the Health Professionals Follow-up Study). Thun et al. observed that the increased mortality risks from smoking were similar for males and females. Hazard ratios of mortality for current smokers to never-smokers were particularly high for lung cancer and COPD, both of which are primarily the result of exposure to smoking.

According to Thun et al. (2013), hazard ratios by gender over the last 50 years for those who continued to smoke has been 1.76 for males and 1.35 for females during the period 1959–65, 2.33 for males and 2.08 for females during the period 1982–86, and 2.80 for males and 2.36 for females during 2000–10. For current smokers, average mortality rates have increased over time, at the same time that the number of cigarettes smoked per day has decreased, indicating either that current smokers have smoked for a longer period or that the effect of cigarettes have become more toxic.

Table 9. Ratios of current and former smokers to never-smokers
with age-adjusted (not multivariable-adjusted) hazard ratios

Cause of death	Females				Males			
	Current Smokers		Former Smokers		Current Smokers		Former Smokers	
	CPS II	Contemporary	CPS II	Contemporary	CPS II	Contemporary	CPS II	Contemporary
	1982-1988	2000-2010	1982-1988	2000-2010	1982-1988	2000-2010	1982-1988	2000-2010
Lung cancer	12.65	25.66	3.77	6.66	25.30	27.32	7.60	7.13
COPD	10.31	23.03	5.84	7.88	10.50	28.97	6.96	7.62
Ischemic heart disease	2.00	2.93	1.20	1.40	1.86	2.69	1.30	1.49
Other heart disease	1.89	1.89	1.15	1.21	1.99	2.35	1.20	1.34
Stroke	2.20	2.12	1.12	1.14	2.08	2.00	1.07	1.16
All causes	2.08	2.76	1.28	1.44	2.43	2.98	1.43	1.53

Source: Thun et al. (2013)

Overall, males appear to have had a greater sensitivity to smoking than females. This in part may be due to consumption by females of fewer cigarettes per day and a tendency to smoke cigarettes with lower tar content.

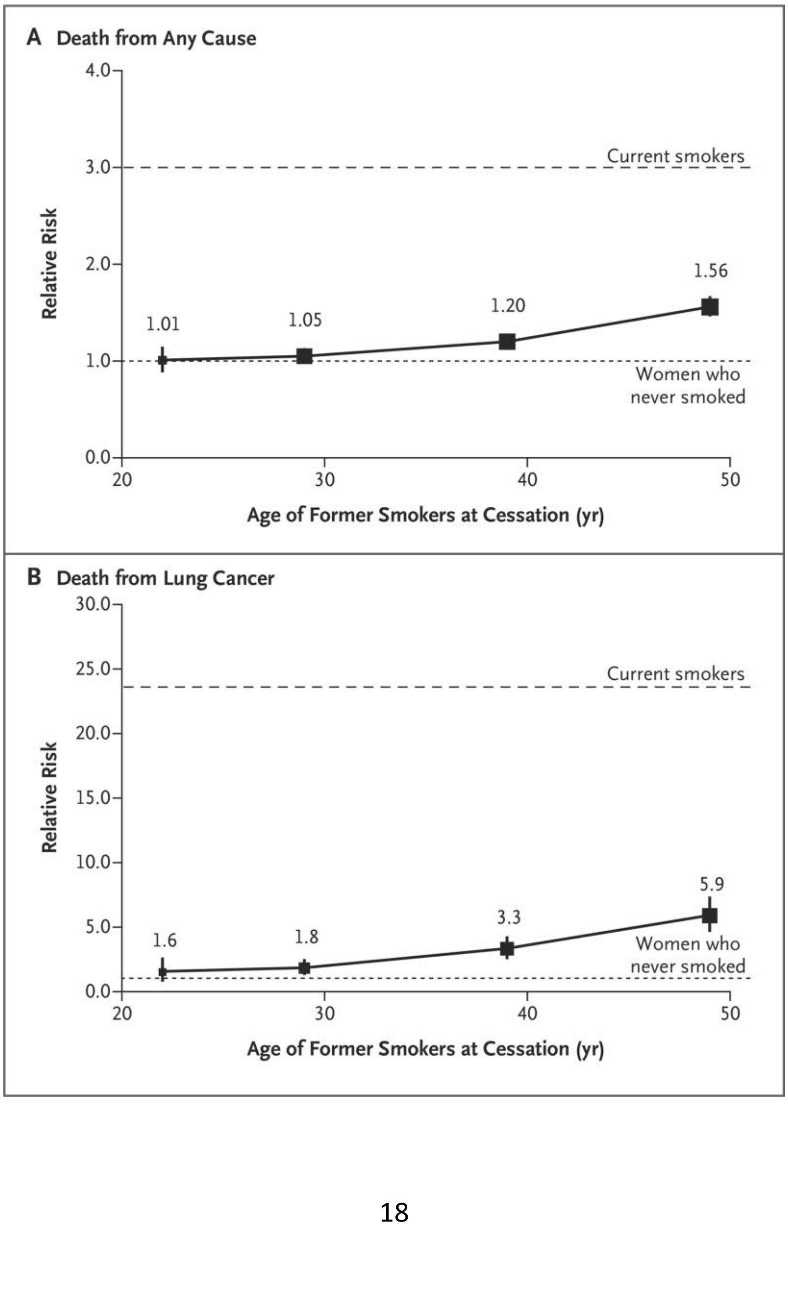
5. Smoking Cessation

While attributable mortality increases slowly after initial exposure to smoking, the effects of cessation appear to emerge more rapidly. According to Jha et al. (2013), adults who quit smoking between ages 25 and 34 live 10 years longer than those who continue to smoke, nine years longer if they quit between 35 and 44, and six years longer if they quit between the ages of 45 and 54. These years of life lost compare with a loss of 10 years of life expectancy for current smokers compared with that of never-smokers. Adults who quit smoking prior to age 40 reduce their risk of death compared with if they had continued to smoke by about 90 percent (although Jha et al. (2013) pointed out this still leaves a 20 percent excess mortality risk for those in the latter category).

