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Mortality Projections With Explicit Consideration of Behavioral Factors

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Abstract

Human behavior plays a significant role in shaping mortality experience. Two primary behavioral drivers of mortality assessed in this paper are smoking and obesity[1]. The smoking epidemic has been on the wane for several decades in the United States, but its adverse consequences on mortality will continue to be felt for quite some time. In the United States, obesity is still on a 40-year rise, with its most significant effects on mortality expected in the future.

This paper reports on the results of an analysis of historical patterns of reductions in smoking and increases in obesity in the United States, together with their effect on mortality. For this purpose, a model was constructed on a gender and age basis, reflecting the effects of both sets of behavior. Reductions in smoking will continue to affect both lung cancer and chronic obstructive pulmonary disease, among other diseases, although over the next 30 years, the decline in smoking will contribute to an overall reduction in mortality. The continued increase in the incidence and severity of obesity is expected to result in an increase in premature deaths.

The estimated deterioration in cohort life expectancy for a 35-year-old in 2015 due to the net effect of reductions in smoking and increases in obesity prevalence is about 0.23 years for a female and about 0.62 years for a male. For a corresponding 65-year-old, the net effect is an estimated deterioration of about 0.02 years for a female and about 0.18 years for a male. Based on alternative obesity prevalence trajectories, the estimated decrease in cohort life expectancy due to the obesity epidemic for a 35-year-old in 2015 is between 0.95 and 1.41 years for females and between 1.34 and 1.84 years for males; for a 65-year-old, the decrease is between 0.53 and 0.78 for females and between 0.67 and 0.90 for males. The overall effect of reductions in smoking is an increase of about 0.96 years for a 35-year-old female and about 0.99 years for a 35-year-old male. For 65-year-olds, the effect is an increase of about 0.61 years for a female and about 0.79 years for a male.

Background

With few exceptions, seemingly inevitable increases in longevity have continued on a regular basis over the centuries, with no clear end in sight. Nevertheless, several factors continue to adversely affect this trend. Among them are lifestyle and behavioral factors that have and will continue to play a leading role as drivers of future mortality.

This paper focuses on the effects of two major behavioral factors: cigarette tobacco smoking and obesity (usually measured by means of an excess of body mass index, or BMI, of 30.0 or greater). These are not

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[1] Obesity, though not strictly a behavior, is a condition associated with a combination of behaviors and genetic factors, which can adversely affect health and in turn mortality. In this paper, obesity is used as a marker for these behaviors.

the only behavioral drivers of mortality; others include drinking alcohol in excess, drug overdose, driving a car, not taking medicine as prescribed, suicide, and effects of behavior of others, such as air pollution. Obesity is not a behavior, but a result of genetic factors and several individual behavioral factors, including unhealthy nutrition, overly long periods spent in a sedentary position, and an inadequate amount of physical activity. Because this combination of behaviors tends to result in body weight that can adversely affect health and in turn mortality, obesity is used here as a marker of these behaviors. Obesity in this sense and cigarette smoking are viewed as being at least to some extent avoidable, and in the United States they represent the two most significant behavioral drivers of mortality ("drivers" in contrast to direct causes of death, such as heart disease and cancers). Further, their study has the advantage of being well documented and measurable.

The Exposure Process

Both smoking and obesity adversely affect human mortality on a lagged basis—that is, there is an extensive period between exposure to these hazards and consequential premature death. In many cases, this lag can take decades to unfold.

Further, the trajectory of their primary impacts on mortality has and will take on different time dimensions. The prevalence of smoking in the United States peaked several decades ago (for males in the 1940s–1950s and for females in the 1960s–1970s) and has decreased monotonically ever since, while the prevalence of obesity may not yet have peaked, with no guarantee that a decline will occur.

There are two stages in the exposure process to these two perils: (1) the period of exposure to the hazard and (2) the time it takes to lead to ill health and subsequent premature death.

The key time-related elements of the first stage of the process are the inception and length of the exposure period (i.e., age and duration of smoking or time during which the individual is obese) and its completion, if applicable, and any resulting adverse medical condition. For example, exposure to smoking usually begins in a person's teenage years; 95 percent of those who smoke as adults have taken a first puff by the age of 21, with 95 percent taking up daily smoking by the age of 26. Cessation can be temporary (and frequent) or permanent, especially later in life. In contrast, the onset of obesity can arise at almost any time in a person's life cycle, from birth to late adulthood. Although attempts to reduce weight (through, for example, dieting) are common, more than 90 percent of such efforts last less than two years—usually far less than that. The trend over the last few decades is that onset of obesity has emerged at an ever-earlier age.

The second stage is between the period of exposure and resulting death.[2] The longer a person's internal organs are exposed to either chemicals associated with smoking or excess adipose tissues, the more harmful the ultimate adverse health effects.

This significant lag differs significantly by individual, the duration of exposure, and the adverse intermediate health conditions that emerge. For example, there is generally a longer lag between smoking and consequential chronic obstructive pulmonary disease (COPD) than between smoking and

[2] This second stage could be further segmented between the time until the resulting adverse health condition(s) arises and the period living with the adverse health condition(s). Since this paper is focused on mortality, this further time segmentation is not as relevant, nor is it as measurable as the entire period.

consequential lung cancer or cardiovascular disease. Smoking cessation and weight loss can favorably affect longevity prospects (although unintended weight loss can be a sign of unrecognized ill health).

An important element in this process is the intensity of the exposure period. Intensity of smoking includes the frequency of smoking over the period, the strength of the cigarettes smoked and the degree of inhaling), while intensity of obesity is the amount of obesity and type and location (especially the waist/abdomen) of the adipose tissues. The period of exposure and time lag to consequential death differ between smoking and obesity. Nevertheless, it has been shown that a positive dose response exists: the longer the period and the more intense the exposure, the greater the resulting excess mortality.

The interaction between the duration of exposure, the lag (if any) after cessation or loss of weight, and the severity of exposure affects the resulting mortality experience. For example, after smoking cessation, adverse health effects can linger for more than 15 years. (Adverse effects after that period can be 10 to 15 percent additional mortality.)

Cohort Versus Period Effects

In mortality studies in most countries, (calendar) period effects have been presumed to be more significant than those of the (birth) cohort. For example, drivers of mortality (such as restrictive regulations, effective sanitation, air pollution, medical infrastructure taxation, social pressures, labor force participation, nutritional trends and advertising) can affect the health of a large population segment over the same general time frame. Trends in smoking or nutrition tend to affect the prevalence of all ages over a calendar period. Nevertheless, to the extent that the age patterns in the exposure process change, smoking and obesity patterns will affect mortality in both a calendar-period and birth-cohort manner.

Some demographers have claimed that it is impractical to properly construct age-period-cohort models. In theory, they are correct, in that there is rarely a unique optimal model or set of parameters, especially considering the many other explanatory factors, such as gender and socioeconomic variables. Nevertheless, this does not mean that in practice a reasonable set of relationships cannot be obtained for such a model.