To illustrate the benefits of smoking cessation, multivariable-adjusted hazard ratios for females whose smoking began by age 19 (using never-smoker females as the benchmark), from Jha and Peto (2014) based on the U.K. Million Women Study, are given in figure 2 for all-causes (A) and for lung cancer (B).

Among those age 45 to 64 in both the United States and the European Union, there are now about as many former smokers as current smokers (in contrast, in many developing countries' stage of smoking prevalence, there are far more current smokers than former smokers).

Figure 2. Hazard ratios of the effect of smoking cessation at various ages of U.K. females



Source: Jha and Peto (2014)

Although as indicated, excess mortality after smoking cessation wears off over time, this period differs depending on the length and intensity of exposure to smoking. Peto et al. (2000) estimated that between 10 and 19 years after cessation, lung cancer mortality rates are 42 and 21 percent of that of current smokers for males and females, respectively; for the period between 20 and 29 years, the corresponding percentages are 28 and 5 percent of that of current smokers. Some studies have indicated that those who stopped smoking for more than 30 years have not experienced any appreciable extra mortality.

The data in table 10 was taken from Kenfield et al. (2008), reporting on hazard ratios from the Nurses Health Study, followed from 1980 to 2004 with a 22-year follow-up period covering 104,519 female lives. The benchmarks for these ratios are age-adjusted mortality rates, adjusted for various physical and medical conditions. This shows an overall decrease in mortality of 31 percent over the first five years since cessation, with decreases in mortality by period since cessation that vary significantly by direct cause of death, with the fastest decrease being for vascular diseases.

Table 10. Effect of smoking cessation on females by years since cessation

Direct cause of death	**Years since smoking cessation**					
	< 5	**5 to < 10**	**10 to < 15**	**15 to < 20**	**20 or more**	**never**
Vascular	69%	52%	51%	43%	30%	31%
Respiratory (excluding lung cancer)	126	82	59	35	15	10
Lung cancer	79	53	33	18	10	5
Other cancers (smoking related)	79	60	40	24	19	14
Other cancers	89	73	79	79	61	63
Other	109	87	71	61	57	54
All cause	87%	67%	59%	49%	37%	36%

Source: Kenfield et al. (2008), adjusted for age and mortality risk factors

As more people have stopped smoking cigarettes and exposure to secondhand smoke has decreased over the last two decades as a result of, among other factors, restrictions in smoking in public places, this wearing off of the adverse effect on mortality has had and will continue to have a significant effect on smoking-attributable deaths.

Note that since some of those who quit smoking do so as a result of the disease that eventually kills them, the hazard ratios for former smoker may be biased upward. As a result, the benefits of cessation reported in studies of current smokers may be greater than indicated.

Of course, given the addictive nature of nicotine, it is extremely difficult to cease smoking. Certainly a majority of cessation efforts and treatments fail, and a majority of current smokers are apparently unwilling to attempt to quit, possibly because of past failed efforts.

6. Mortality improvement

Table 11 provides perspective on overall rates of annual mortality improvement for adults in five-year age groupings between five-year calendar years, based on data in the Human Mortality Database (as of November 2013).

Table 11. Annual all-cause annual rate of change in mortality rates for U.S. adults by age, gender and calendar period