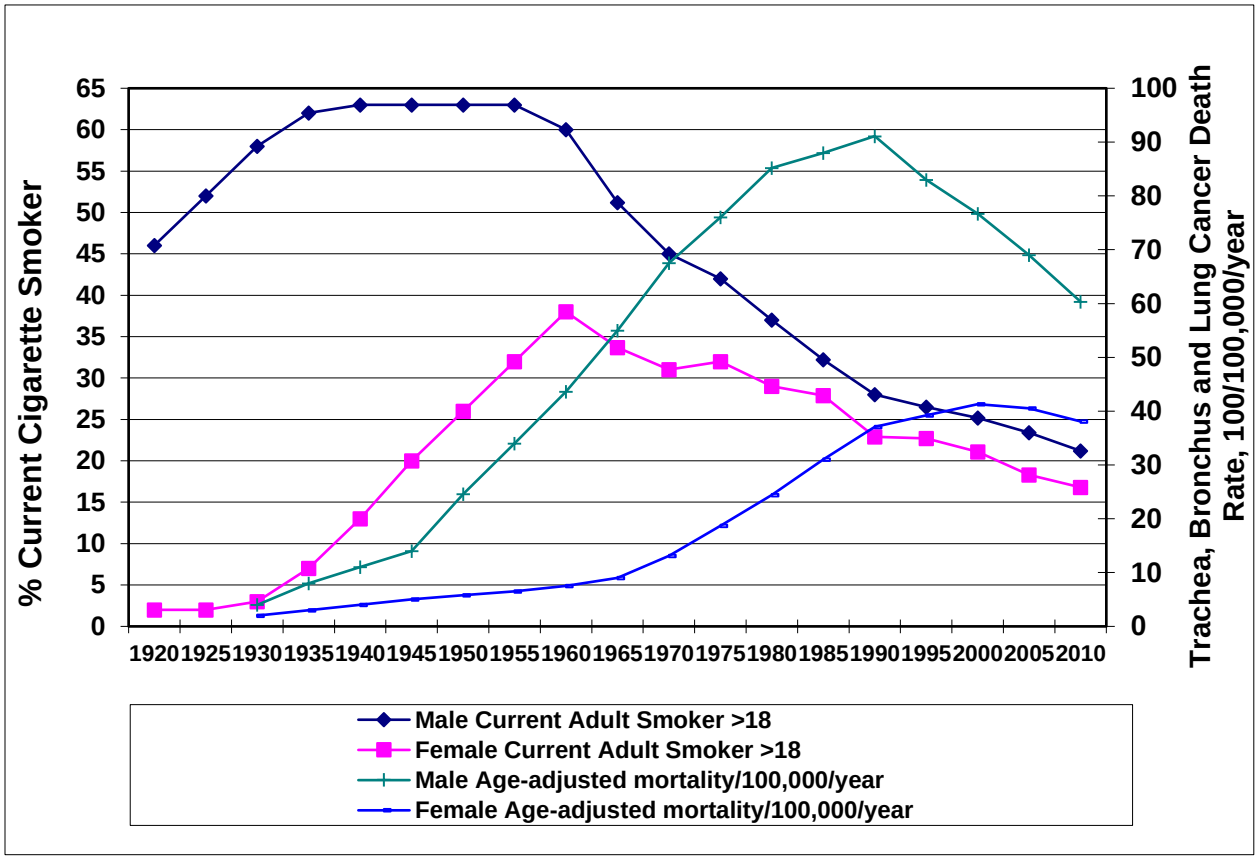
Because of the importance of the exposure process over a life cycle, overall trends in smoking and obesity prevalence have a different effect on different birth cohorts. Thus, because individuals of a certain age have been exposed to smoking or obesity for different lengths of time and ages, possibly at different intensities, the risk of harm can differ by different ages and calendar periods. The cohort effect is more obvious in the case of smoking than in obesity. Smoking habits have widely differed by period, racial/ethnic group, income level, age and gender (note that differences by gender are more evident in countries such as Japan, although still significant in the United States).

The effect of obesity by birth cohort also is important, as indicated in Masters (2013), who noted “rapid increases in obesity prevalence among more recent birth cohorts,” and Yu (2012), not least because the age at which obesity first emerges has decreased in recent years. The period effect of this epidemic has resulted in what will in the future be a longer average exposure duration for many. Growth in the prevalence of morbid obesity also appears to be emerging more as a period than cohort effect, although it should be expected that mortality of the obese will be different by birth cohort as well as other factors.

Smoking: Experience

The rate of smoking tobacco cigarettes in the United States increased rapidly in the first half of the 20th century, especially by males, hitting a peak in the 1940s and 1950s, as shown in Figure 1. The percent of females who smoke peaked in the 1970s and 1980s, albeit at a lower level than for males. (Note that the tobacco industry made a big push to attract female customers as the male prevalence rate declined.) After these peaks, for both genders, there has been a significant though gradual reduction in the prevalence of smokers. This decline has recently been accompanied by an increase in the use of multiple tobacco or nicotine-based products at many ages, especially by adolescents (prevalence at these ages has been more cyclical, with an increase to a peak in the 1990s and decreasing since then).

Fig. 1. Smoking Prevalence and Death Rate for Trachea, Bronchus and Lung Cancer, by Gender



Source: Gutterman (2015).

Mortality increases with duration of smoking, as well as its intensity. Excess mortality decreases after smoking cessation, although it appears that it never goes away entirely.

Even though the prevalence of smoking has diminished over the last few decades (a decrease of two-thirds for males and more than half for females from their peaks, as shown in Figure 1), smoking still represents the most significant behavioral contributor to premature deaths due to human behavior in the United States and in many other countries. Estimates of these deaths in the United States developed by the Centers for Disease Control and Prevention (CDC) indicates that at least 480,000 deaths per year occur

between 2005 and 2009, which is more than 18 percent of all deaths (these include about 127,000 directly due to lung cancer, 151,000 due to cardiovascular diseases and 100,000 due to COPD).

It is estimated that about 16 million adults are living with smoking-related diseases. In 2014, about 40 million American adults were current smokers, representing about 16.8 percent of adults (18.8 percent of males and 14.8 percent of females). To demonstrate recent changes, Table 1 details the smoking prevalence by age group and gender in 2005 and 2014. Notice the significant drop-off in prevalence after age 65. There are currently more former smokers than current smokers in the United States.

Table 1. Smoking Prevalence for American Adults, by Gender and Age Category

Gender	Males (%)		Females (%)		Total (%)	
Age in Year	**2005**	**2014**	**2005**	**2014**	**2005**	**2014**
18–24	28.0	18.5	20.7	14.8	24.4	16.7
24–44	26.8	22.9	21.4	17.2	24.1	20.0
45–64	25.2	19.4	18.8	16.8	21.9	18.0
65+	8.9	9.8	8.3	7.5	8.6	8.5
Total	23.9	18.8	18.1	14.8	20.9	16.8

Source: Centers for Disease Control and Prevention (CDC).

Over the same decade, the use of cigarettes by smokers became more intermittent. As shown in Table 2, the number of cigarettes that American adults smoked per day decreased between 2005 and 2014.