from:	1935-1939	1940-1944	1945-1949	1950-1954	1955-1959	1960-1964	1965-1969	1970-1974	1975-1979	1980-1984	1985-1989	1990-1994	1995-1999	2000-2004
to:	1940-1944	1945-1949	1950-1954	1955-1959	1960-1964	1965-1969	1970-1974	1975-1979	1980-1984	1985-1989	1990-1994	1995-1999	2000-2004	2005-2009
Females														
40-44	-3.5%	-4.1%	-3.5%	-2.9%	-0.5%	0.3%	-1.0%	-3.8%	-3.3%	-1.7%	-0.4%	0.5%	0.7%	-0.9%
45-49	-3.4%	-2.9%	-3.3%	-2.4%	-0.4%	0.2%	-0.9%	-3.2%	-2.6%	-1.8%	-1.2%	-0.8%	0.8%	0.1%
50-54	-2.8%	-2.9%	-2.3%	-2.7%	-0.6%	-0.3%	-1.2%	-2.3%	-1.7%	-1.2%	-1.7%	-1.4%	-0.6%	0.0%
55-59	-1.9%	-2.5%	-2.8%	-1.9%	-1.6%	-0.1%	-0.4%	-2.5%	-0.8%	-0.8%	-1.2%	-1.3%	-1.4%	-1.7%
60-64	-2.1%	-2.4%	-2.2%	-1.9%	-0.2%	-1.5%	-1.3%	-1.7%	-0.8%	-0.3%	-1.1%	-0.9%	-1.5%	-2.2%
65-69	-2.4%	-2.7%	-1.9%	-1.2%	-1.4%	-0.7%	-1.9%	-2.6%	0.0%	-0.3%	-0.8%	-0.7%	-1.2%	-2.4%
70-74	-1.4%	-2.3%	-2.1%	-1.8%	-1.2%	-1.2%	-0.8%	-2.7%	-1.2%	-0.3%	-1.0%	-0.3%	-1.1%	-2.1%
75-79	-1.6%	-1.6%	-2.0%	-1.4%	-1.2%	-1.0%	-1.7%	-3.2%	-1.3%	-0.4%	-1.1%	-0.2%	-0.5%	-1.9%
80-84	-0.6%	-2.2%	-1.3%	-0.5%	-0.5%	-1.1%	-1.7%	-2.7%	-1.0%	-0.7%	-1.0%	0.2%	-0.6%	-2.1%
85-89	-1.0%	-1.4%	-1.3%	-0.1%	-0.3%	-0.9%	-1.7%	-2.7%	-0.9%	-0.4%	-1.2%	0.6%	0.1%	-2.0%
90-94	-0.2%	-1.3%	-0.3%	-0.2%	0.1%	-0.7%	-1.4%	-2.2%	-0.8%	0.2%	-0.9%	0.8%	0.6%	-1.4%
95-99	0.0%	-0.2%	1.6%	0.4%	0.4%	-0.6%	-0.9%	-1.7%	-0.4%	0.6%	-0.5%	1.1%	0.9%	-1.1%
Males														
40-44	-3.3%	-2.7%	-2.4%	-1.9%	-0.3%	0.8%	-0.8%	-3.2%	-2.8%	-0.2%	1.4%	-1.8%	-1.6%	-1.6%
45-49	-2.3%	-2.0%	-1.8%	-1.4%	-0.1%	0.3%	-0.6%	-3.1%	-2.8%	-1.7%	-0.7%	-1.1%	-0.3%	-1.2%
50-54	-1.3%	-1.2%	-1.3%	-1.1%	-0.1%	-0.1%	-1.5%	-2.3%	-2.3%	-2.0%	-2.0%	-2.0%	-0.3%	-0.1%
55-59	-0.1%	-0.8%	-1.3%	-1.0%	-0.4%	0.4%	-0.8%	-3.1%	-1.5%	-1.7%	-2.2%	-2.2%	-1.7%	-0.7%
60-64	-0.6%	-0.6%	-0.6%	-0.3%	0.4%	0.0%	-1.2%	-2.3%	-2.2%	-1.1%	-2.0%	-2.0%	-2.4%	-2.0%
65-69	-1.2%	-1.3%	0.0%	0.1%	0.2%	0.0%	-1.0%	-2.5%	-1.4%	-1.5%	-1.6%	-1.9%	-2.4%	-2.6%
70-74	-0.6%	-1.5%	-0.6%	-0.2%	0.1%	0.4%	-0.4%	-1.9%	-1.6%	-1.1%	-2.3%	-1.3%	-2.3%	-2.9%
75-79	-1.1%	-1.0%	-1.2%	-0.5%	0.2%	0.3%	-0.5%	-2.2%	-0.9%	-0.8%	-1.9%	-1.3%	-1.6%	-2.6%
80-84	-0.2%	-1.9%	-0.6%	-0.1%	0.1%	-0.2%	-0.8%	-1.5%	-0.6%	-0.5%	-1.2%	-0.8%	-1.8%	-2.7%
85-89	-0.5%	-1.2%	-0.8%	0.0%	0.2%	-0.4%	-1.0%	-1.6%	-0.4%	-0.2%	-0.9%	0.0%	-0.9%	-2.5%
90-94	0.3%	-1.0%	-0.3%	0.0%	0.3%	0.0%	-1.2%	-1.4%	-0.4%	0.4%	-0.6%	0.5%	0.0%	-1.7%
95-99	0.4%	0.2%	1.9%	0.6%	0.7%	-0.7%	-0.2%	-1.2%	0.2%	0.5%	0.0%	0.5%	0.6%	-1.2%
from:	**1935-1939**	**1940-1944**	**1945-1949**	**1950-1954**	**1955-1959**	**1960-1964**	**1965-1969**	**1970-1974**	**1975-1979**	**1980-1984**	**1985-1989**	**1990-1994**	**1995-1999**	**2000-2004**
to:	**1940-1944**	**1945-1949**	**1950-1954**	**1955-1959**	**1960-1964**	**1965-1969**	**1970-1974**	**1975-1979**	**1980-1984**	**1985-1989**	**1990-1994**	**1995-1999**	**2000-2004**	**2005-2009**
Males - Females														
40-44	-0.2%	-1.4%	-1.0%	-1.1%	-0.2%	-0.5%	-0.2%	-0.6%	-0.5%	-1.5%	-1.8%	2.3%	2.3%	0.7%
45-49	-1.1%	-0.9%	-1.6%	-0.9%	-0.3%	0.0%	-0.3%	-0.1%	0.3%	-0.1%	-0.5%	0.2%	1.0%	1.3%
50-54	-1.4%	-1.7%	-0.9%	-1.5%	-0.6%	-0.2%	0.3%	0.0%	0.6%	0.8%	0.3%	0.6%	-0.3%	0.1%
55-59	-1.8%	-1.7%	-1.6%	-0.9%	-1.2%	-0.5%	0.4%	0.6%	0.7%	0.9%	1.0%	0.9%	0.4%	-0.9%
60-64	-1.6%	-1.8%	-1.6%	-1.6%	-0.7%	-1.5%	0.0%	0.6%	1.4%	0.9%	0.8%	1.2%	0.8%	-0.2%
65-69	-1.2%	-1.4%	-2.0%	-1.3%	-1.6%	-0.7%	-0.9%	-0.2%	1.4%	1.2%	0.8%	1.2%	1.2%	0.2%
70-74	-0.8%	-0.8%	-1.6%	-1.6%	-1.4%	-1.6%	-0.5%	-0.8%	0.4%	0.7%	1.2%	1.0%	1.2%	0.7%
75-79	-0.4%	-0.6%	-0.9%	-0.9%	-1.3%	-1.3%	-1.2%	-1.0%	-0.3%	0.4%	0.8%	1.1%	1.1%	0.7%
80-84	-0.4%	-0.3%	-0.7%	-0.4%	-0.7%	-0.9%	-0.9%	-1.1%	-0.4%	-0.2%	0.2%	0.9%	1.3%	0.5%
85-89	-0.4%	-0.2%	-0.5%	-0.1%	-0.5%	-0.4%	-0.7%	-1.0%	-0.5%	-0.2%	-0.3%	0.5%	1.0%	0.6%
90-94	-0.5%	-0.3%	-0.1%	-0.1%	-0.1%	-0.6%	-0.2%	-0.9%	-0.4%	-0.2%	-0.3%	0.3%	0.6%	0.3%
95-99	-0.4%	-0.4%	-0.3%	-0.1%	-0.3%	0.2%	-0.8%	-0.5%	-0.7%	0.0%	-0.5%	0.5%	0.3%	0.2%
Unweighted average														
	-0.9%	-1.0%	-1.1%	-0.9%	-0.7%	-0.7%	-0.4%	-0.4%	0.2%	0.2%	0.1%	0.9%	0.9%	0.3%

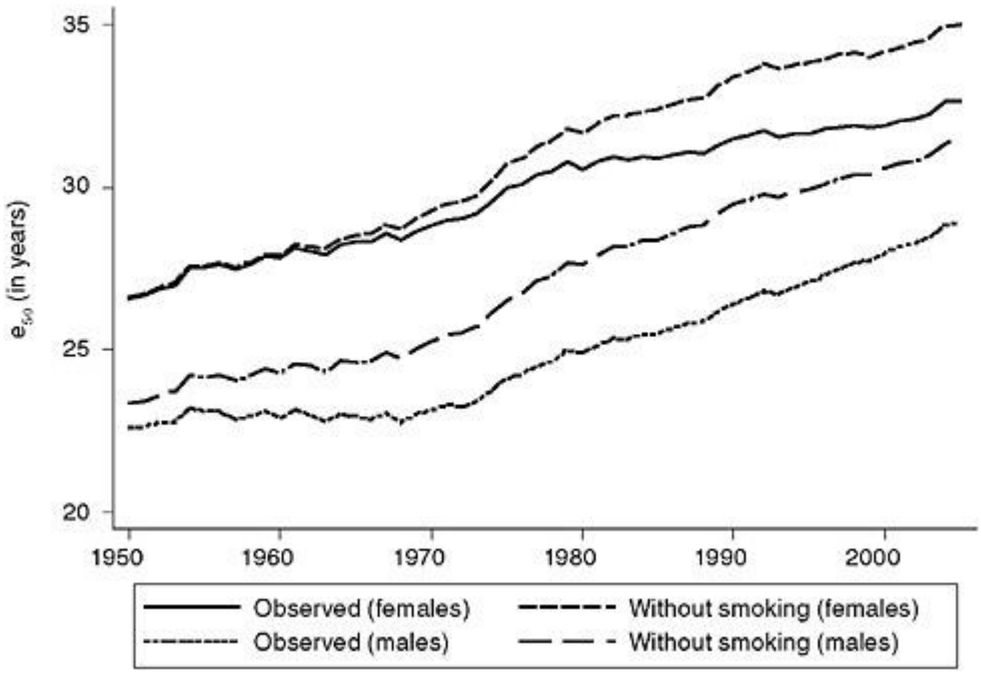
Source: Human Mortality Database
Note: a negative value in the part of this table represents a mortality improvement

Aggregate gender differences in adult mortality rates can be seen by comparing life expectancies at ages such as 50. Trends in life expectancy at age 50 for males and females are shown in figure 3; differences between them are shown in figure 4. The differential in life expectancy at age 50 by gender reached a maximum in the United States in the 1970s and has decreased since then. Also shown is the estimated effect of these life expectancies without smoking—note the limited effect of smoking-attributable deaths on females prior to 1950, reflecting the limited smoking by females prior to the 1940s as seen in figure 1.

Preston, Glei and Wilmoth (2010) decomposed the sources of gain in life expectancies over the period 1950–2003 into smoking-attributable and non-smoking attributable gains using the method described by Pollard (1988). Pollard's method performs a decomposition in terms of observed changes in the mortality differentials of the individual causes and observed change in overall mortality level. Preston, Glei and Wilmoth found that life expectancy for males that increased by 5.82 years consisted of a deterioration due to smoking of 0.82 years, offset by an improvement due to other factors of 6.64 years. Corresponding values for females were a total gain of 5.70 years, consisting of a deterioration of 1.58 years due to smoking, offset by improvement due to other factors of 7.28 years.

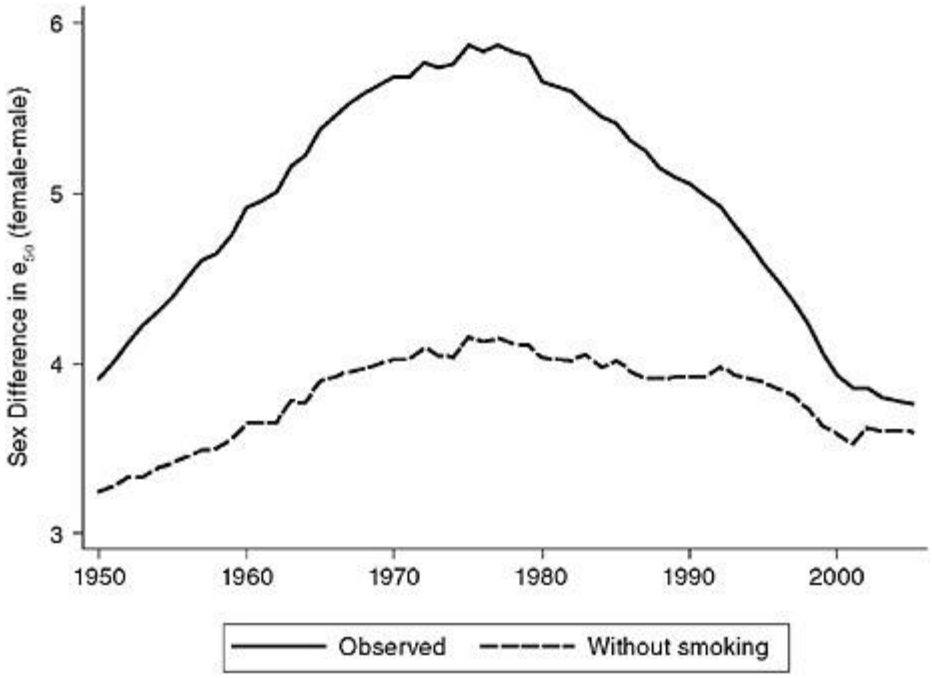
Key drivers of these changes, as described above, include the lagged effects of changes and timing in the patterns of smoking prevalence. At some time in the future, the rate of improvement in male mortality will decline as the effect of the reduction in smoking prevalence wears off. Females will experience a consequential mortality improvement from their reduction in smoking prevalence later than have males.