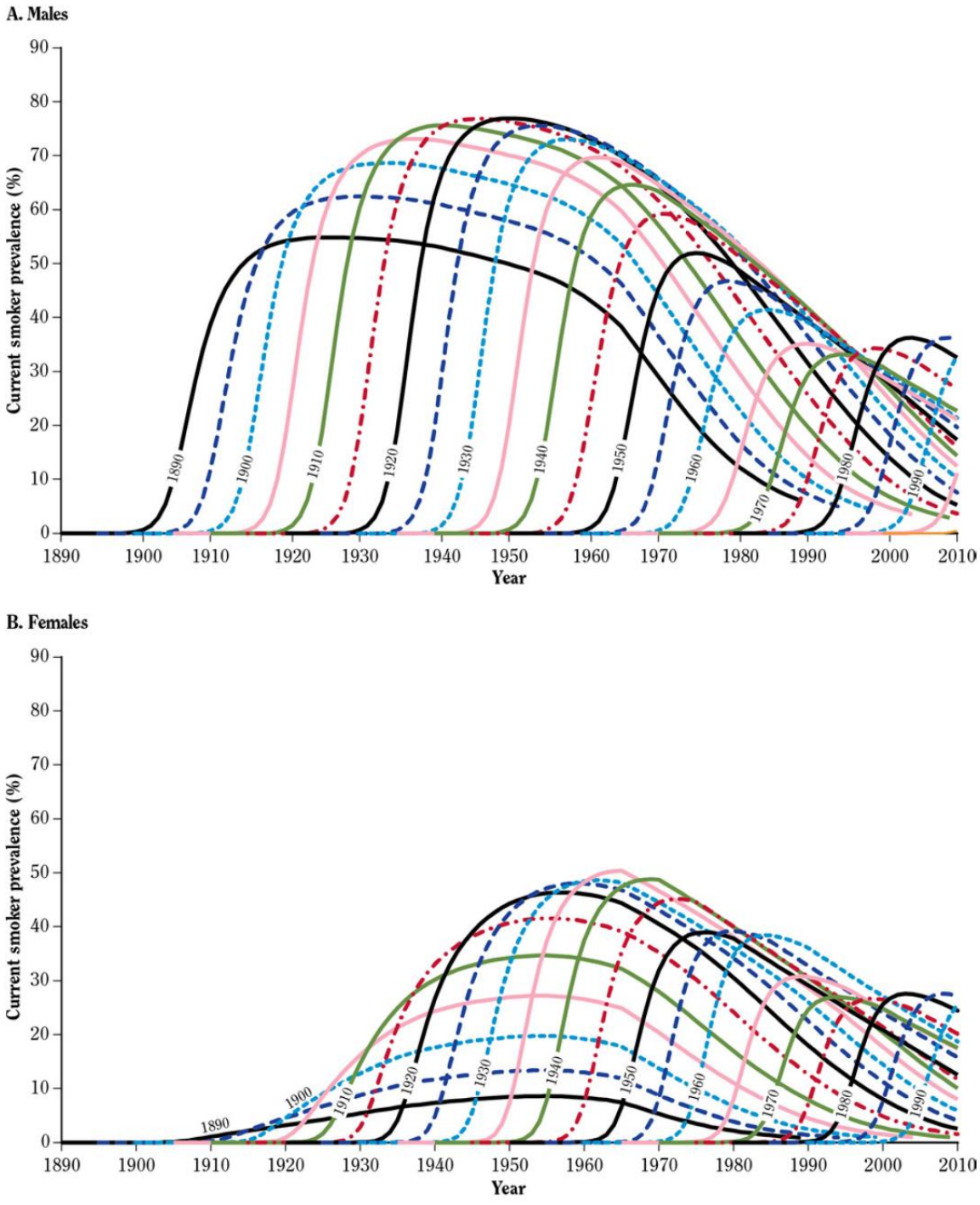
Table 2. Number of Cigarettes per Day Smoked by American Adults

Number of Cigarettes	Percent of Smokers, by Year	
	2005	**2014**
1–9	16	27
10–19	35	39
20–29	13	28
30+	36	9

Source: CDC.

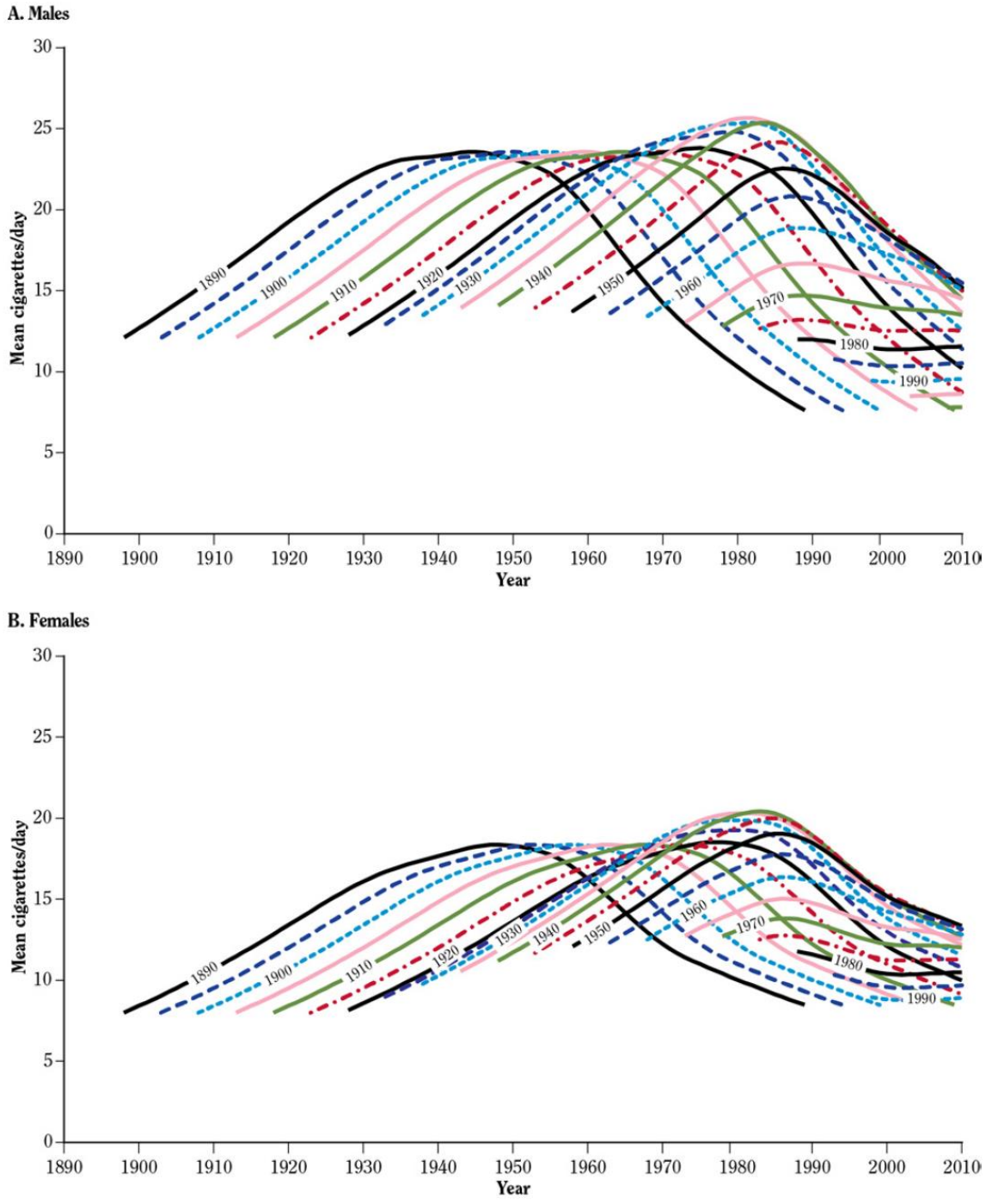
Figures 2 and 3 illustrate the effect of cohort, period and gender on the smoking habits of American adults over a long period. Figure 2 shows smoker prevalence, while Figure 3 shows the average number of cigarettes smoked per capita per day. Although the patterns are similar for males and females, the genders have experienced different levels of smoking. Smoking prevalence for each gender has declined sharply over the last several decades on both a period and cohort basis, with more recent cohorts peaking at a much lower level and at an earlier age than earlier cohorts.

Fig. 2. U.S. Current-Smoker Prevalence, by Gender and Birth Cohort



Source: U.S. Surgeon General (2014).

Fig. 3. U.S. Average Number of Cigarettes Smoked per Day, by Gender and Birth Cohort



Source: U.S. Surgeon General (2014).

The trend in prevalence of smoking parallels the trend in per capita annual cigarette smoking in the United States. Based on data from the Department of Agriculture, per capita cigarettes smoked increased from 54 in 1900 to 665 in 1920, 1,485 in 1930, 1,976 in 1940, 3,522 in 1950, and 4,171 in 1960. It then began a decline to 3,985 in 1970, 3,851 in 1980, 2,827 in 1990, 2,076 in 2000, and 1,278 in 2010. It should be

expected that this decrease will continue, due to fewer individuals who each smoke a smaller number of cigarettes, although the ultimate level is uncertain. In any case, it is unlikely that smoking will disappear, as evidenced by prevalence rates in adolescents, although the mix of type of smoking (e.g., use of e-cigarettes, hookahs and smokeless tobacco) will likely continue to change.

The following analysis addresses smoking-attributable mortality of American adults.

The author focused on historical experience due to (1) lung, bronchus and trachea cancers (hereafter referred to as "lung cancer") and (2) other pulmonary diseases—primarily COPD, but excluding influenza. This is the focus because a large percentage of deaths due to these causes are the result of smoking. According to the U.S. Surgeon General (2014), about 80 percent of those who die of lung cancer and about 80 percent of deaths due to COPD (83 percent of males and 77 percent of females) are the result of smoking.

A crude overall relationship between smoking prevalence and mortality by gender due to lung cancer is shown in Figure 1. This figure suggests that, in the aggregate, there is about a 30- to 35-year lag between these two metrics. There is a somewhat longer lag between smoking prevalence and consequential COPD, with a somewhat shorter lag between smoking prevalence and cardiovascular disease, another major cause of deaths resulting from smoking.

Tables 3 and 4 show trends in deaths due to lung cancer and COPD by quinquennial age and gender categories as a percentage of total deaths in the United States by quinquennial years. Tables 5 and 6 show corresponding rates of mortality per 100,000 lives by quinquennial age and gender categories.

Table 3. Percentage of Total Deaths Due to Lung, Trachea and Bronchus Cancers, by Gender, Age and Calendar Period

Females	35-39	40-44	45-49	50-54	55-59	60-64	65-69	70-74	75-79	80-84	85-89	90-94	95-99
1970-1974	1.48%	3.02%	4.28%	4.75%	5.05%	4.05%	2.95%	1.97%	1.27%	0.77%	0.51%	0.35%	0.17%
1975-1979	1.70%	4.13%	5.76%	7.11%	6.93%	6.65%	5.32%	3.43%	2.12%	1.25%	0.71%	0.48%	0.32%
1980-1984	1.72%	3.93%	6.91%	8.97%	9.68%	8.77%	7.57%	5.62%	3.36%	1.84%	1.04%	0.59%	0.40%
1985-1989	1.56%	3.82%	7.32%	10.04%	10.69%	10.91%	9.35%	7.67%	4.99%	2.71%	1.33%	0.72%	0.44%
1990-1994	1.71%	3.41%	6.50%	9.65%	11.62%	12.19%	11.61%	9.61%	6.91%	4.05%	2.03%	0.96%	0.54%
1995-1999	1.66%	3.63%	5.45%	8.61%	11.36%	12.23%	12.16%	10.71%	7.75%	4.99%	2.53%	1.23%	0.54%
2000-2004	1.51%	3.25%	5.87%	7.63%	10.05%	12.20%	12.48%	11.40%	8.94%	5.59%	2.93%	1.41%	0.65%
2005-2009	1.17%	2.69%	5.54%	7.80%	9.17%	11.04%	12.73%	11.94%	9.78%	6.45%	3.49%	1.64%	0.82%
2010-2014	0.94%	1.84%	4.13%	7.30%	9.43%	10.02%	10.99%	11.62%	9.49%	6.71%	3.77%	1.77%	0.86%
Males													
1970-1974	1.82%	4.10%	6.12%	7.47%	8.70%	8.80%	8.44%	7.07%	5.27%	3.39%	1.81%	0.92%	0.57%
1975-1979	1.61%	4.12%	6.82%	9.38%	10.59%	10.90%	10.26%	8.87%	6.69%	4.46%	2.60%	1.29%	0.82%
1980-1984	1.29%	3.93%	7.11%	10.25%	12.06%	12.64%	11.84%	10.27%	8.09%	5.46%	3.36%	1.73%	1.05%
1985-1989	1.10%	3.26%	6.64%	10.35%	12.63%	13.93%	13.04%	11.39%	8.97%	6.17%	3.86%	2.14%	1.13%
1990-1994	0.91%	2.28%	5.21%	9.34%	12.50%	14.18%	14.21%	12.58%	9.86%	7.01%	4.45%	2.49%	1.32%
1995-1999	0.94%	2.49%	4.48%	7.61%	11.03%	13.25%	13.75%	12.87%	10.00%	7.14%	4.56%	2.53%	1.48%
2000-2004	0.80%	2.16%	4.56%	6.59%	9.63%	12.41%	13.29%	12.99%	10.71%	7.50%	4.59%	2.52%	1.45%
2005-2009	0.76%	1.58%	3.81%	6.05%	8.19%	10.79%	12.84%	12.89%	10.85%	8.15%	5.04%	2.75%	1.48%
2010-2014	0.59%	1.34%	2.87%	5.16%	7.72%	9.30%	11.00%	11.49%	10.14%	7.69%	5.06%	2.69%	1.38%

Note: Some discontinuities may occur due to changes in ICD coding over time.
Source: Human Mortality Database, cause-of-death data.