Figure 3. Trends in observed and estimated without-smoking life expectancy (e_{50}) age 50 of Americans



Source: Preston, Glei and Wilmoth (2010), based on 2009 figures from the Human Mortality Database and World Health Organization Mortality Database

Figure 4. Trends in observed and estimated gender difference in life expectancy at age 50 of Americans



Source: Preston, Glei and Wilmoth (2010), based on 2009 figures from the Human Mortality Database and World Health Organization Mortality Database

Ho and Elo (2013), using the PGW indirect estimation method based on NHIS with deaths through 2006, found that a significant reason for the difference in mortality between black and white American males was the difference in exposure to smoking, while there was a much smaller contribution from differences in exposure to smoking for females. While smoking-attributable mortality reduced life expectancy at age 50 for white males by 2.86 years in 1990 and 2.21 years in 2005, corresponding reductions for black males were 4.50 years in 1990 and 3.09 years in 2005. They estimated that 29.7 percent of white male deaths and 33.1 percent of black male deaths were attributable to smoking, with the much larger prevalence of current light smokers (less than one pack per day) of black males more than offsetting the smaller prevalence of heavy smokers of white males. The corresponding effects by race of smoking on mortality differentials by race for females were much smaller: a reduction in life expectancy at age 50 of 0.74 years for white females and 0.80 for black females. By 2005, these had increased to 1.72 and 1.66 years for white females and black females, respectively.

Ho and Elo also found that, although excess mortality rates attributable to smoking for males differed by race, the proportional effects of smoking did not differ appreciably by race. Black males have experienced greater smoking-attributable mortality in spite of relatively similar cohort smoking prevalence patterns—they hypothesized that this difference may be due to lower smoking cessation rates, longer smoking durations, different types of inhalation and percent of each cigarette smoked, as well as a possible tendency for blacks to be diagnosed at a later stage for smoking-related cancers and with a greater burden of comorbidities.

Mehta and Preston (2012) found that the relative risk of death among current and former smokers has continued to increase over time. This may be due to the fact that those currently smoking have smoked for a longer period of time and tended on average to draw on cigarettes more intensely. They concluded that due to these factors, the lag between the reduction in smoking prevalence and mortality improvement should be expected to lengthen over time.

7. Projections

Several recent mortality projections have considered the effect of smoking, several of which also considered the effect of obesity. Examples include Preston et al. (2014); Mehta and Chang (2011); Reither, Olshansky and Yang (2011); Stewart, Cutler and Rosen (2009); Wang and Preston (2009); Preston et al. (2009); and Preston and Wang (2006).

Preston and Wang (2006) projected under three possible scenarios the probability of those at age 50 who survive to age 85 as of 2003 using an age-period cohort model. The first, based on actual smoking histories, resulted in probabilities of 30.4 and 46.8 percent for males and females, respectively. Second, based on 2000 current smoking behavior, these probabilities were 38.4 and 47.9 percent for males and females, respectively. In contrast to the first two scenarios, if no one had smoked, these probabilities would be 46.4 percent and 51.9 percent for males and females, respectively. The ratios of survival probabilities for females to males in these three scenarios are 154, 125 and 112 percent respectively.

Wang and Preston (2009) projected continued significant reductions in male mortality due to changes in smoking prevalence at ages older than 50 in the United States between now and 2034, while they projected improvements among females were projected to be at a slower pace over this period. They concluded that the rate of mortality improvement would subside thereafter, with continued improvement having to come from other sources. Life expectancy (e_{50}) for males in 2003 was estimated by Preston et al. (2009) to be 2.8 years greater if smoking-attributed deaths were eliminated, while female e_{50} would be 2.6 years longer. For their projection period of 2009 and 2034, Wang and Preston (2009) estimated that reductions in smoking will increase the probability of male survival to age 85 by 15.8 percent (equivalent to an average annual rate of 0.59 percent) and female survival by 7.2 percent (equivalent to an average annual rate of 0.28 percent).

In a similar projection, Preston et al. (2014) estimated that between 2010 and 2035, an improvement in this probability of 13.4 percent (equivalent to an average annual rate of 0.50 percent) for males and 4.7 percent (equivalent to an average annual rate of 0.18 percent) for females.

Stewart, Cutler and Rosen (2009) developed a corresponding projection but did not differentiate their extrapolated trends by gender. They used data from NHIS and NHANES in projecting a 0.31 gain in life expectancy at age 18 between 2005 and 2020. Fairly consistent with this, Preston et al. (2014) projected an increase in life expectancy at age 40 by 0.80 years for males and 0.15 years for females (with an average of 0.47 years). In Preston et al.'s projection for the 10-year period ending in 2020, there was for an annual improvement of 0.28 years, compared to Stewart, Cutler and Rosen's 0.31 years over a 15-year period.