Table 4. Percentage of Total Deaths Due to Other Pulmonary Diseases (Primarily COPD), by Gender, Age and Calendar Period

Females	35-39	40-44	45-49	50-54	55-59	60-64	65-69	70-74	75-79	80-84	85-89	90-94	95-99
1980-1984	0.20%	0.55%	0.93%	1.45%	2.11%	2.76%	3.35%	3.36%	2.67%	1.91%	1.25%	0.86%	0.59%
1985-1989	0.20%	0.30%	0.92%	1.67%	2.72%	3.63%	4.24%	4.66%	4.25%	3.10%	2.01%	1.30%	0.93%
1990-1994	0.18%	0.33%	0.70%	1.70%	2.84%	4.28%	5.32%	5.68%	5.78%	4.50%	3.06%	1.94%	1.29%
1995-1999	0.19%	0.45%	0.84%	1.76%	3.18%	4.75%	5.97%	6.77%	6.65%	5.72%	4.09%	2.64%	1.78%
2000-2004	0.44%	0.59%	1.16%	1.86%	3.14%	5.32%	6.84%	7.78%	7.56%	6.63%	5.15%	3.48%	2.43%
2005-2009	0.33%	0.75%	1.46%	2.54%	3.37%	5.19%	7.24%	8.56%	8.59%	7.63%	5.83%	4.11%	3.01%
2010-2014	0.36%	0.66%	1.49%	3.02%	4.16%	5.30%	7.11%	9.11%	9.10%	8.18%	6.35%	4.54%	3.37%
Males													
1980-1984	0.16%	0.37%	0.62%	1.24%	2.08%	3.02%	4.08%	5.17%	5.42%	4.90%	4.02%	2.81%	1.99%
1985-1989	0.18%	0.33%	0.69%	1.23%	2.19%	3.39%	4.47%	5.43%	5.97%	5.69%	4.92%	3.51%	2.65%
1990-1994	0.12%	0.30%	0.54%	1.23%	2.22%	3.37%	4.86%	5.64%	6.23%	6.11%	5.38%	4.13%	3.39%
1995-1999	0.13%	0.33%	0.63%	1.30%	2.37%	3.59%	4.90%	6.22%	6.62%	6.54%	5.92%	4.73%	3.86%
2000-2004	0.17%	0.42%	0.80%	1.38%	2.33%	3.88%	5.20%	6.63%	7.16%	6.92%	6.28%	5.22%	4.20%
2005-2009	0.17%	0.42%	0.93%	1.58%	2.49%	3.83%	5.55%	6.91%	7.58%	7.45%	6.40%	5.22%	4.26%
2010-2014	0.14%	0.45%	0.77%	1.63%	2.69%	3.86%	5.38%	7.28%	7.59%	7.49%	6.70%	5.31%	4.58%

Note: Some discontinuities may occur due to changes in ICD coding over time.
Source: Human Mortality Database, cause-of-death data.

Table 5. Mortality Rates (per 100,000) Due to Lung, Trachea and Bronchus Cancers, by Gender, Age and Calendar Period

Females	35-39	40-44	45-49	50-54	55-59	60-64	65-69	70-74	75-79	80-84	85-89	90-94	95-99
1970-1974	2.53	8.05	17.41	27.99	44.27	51.92	56.90	62.45	65.36	64.65	70.67	74.37	53.10
1975-1979	2.29	9.08	19.91	37.33	53.47	78.17	89.67	94.79	92.36	91.43	85.82	90.15	89.05
1980-1984	1.99	7.31	20.99	43.28	71.67	98.86	127.63	146.58	137.13	128.16	119.05	108.33	109.49
1985-1989	1.77	6.50	20.26	45.59	75.93	121.23	154.78	196.56	199.46	182.43	150.64	132.40	124.52
1990-1994	2.02	5.68	16.94	40.20	77.82	127.92	184.36	234.09	261.41	259.06	216.79	169.19	147.47
1995-1999	1.95	6.20	13.63	33.45	71.09	122.95	186.80	257.29	289.67	322.48	277.46	225.83	157.38
2000-2004	1.73	5.75	15.27	28.79	58.73	113.46	180.34	259.23	326.35	355.22	325.15	266.51	197.74
2005-2009	1.25	4.56	14.49	29.43	49.29	91.76	163.23	243.70	324.86	370.02	356.00	292.12	238.71
2010-2014	0.98	2.85	10.22	27.54	50.53	77.53	129.73	217.52	292.64	354.50	359.18	299.08	240.89
Males													
1970-1974	5.52	18.86	45.13	84.19	155.13	236.89	333.40	413.91	447.46	419.25	328.99	238.17	198.80
1975-1979	4.15	16.13	43.06	94.24	161.33	260.95	357.53	471.94	507.93	510.19	435.72	310.81	271.41
1980-1984	2.96	13.33	38.93	91.64	170.03	271.03	384.70	504.69	585.60	605.80	551.31	409.73	350.27
1985-1989	2.86	10.93	33.38	83.49	163.64	282.03	392.87	530.83	622.45	667.94	629.31	514.72	386.01
1990-1994	2.58	8.20	25.36	68.15	144.99	260.18	394.99	522.88	621.97	713.72	692.73	581.80	453.65
1995-1999	2.21	8.17	20.66	50.23	114.17	219.11	347.37	502.12	589.27	701.40	713.05	610.51	525.93
2000-2004	1.64	6.55	20.74	42.78	91.37	181.92	297.14	450.92	581.75	677.22	689.83	608.35	530.68
2005-2009	1.43	4.43	16.34	39.18	74.92	142.79	251.43	387.18	517.45	645.30	673.35	615.81	517.38
2010-2014	1.06	3.30	11.21	31.55	70.44	119.27	199.52	316.87	441.75	554.26	618.75	559.42	454.94

Note: Some discontinuities may occur due to changes in ICD coding over time.
Source: Human Mortality Database, cause-of-death data.

Table 6. Mortality Rates (per 100,000) Due to COPD, by Gender, Age and Calendar Period

Females	35-39	40-44	45-49	50-54	55-59	60-64	65-69	70-74	75-79	80-84	85-89	90-94	95-99
1980-1984	0.23	1.02	2.83	7.02	15.61	31.14	56.53	87.72	109.08	132.96	144.01	157.83	161.20
1985-1989	0.22	0.51	2.56	7.57	19.36	40.38	70.30	119.53	169.92	208.48	227.61	239.28	262.78
1990-1994	0.21	0.55	1.82	7.08	19.04	44.94	84.48	138.49	218.51	287.64	325.87	341.17	353.31
1995-1999	0.23	0.76	2.11	6.84	19.87	47.72	91.72	162.68	248.86	369.87	448.89	485.03	517.76
2000-2004	0.50	1.05	3.01	7.01	18.37	49.44	98.80	176.85	275.85	420.89	571.52	659.44	738.43
2005-2009	0.35	1.27	3.83	9.59	18.12	43.19	92.87	174.64	285.51	437.32	594.24	733.53	873.08
2010-2014	0.38	1.03	3.68	11.39	22.27	41.03	83.94	170.51	280.77	432.13	605.52	768.03	939.64
Males													
1980-1984	0.37	1.24	3.41	11.09	29.34	64.71	132.61	253.92	392.23	543.38	661.28	664.81	663.71
1985-1989	0.47	1.12	3.47	9.95	28.44	68.68	134.76	253.05	414.30	615.80	801.33	844.72	909.61
1990-1994	0.35	1.06	2.63	8.99	25.77	61.77	134.94	234.67	392.75	622.91	838.24	966.37	1,164.40
1995-1999	0.30	1.08	2.92	8.56	24.52	59.34	123.76	242.83	390.04	643.18	925.79	1,141.26	1,369.01
2000-2004	0.36	1.29	3.62	8.97	22.13	56.91	116.15	230.02	388.94	625.30	943.24	1,261.58	1,537.43
2005-2009	0.32	1.17	4.00	10.22	22.81	50.71	108.62	207.59	361.50	589.57	855.69	1,169.30	1,489.30
2010-2014	0.25	1.11	2.99	9.94	24.55	49.43	97.53	200.81	330.55	540.08	819.32	1,103.06	1,511.19

Note: Some discontinuities may occur due to changes in ICD coding over time.
Source: Human Mortality Database, cause-of-death data.

Several observations can be made from these tables:

- Both percentages of total mortality and mortality rates increased in the early periods shown, followed by decreases in the later periods in most cases.
- There is a clear age effect for both causes of death, with a significant decrease in percent of total deaths at older ages. This is partly because of the significant reduction in smoking after age 65 shown in Table 1 (and consequential relative reduction in this risk). As indicated earlier, deaths due to COPD arise somewhat later in life. Whether period or birth cohort dominates these effects is difficult to discern; nevertheless, the percentages for the more recent birth cohort groupings have been decreasing. As expected, the effects at older ages have emerged later. An exception is COPD at age categories under 60–64 for females and under 55–59 for males, where there has been an increase in some cases.
- Tables 3 through 6 show a definite cohort effect for mortality due to lung cancer and COPD, with mortality rates peaking for males earlier than for females, consistent with reductions in smoking prevalence for females occurring somewhat later. Unlike, but consistent with, the recent peaking in overall lung cancer mortality for females, the mortality rate for lung cancer appears to have peaked for females born in the 1930s–1940s and for males born in the 1910s–1920s.
- Overall, the patterns for mortality for males and females are similar, although the mortality patterns for females have tended to emerge five or 10 years later than those of males, corresponding to differences in smoking prevalence by gender. It appears that females are more sensitive to the effects of smoking, as their mortality rates are greater than if they had been proportional to the rates of smoking prevalence for males. (An alternative cause is that other contributors to lung cancer may be more significant for females than for males.)
- During 2010–14, the percentages of total deaths for lung cancer for females are equal to or greater than those for males through the age category 70–74, while for COPD, they are greater through the age category 80–84. The mortality rates for females remain less than the corresponding rates for males (except for age categories younger than 55–60 for COPD).

The appendix provides an expanded set of tables, including ones showing percentages of total deaths by cause, percentage changes in the mortality rates by quinquennial periods, and the relationship between

female and male mortality for both disease categories. Additional discussion of the effect of changes in ICD coding also is provided there.

As can be seen in a review of the decreases in the two major smoking-related causes of death studied here, the earlier and larger size of the decrease in smoking for males compared with that of females has been a significant contributing factor to the larger mortality improvement for males that has occurred over the last two decades in the United States. Although this differential effect on gender mortality should be expected to continue for the next decade or so, after that time the difference in gender mortality improvement may disappear.

Smoking: Projection Methodology

The approach taken to estimate the effect of the reduction in smoking on future mortality was to construct a fairly straightforward model that takes into account the expected reductions in two causes of death (separately by gender, age group and calendar period) that are primarily driven by smoking and through extrapolation to estimate the total number of smoking-attributable deaths.

The trends in the percentage of each of the two causes of death categories by gender, age group and quinquennial calendar period shown in Tables 3 and 4 were reviewed, focusing on the reduction over time measured from the period with the largest percentage of total deaths attributable to the cause of death. In most cases, the annual reduction was between 1 and 2 percent per year (5 to 10 percent for the five years starting with the period with the peak percentage). A continued reduction using a similar pattern for each gender-attained-age category for each of the two causes of death was applied to determine the expected pattern of percent of total deaths.

An ultimate percent (for each age category and gender) of the peak percentage was selected: between 25 and 75 percent for lung cancer and between 65 and 80 percent for other pulmonary diseases, both increasing between these percentages by attained age group. These ultimate percentages were selected based on the patterns for age groups 30s, 40s and 50s, where there was sufficient experience after the peak percentage was reached. In a few older age categories for females, continued increases in these percentages were assumed to occur for the next five or 10 years before reductions begin, consistent with the observed patterns for younger ages. After 2045, no further decreases were assumed, because (1) some residual smoking is assumed to continue and (2) drivers of these cause categories other than smoking may continue.

The percentage reductions in total deaths due to the two causes associated with smoking were then added together. But since there are additional direct causes of death that result from smoking, such as cardiovascular diseases, a further adjustment was needed. Based on the U.S. Surgeon General's (2015) reported relationships between smoking-attributable deaths by cause by gender and broad age categories, total deaths by cause by gender and broad age categories, and total deaths by gender and broad age categories, the total number of deaths from these two direct causes of death (not just those due to smoking) was estimated to be about 61 percent of total smoking-attributable deaths for females and 47 percent for males. Therefore, the sum of the percentages derived earlier of the two causes of death studied was divided by the applicable percent (61 percent and 47 percent, respectively). These factors were then converted to annual rates of reduction in mortality.

Recent mortality experience forms the basis for the future mortality assumptions used by the Trustees of the Social Security system (United States) in developing intermediate population projections that underlie the 2016 Trustees report regarding this large social insurance system. Their intermediate mortality assumptions, which represent their best estimate of the future, are used as the baseline from which the estimated effect on mortality of the reduction in smoking is projected from the base year of 2015.

The methodology followed was to apply the resulting estimates of annual rates of reduction in mortality by gender and age to the assumptions of the Trustees to estimate the effect on mortality of the reductions in smoking. This does not suggest that the Trustees ignored the effects of the reduction in smoking; rather, because this is one of many considerations in deriving their assumptions, it was used as a reasonable baseline set of cohort mortality rates from which to estimate the continued effect of reductions in smoking over the next 30 years. The expected differences in cohort life expectancies were derived by comparing those resulting from the application of the Trustees' intermediate assumptions with the reduced mortality rates obtained based on the above approach. It was assumed that there is no impact from smoking on mortality of those younger than the category for ages 35–39, nor older than the 95–99 age category. This assumption appears reasonable based a review of the cause-of-death data available from the Human Mortality Database. Based on these assumptions, the effect on cohort life expectancy is as shown in Table 7.

Table 7. U.S. Cohort Life Expectancy With Changes in Smoking

	At Age 35		At Age 65	
Scenario	**Females**	**Males**	**Females**	**Males**
2016 Trustees report	46.27	42.38	18.70	16.37
With expected reductions in smoking	47.23	43.37	19.31	16.98
Effect of reduction in smoking	+0.96	+0.99	+0.61	+0.61

The estimated effect of the reduced prevalence in smoking on cohort life expectancy for a 35-year-old in 2015 is an increase of about 0.96 years for females and about 0.99 years for males; for a 65-year-old in 2015, it is about 0.61 for females and males, compared with a baseline estimate of cohort life expectancy in 2015. Note that this does not represent an estimate of the effect of smoking (which is adverse), but rather the estimated future effect on mortality (and corresponding life expectancies) from past and future reductions in smoking. Although a significant amount of the overall improvement in life expectancy due to reduced smoking prevalence occurred for males prior to 2015, the future (cohort) effect of changes in smoking habits on life expectancy is about the same for males than for females because the peak smoking prevalence for males was significantly greater and earlier than that for females.