Preston et al. (2014) found, in studying the combined effect of smoking and obesity, that the mortality effect of smoking dominates that of obesity at ages older than 60, while the opposite holds at ages younger than 60. Their projected effect of smoking on life expectancy at age 50 is given in table 12. Through 2040, they projected that reductions in smoking prevalence for males will more than offset the effect of increases in obesity—at age 40 the combined effect is expected to be an increase in life expectancy for males of 0.83 years, with the effect of the two factors on females largely offsetting each other, with an expected gain in life expectancy at age 40 of 0.09 years by 2040. For changes in smoking alone, the gain in life expectancy is 1.54 years for males and 0.85 years for females, while for the changes in obesity alone, the corresponding reduction in life expectancy is 0.73 years for males and 0.82 for females.

Male cohorts with the highest smoking prevalence rates are now older than 80, while for females the excess mortality in the older-age cohorts will get worse at older ages as the cohort with the highest smoking prevalence rates replaces the lighter smokers at ages of greatest vulnerability to premature death. Note in table 12, the limited growth in life expectancy in females until about 2025, when the heaviest smoking cohort continues to disappear. Between 2025 and 2040, Preston et al. (2014) project about the same level of improvement due to changes in smoking for both genders.

Table 12. Cumulative projected effect of smoking in years of life expectancy at age 50 from 2010

Projection year	Males	Females
2015	+0.256	−0.026
2020	0.529	+0.038
2025	0.799	0.146
2030	1.035	0.322
2035	1.294	0.622
2040	1.515	0.848
2025–40	0.716	0.702

Source: Preston et al. (2014)

Several approaches to reflecting these gender-specific mortality effects of smoking have been used. One approach is to use estimates developed from a comprehensive cause-of-death mortality model, at least over the short-term period (such assumptions after, say, 20 or 30 years are speculative, at best, in any event). Another is to modify a cause-independent approach. An example of the latter approach is seen in Wang and Preston (2009), who added a cohort-specific term to a Lee-Carter based projection. With a projection period between 2009 and 2034, they estimated the probability of survival between ages 50 and 85 (shown in table 13) that increased 15.8 percent for males and 7.2 percent for females.

Table 13. Probability of surviving from age 50 to age 85

Year	Lee-Carter with smoking factor		Lee-Carter without smoking factor	
	Males	**Females**	**Males**	**Females**
2004	31.9%	47.2%	31.3%	47.8%
2009	35.9	49.8	34.0	49.7
2014	40.4	42.4	36.6	51.6
2019	44.9	55.1	39.3	43.5
2024	49.3	57.9	42.0	55.3
2029	53.8	60.7	44.6	57.1
2034	57.7	63.2	47.1	58.9

Source: Wang and Preston (2009)

The estimation of the effect of smoking on mortality and mortality trends involves significant challenges and uncertainties. This is due, among other factors, to the changing dynamics of contributions to and historical trends in mortality, a lack of availability of relevant and high quality attributable mortality data, reference populations of smoker and never-smoked lung cancer deaths, confounding and relative risk attribution to causes such as obesity, changes in smoking patterns and the fundamentally long lag between exposure to smoking and death that varies by cause and confounding factor, the effect of carcinogenic effects including environmental smoke, changes in treatment of applicable medical conditions, changes in future exposure and effects of cessation.

8. Final observations

Trends in smoking prevalence and consequential mortality by gender are important factors to consider in any long-term mortality projection.

Many approaches have been used to determine smoking attribution to mortality, mostly indirect methods using as a base the differential rates of lung cancer and relationship between lung cancer (more than 90 percent for males and about 85 percent for females that are due to smoking) and all-cause mortality.

Rates of mortality improvement, which in the last several decades has been greater for males, could converge to those of females after the next several decades as the effect on mortality of the earlier dramatic decreases in male smoking prevalence are followed by the effects of the smaller but still significant (but similar in percentage terms) reductions in female smoking prevalence.

Consideration of the effect of smoking and smoking cessation should be made in any mortality projection. Several approaches can be utilized, including incorporating a cause-of-death based projection or an adjustment to a statistical technique such as Lee-Carter. Depending on the timeframe of the projection, a strictly statistical extrapolation of trends will not capture these significant underlying changes.

Although the focus of this paper is on the relationship between smoking and mortality, smoking also has significant effects on overall health. According to the 2014 surgeon general's report, "The evidence is sufficient to infer a causal relationship between smoking and diminished overall health. Manifestations of diminished overall health among smokers include self-reported poor health, increased absenteeism from work, and increased health care utilization and cost." Estimates from three approaches to estimating smoking-attributable health care costs have ranged from 7.6 to 8.7 percent of total health care expenditures.

To continue to reduce the prevalence of smoking, aggressive action in each country will have to be taken. According to the World Health Organization's "WHO Report on the Global Tobacco Epidemic 2013," six programs need to implemented, addressing the measurement, education and mitigation of the adverse health effects of smoking: (1) monitoring tobacco use and prevention policies, (2) warning people about the dangers of tobacco by means of health warning labels on cigarette packaging and through mass media campaigns, (3) enforcing bans on tobacco advertising, promotion and sponsorship, (4) protecting people from secondhand smoke through expanded smoke-free areas, (5) offering help to quit tobacco use and (6) increasing taxes on tobacco.

More research is needed to further refine the measurement and projection of the effects of smoking-attributable mortality by gender, age and cohort as smoking prevalence continues its decline of the past several decades.

Mortality of Smoking by Gender, by Sam Gutterman, FSA, FCAS, CERA, HonFIA

2014 Living to 100 Symposium

List of figures and tables

Figures

Tables

References

Blackwell, Debra L., Jacqueline W. Lucas, Tainya C. Clarke. "Summary Health Statistics for U.S. Adults: National Health Interview Survey 2012." *National Center for Health Statistics.* Vital Health Stat 10(260). 2014.