Obesity: Experience

The relationship between obesity and mortality (see Gutterman 2016) has been more complex than the corresponding relationship between smoking and mortality (see Gutterman 2015). Based on various studies (especially Flegal et al. 2013), it appeared that those who are overweight and possibly those who are moderately obese have enjoyed favorable mortality experience in the United States compared with those of normal weight, measured by BMI (weight in kilograms divided by the square of height measured in meters). However, two meta-studies published in 2016 (Aune et al. 2016; Global BMI Mortality Collaboration 2016) appear to indicate that those with overall moderate obesity have experienced mortality at a higher level than those of normal or overweight BMI.

The first step taken to assess the effects of obesity on mortality was to estimate obesity's current and future prevalence and distribution. Most studies have been based on BMI, although it is not an ideal metric. Nevertheless, it is the most commonly used, primarily due to its practicality (see Gutterman 2016). The population in the United States, as well as in most of the rest of the world, has seen a steady increase in average BMI over the last several decades, to the point that the prevalence of obesity in U.S. adults was 35.0 percent for male adults and 40.4 percent for female adults on a professionally measured basis (from the National Health and Nutrition Examination Survey (NHANES) 2013–14, a nationally representative survey of the United States). Historical values from recent NHANES are shown in Table 8.

Table 8. Adult BMI-Obesity as a Percent of U.S. Adult Population, by Gender and Age, 1988–94 to 2013–14

	Males, by Age (%)				Females, by Age (%)			
NHANES Years	**20–39**	**40–59**	**60+**	**All**	**20–39**	**40–59**	**60+**	**All**
1988–1994	14.8	25.4	21.2	20.2	20.7	30.3	25.6	25.4
1999–2002	23.0	30.5	30.8	27.6	29.1	36.7	35.0	33.3
2003–2006	28.0	37.2	31.3	32.2	29.7	39.9	33.0	34.2
2007–2010	30.3	35.7	36.8	33.9	32.9	37.0	37.9	35.6
2011–2014	30.3	38.3	34.8	34.3	34.4	42.1	38.8	38.3
2013–2014	31.6	37.2	37.5	35.0	37.0	44.6	39.4	40.4
2013–2014: class 3+ obese	6.0	5.2	5.0	5.5	10.1	11.9	6.4	9.7

Note: All age totals are age-adjusted; four-year values are equal to the average of the two sets of two-year survey results, where applicable. BMI-obesity is considered to be a BMI ≥30 on an age-adjusted basis.
Source: NHANES, for adults aged 20+; Flegal et al. (2016); Fryar et al. (2016).

In addition to the tremendous increase in obesity prevalence, there has been a correspondingly greater increase in a higher average BMI in the aggregate obese category. That is, there has been faster growth in the prevalence of those in the morbidly obese category (those with a BMI of at least 40.0, or so-called class 3 and higher obesity levels); the percentages in class 3+ for the most recently reported NHANES are also shown in Table 8. This is significant, especially because of the large differential in mortality of those in the morbidly obese category: the larger the BMI, the greater the mortality rate. The movement into higher obesity classes can be seen in the findings determined in Preston et al. (2014) of transitions between BMI categories, as evidenced in decadal changes between NHANES for 1980–90, 1990–2000 and 1998–2008. Table 9 is based on an estimated average change between these three decadal measurements.

Table 9. Transitions Between BMI Categories Over 10-Year Periods

BMI Class	Gender	% Transitioning to Given Class			
		Normal	Overweight	Class 1 Obese	Class 2+ Obese
Normal	Both	62	34	4%	0
Overweight	Males	13	53	27	7
	Females	7	44	37	31
Obese 1	Males	2	23	44	31
	Females	2	16	41	40
Obese 2+	Both	0	5	25	70

Source: Based on Preston et al. (2014), between decadal NHANES; underweight not reflected, because of its relatively small prevalence.

Table 9 demonstrates the process underlying the gradual upward trajectory of BMI in American adults over the last several decades, which has resulted in a significant increase in obesity. Despite this recent experience, the author of this paper does not believe that these asymmetric trends can continue at this pace experienced over the last 20 years. In applying a more refined set of decadal transition percentages, Preston et al. (2014) estimated that by 2040, 47 percent of males and 51 percent of females in the United States will be obese—expressed as a percentage of the current (2013–14 NHANES) prevalence rates of obesity of about 37 percent for males and 33 percent for females.

The author does not believe that this increase in obesity prevalence is reasonable over the long-term. Therefore, three trajectories were developed that are felt to be more reasonable: a lower bound at the current NHANES (2013–14) level, an increase of 10 percent as the best estimate, and an increase of 20 percent as the upper bound of likely values. This range was developed by judgment, with an eye toward development of reasonable results.

Unlike trajectories of smoking, with initial exposure that primarily begins in the teens or early twenties, initial attainment of obesity can occur at any age. Looking ahead, there is concern that the increase in adolescent obesity over the last few decades will lead to an earlier inception of adult obesity, which in turn could increase the duration of and exposure to obesity, with a resultant increase in the number of resulting premature deaths. Thus, while for a given birth cohort, smoking prevalence tends to decrease after ages in the 20s, with smoking cessation at increasing age (as can be seen from Figures 2 and 3), obesity prevalence can both increase and decrease. In Table 8, for instance, obesity prevalence in the aggregate peaks in the age 40–59 category, although this fluctuation might be due to statistical fluctuations in surveys. Further, most decreases on an individual level have been temporary.

A reasonable range of assumptions for consequential mortality due to obesity is quite wide—not primarily because of pure statistical fluctuations, but rather because future trends are uncertain. For example, many studies of the effects of obesity exclude a sizable segment of the population (e.g., those who have smoked, are currently ill and are institutionalized). Because in the current analysis the emphasis is on the effect on mortality on the overall population (in contrast to an attempt to estimate the direct effect of obesity), it is more appropriate to include the expected number of premature deaths of all individuals in the population.

Table 10 was derived from a recently published meta-analysis, the Global BMI Mortality Collaboration (2016). This study found that overweight and obese mortality hazard ratios were smaller for

measurements made after 1990 than for those prior to 1990 (see Table 10). Hazard ratios comparing mortality of the obese with those having normal BMI levels were smaller for ever-smokers than for never-smokers. A significant reason for this relative improvement in the relative mortality of the obese is the decrease over the last several decades in the percentage of total deaths caused by cardiovascular diseases, for which obesity is one of the drivers.