Doll, Richard, Richard Peto, Jillian Boreham, and Isabelle Sutherland. 2004. "Mortality in Relation to Smoking: 50 Years' Observations on Male British Doctors." *BMJ* 328 (7455): 1–9. doi:10.1136/bmj.38142.554479.AE.

Ezzati, Majid, and Alan D. Lopez. 2003. "Estimates of Global Mortality Attributable to Smoking in 2000." *The Lancet* 362 (9387): 847–52.

———. 2004. "Smoking and Oral Tobacco Use." In *Comparative Quantification of Health Risks*, vol. 1, edited by Majid Ezzati, Alan D. Lopez, Anthony Rodgers, and Christopher J. L. Murray, 883–937. Geneva: World Health Organization.

Fenelon, Andrew, and Samuel H. Preston. 2012. "Estimating Smoking-Attributable Mortality in the United States." *Demography* 49 (3): 797–818. doi:10.1007/s13524-012-0108-x.

Giovino, Gary A., Sara A. Mirza, Jonathan M. Samet, Prakash C. Gupta, Martin J. Jarvis, Neeraj Bhala, Richard Peto, et al. 2012. "Tobacco Use in 3 Billion Individuals from 16 Countries: An Analysis of Nationally Representative Cross-Sectional Household Surveys." *The Lancet* 380 (9842): 668–79.

Ho, Jessica Y., and Irma T. Elo. 2013. "The Contribution of Smoking to Black-White Differences in U.S. Mortality." *Demography* 50 (2): 545–68. doi:10.1007/s13524-012-0159-z.

Janssen, Fanny, Leo J. G. van Wissen, and Anton E. Kunst. 2013. "Including the Smoking Epidemic in Internationally Coherent Mortality Projections." *Demography* 50 (4): 1341–62. doi:10.1007/s13524-012-0185-x.

Jha, Prabhat. 2009. "Avoidable Global Cancer Deaths and Total Deaths from Smoking." *Nature Reviews Cancer* 9 (September): 65564. doi:10.1038/nrc2703.

Jha, Prabhat, and Richard Peto. 2014. "Global Effects of Smoking, of Quitting, and of Taxing Tobacco." *New England Journal of Medicine* 370 (1): 60–64.

Jha, Prabhat, Chinthanie Ramasundarahettige, Victoria Landsman, Brian Rostron, Michael Thun, Robert N. Anderson, Tim McAfee, and Richard Peto. 2013. "21st-Century Hazards of Smoking and Benefits of Cessation in the United States." *New England Journal of Medicine* 368 (4): 341–50.

Kenfield, Stacey A., Meir J. Stempfer, Bernard A. Rosner, and Graham A. Colditz. 2008. "Smoking and Smoking Cessation in Relation to Mortality." *Journal of the American Medical Association* 299 (17): 2037–47. doi:10.1001/jama.299.17.2037.

Lee, Peter N., and Barbara A. Forey. 2013. "Indirectly Estimated Absolute Lung Cancer Mortality Rates by Smoking Status and Histological Type Based on a Systematic Review." *BMC Cancer* 13 (1): 189.

Malarcher, Ann M., Jane Schuman, Leonardo A. Epstein, Michael J. Thun, Paul Mowery, Ben Pierce, Luis Escobedo, and Gary A. Giovino. 2000. "Methodological Issues in Estimating Smoking-Attributable Mortality in the United States." *American Journal of Epidemiology* 152 (6): 573–84.

Mehta, Neil K., and Virginia W. Chang. 2011. "Secular Declines in the Association Between Obesity and Mortality in the United States." *Population and Development Review* 37 (3): 435–51.

Mehta, Neil K., and Samuel H. Preston. 2012. "Continued Increases in the Relative Risk of Death From Smoking." *American Journal of Public Health* 102 (11): 2181–86. doi:10.2105/AJPH.2011.300489.

National Center for Health Statistics. 2013. "Health, United States, 2012: With Special Emphasis on Emergency Care." Hyattsville. 2013.

Ng, Marie, Michael K. Freeman, Thomas D. Fleming, Margaret Robinson, Laura Dwyer-Lindgren, Blake Thomson, Alexandra Wollum, et al. 2014. "Smoking Prevalence and Cigarette Consumption in 187 Countries, 1980–2012." *Journal of the American Medical Association* 311 (2): 183–92. doi:10.1001/jama.2013.284692.

Oberg, Mattias, Maritta S. Jaakkola, Alistair Woodward, Armando Peruga, and Annette Pruss-Ustun. 2011. "Worldwide Burden of Disease from Exposure to Second-Hand Smoke: A Retrospective Analysis of Data From 192 countries." *The Lancet* 377 (9760): 139–46.

Oza, Shefali, Michael J. Thun, S. Jane Henley, Alan D. Lopez, and Majid Ezzati. 2011. "How Many Deaths are Attributable to Smoking in the United States? Comparison of Methods for Estimating Smoking-Attributable Mortality When Smoking Prevalence Changes." *Preventive Medicine* 52 (6): 428–33.

Perez-Rios, Monica, and Agustin Montes. 2008. "Methodologies Used to Estimate Tobacco-Attributable Mortality: A Review." *BMC Public Health* 8 (1): 22. doi:10.1186/1471-2458-8-22.

Peto, Richard, Sarah Darby, Harz Deo, Paul Silcocks, Elise Whitley, and Richard Doll. 2000. "Smoking, Smoking Cessation, and Lung Cancer in the UK Since 1950: Combination of National Statistics with Two Case-Control Studies." *BMJ* 321 (7257): 323–29.

Peto, Richard, Alan D. Lopez, Jillian Boreham, Michael Thun, Clark W. Heath, Jr., and Richard Doll. 1992. "Mortality from Tobacco in Developed Countries: Indirect Estimation from National Vital Statistics." *Lancet* 1992; 339: 1268-78.

Peto, Richard, Alan D. Lopez, Jillian Boreham, and Michael Thun. 2012. "Mortality From Smoking in Developed Countries 1950–2000." Monograph, Clinical Trial Service Unit and Epidemiological Studies Unit, University of Oxford.

Pollard, John H. 1988. "On the Decomposition of Changes in Expectation of Life and Differentials in Life Expectancy." *Demography* 25(2): 265-76.

Preston, Samuel H., Dana A. Glei, and John R. Wilmoth. 2010a. "Contribution of Smoking to International Differences in Life Expectancy." In *International Differences in Mortality at Older Ages: Dimensions and Sources,* edited by Eileen M. Crimmins, Samuel H. Preston, and Barney Cohen, 105–31. Washington, DC: The National Academy Press.

———. 2010b. "A New Method for Estimating Smoking-Attributable Mortality in High-Income Countries." *International Journal of Epidemiology* 39 (2): 430–38. doi:10.1093/ije/dyp360.

Preston, Samuel H., Jessica Ho, Dana A. Glei, and John R. Wilmoth. 2009. "Causes of Lagging Life Expectancy at Older Ages in the United States." Paper presented at the 11th annual Joint Conference of the Retirement Research Consortium, Washington, DC, August 10–11.

Preston, Samuel H., Andrew Stokes, Neil K. Mehta, and Bochen Cao. 2014. "Projecting the Effect of Changes in Smoking and Obesity on Future Life Expectancy in the United States." *Demography* 51: 27–49. doi:10.1007/s13524-013-0246-9.

Preston, Samuel H., and Haidong Wang. 2006. "Sex Mortality Differences in the United States: The Role of Cohort Smoking Patterns." *Demography* 43 (4): 631–46. doi:10.1353/dem.2006.0037.

Reither, Eric N., S. Jay Olshansky, and Yang Yang. 2011. "New Forecasting Methodology Indicates More Diseases and Earlier Mortality Ahead for Today's Younger Americans." *Health Affairs* 30 (8): 1562–68. doi:10.1377/hlthaff.2011.0092.

Rogers, Richard G., Bethany G. Everett, Jarron M. Saint Onge, and Patrick M. Krueger. 2010. "Social, Behavioral, and Biological Factors, and Sex Differences in Mortality." *Demography* 47(3): 555–78.

Rogers, Richard G., Robert A. Hummer, Patrick M. Krueger, Fred C. Pampel. 2005. "Mortality Attributable to Cigarette Smoking in the United States." *Population and Development Review*. 2005; 31(2): 259-92.

Rostron, Brian L. 2010. "A Modified New Method for Estimating Smoking-Attributable Mortality in High Income Countries." *Demographic Research* 23 (14): 399–420. doi:10.40454/DemRes.2010.23.14.

Rostron, Brian L. 2011. "Smoking-Attributable Mortality in the United States." *Epidemiology* 22 (3): 350–55.

Rostron, Brian L., and John R. Wilmoth. 2011. "Estimating the Effect of Smoking on Slowdowns in Mortality Declines in Developed Countries." *Demography* 48 (92): 461–79. doi:10.1007/s13524-011-0020-9.

Schroeder, Steven A., and Howard K. Koh. 2014. "Tobacco Control 50 Years After the 1964 Surgeon General's Report." *Journal of the American Medical Association* 311 (2): 141–43.

Soneji, Sam, and Gary King. 2012. "Statistical Security for Social Security." 2012 Aug; 49(3): 1037-60. Doi:10.1007/s13524-012-0106-z.

Staetsky, Laura. 2009. "Diverging Trends of Old-Age Mortality: A Reappraisal." *Demographic Research* 21 (30): 885–914. doi:10.4045/DemRes.2009.21.30.

Stewart, Susan T., David M. Cutler, and Allison B. Rosen. 2009. "Forecasting the Effects of Obesity and Smoking on U.S. Life Expectancy." *The New England Journal of Medicine* 361 (23): 2252–60.

Thun, Michael J., Brian D. Carter, Diane Feskanich, Neal D. Freedman, Ross Prentice, Alan D. Lopez, Patricia Hartge, and Susan M. Gapstur. 2013. "50-Year Trends in Smoking-Related Mortality in the United States." *The New England Journal of Medicine* 368 (4): 351–64. doi:10.1056/NEJMsa1211127.

Thun, Michael J., Cathy A. Lally, John T. Flannery, Eugenia E. Calle, W. Dana Flanders, Charles W. Heath, Jr. 1997. "Cigarette Smoking and Changes in the Histopathology of Lung Cancer." *Journal of the National Cancer Institute* 1997; 89: 1580-6.

U.S. Department of Health, Education and Welfare. 1964. "Smoking and Health: Report of the Advisory Committee to the Surgeon General of the Public Health Service." Public Health Service Publication No. 1103, United States Public Health Service, Office of the Surgeon General, Washington, DC.

U.S. Department of Health and Human Services. 2014. "The Health Consequences of Smoking—50 Years of Progress: A Report of the Surgeon General." U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Center for Chronic Disease Prevention and Health Promotion, Office on Smoking and Health, Atlanta, GA.

Wang, Haidong, and Samuel H. Preston. 2009. "Forecasting United States Mortality Using Cohort Smoking Histories." *Proceedings of the National Academy of Sciences* 106 (2): 393–98.

Weiss, William. 1997. "Cigarette Smoking and Lung Cancer Trends." *CHEST* 1997; 111: 1414-6.

World Health Organization. 2013. "WHO Report on the Global Tobacco Epidemic 2013: Enforcing Bans on Tobacco Advertising, Promotion and Sponsorship." World Health Organization, Luxembourg.

Yang, Yang. 2008. "Trends in U.S. Adult Chronic Disease Mortality, 1960–1999: Age, Period, and Cohort Variations." *Demography* 45 (2): 387–416.