Table 10. Hazard Ratios From the Global BMI Mortality Collaboration, by Gender and Period

BMI Category	Total	Males	Females	Measured Before 1990	Measured in 1990 or Later
15.0–18.4	1.51	1.83	1.53	1.43	1.53
18.5–19.9	1.33	1.00	1.00	1.00	1.00
20.0–22.4	1.00				
22.5–24.9	1.00				
25.0–27.4	1.07	1.12	1.08	1.14	1.05
27.5–29.9	1.20				
30.0–34.9	1.45	1.70	1.37	1.58	1.31
35.0–39.9	1.94	2.68	1.86	2.10	1.76
40.0+	2.76	4.24	2.71	2.88	2.49

Note: "Total" data are based on 189 studies, male data are based on 157 studies, and female data are based on 141 studies; as a result, the gender-specific hazard ratios are not necessarily consistent with the total ratios.
Source: Global BMI Mortality Collaboration (2016).

Obesity: Projection Methodology

The CDC has estimated that about 300,000 obesity-related premature deaths occur annually in the United States, although there has been a range of estimates of these deaths, as obesity is rarely identified as the primary cause of death in national vital statistics. Major immediate (direct) causes of death, as indicated in Gutterman (2016), include type 2 diabetes (almost 90 percent of those with diabetes are overweight or obese), cardiovascular and heart diseases, stroke, various cancers (including those of the colon, esophagus, kidney, breast in postmenopausal females, and pancreas), dementia, and kidney, liver and gallbladder diseases.

Because of the high percent of those suffering from diabetes who are overweight or obese, the trend in the rate of mortality due to diabetes was reviewed (shown in the appendix, Tables A-10 through A-12). A review of these tables through the 2010–14 period indicates that, although there are clear age, gender and period effects, no cohort effect is noticeable, other than what might be an emerging adverse cohort for males who were in the 45–59 age category during 2010–14.

Four scenarios were developed, consisting of sets of BMI prevalence rates: one set was based on NHANES 1988–94, and three sets (low, mid and high scenarios) were based on NHANES 2013–14. The mid and high 2013–14 scenarios reflected increases in overall obesity prevalence of 10 percent and 20 percent, respectively. All three 2013-14 scenarios incorporated a continued movement toward a somewhat greater percentage of those in the class 2 and 3 obesity categories.

To estimate the effect on mortality of the increase in obesity over the past several decades, two factors were multiplied. One factor was the estimated prevalence by BMI category (underweight, normal, overweight, obese 1, obese 2 and obese 3+, with the distribution between the obese 1 and obese 2

categories estimated based on an earlier survey), from the 1988–94 and the applicable 2013–14 NHANES. The second factor was the corresponding hazard ratio. These values are shown in Table 11 for each BMI category.

Table 11. Prevalence Rates and Mortality Hazard Ratios, by BMI Category

BMI Category	Prevalence, 1988–94 NHANES, %		Prevalance, by Scenario, 2013–14 NHANES, %						Hazard Ratios from Table 10	
			Low Scenario (100%)		Mid Scenario (110%)		High Scenario (120%)			
	Males	Females	Males	Females	Males	Females	Males	Females	Males	Females
Underweight	4.0	4.0	2.0	2.0	2.0	2.0	2.0	2.0	1.83	1.53
Normal	35.1	44.7	24.3	31.1	21.8	27.1	19.8	23.5	1.00	1.00
Overweight	40.7	25.9	38.7	26.5	38.7	26.5	38.7	26.5	1.12	1.08
Obese 1	12.0	12.0	19.0	17.0	20.0	18.5	20.5	19.1	1.70	1.37
Obese 2	6.5	9.5	10.5	13.5	11.0	14.5	11.5	16.5	2.68	1.86
Obese 3	1.7	3.9	5.5	9.9	6.5	11.4	7.5	12.4	4.24	2.71

It was assumed that the effect of the obesity prevalence at the time of the 1988–94 NHANES approximately corresponds with recent mortality experience, in that it might be expected that in the aggregate there is about a 30-year lag between exposure to obesity and resulting premature mortality experience,[3] as indicated above.

Recent mortality experience forms the baseline prior to application of rates of mortality improvement for the assumption of future mortality used by the Trustees of the Social Security system in their Intermediate demographic assumptions underlying the 2016 Trustees report of this large social insurance system. The mortality assumption for 2015 and subsequent years is used in the model as the baseline from which the lagged mortality effect of the obesity epidemic is based, in a manner similar to the estimated differential effect of smoking, as indicated above.

The Trustees' projections of future mortality rates represent their current best estimates of the future. The approach taken here is to use these projections as a reasonable baseline from which to estimate the future effect of the recent obesity epidemic. A comparison is made between current mortality experience and the expected future mortality experience that corresponds with the current and expected future obesity prevalence level. The ultimate excess ratio of mortality for each scenario was estimated to be the excess of the prevalent rate and corresponding mortality hazard ratio on a weighted basis for each of the three 2013–14 NHANES scenarios compared with the 1988–94 NHANES ratio.

This does not suggest that the Trustees ignored the effects of the obesity epidemic, but rather that their projections can serve as a reasonable base for the starting point of the obesity epidemic from which to estimate the future effect of the recent changes in BMI distributions. This baseline approach is similar to what was used for the analysis of the effect of the decreasing prevalence of smoking.

The results of these calculations represent estimates of the ultimate ratio comparing each of the three scenarios with the baseline level. For males, the scenario-to-baseline ratios are 1.166, 1.202 and 1.235 for the low, mid and high scenarios. The corresponding ratios for females are 1.118, 1.150 and 1.180, respectively.

[3] This period is somewhat less than 30 years. As a result, the differential effect may be somewhat understated.

It was assumed that for each scenario, the mortality hazard ratios applied to the applicable lagged BMI distributions are increased at a uniform annual rate over 30 years (a period selected based on judgment) from the 2010–15 period. The resulting factors were applied to the Trustees' intermediate cohort mortality assumption. The annual increases in mortality rates for 30 years are 0.372, 0.467 and 0.552 percent for females for the low, mid and high scenarios, respectively, and 0.512, 0.614 and 0.706 percent for males.

The resulting projection is that, overall, mortality in 30 years would lie within the range between 16.6 percent and 23.5 percent higher, corresponding with the three 2013–14 NHANES scenarios, than it would have been if the obesity epidemic had not occurred and obesity prevalence were consistently the same as indicated in the 1988–94 NHANES. The effects of the scenarios on life expectancy at ages 35 and 65 by gender are shown in Table 12.

Table 12. Estimated U.S. Cohort Life Expectancy and Effect of Increase in Obesity, by Obesity Prevalence Scenario

	At Age 35 in 2015		At Age 65 in 2015	
Life Expectancy in the NHANES Scenario	**Females**	**Males**	**Females**	**Males**
1988–94 NHANES	46.27	42.38	18.70	16.37
Low	45.32	41.04	18.17	15.70
Mid	45.08	40.77	18.03	15.58
High	44.86	40.54	17.92	15.47
Effect of Increases in Obesity From 1988–94 NHANES				
Low	–0.95	–1.34	–0.53	–0.67
Mid	–1.19	–1.61	–0.63	–0.79
High	–1.41	–1.84	–0.78	–0.90

The resulting estimated reduction in cohort life expectancy due to the increase in obesity for a 35-year old in 2015 is between 0.95 and 1.41 years for females and between 1.34 and 1.84 years for males, depending on the scenario; for a 65-year-old in 2015, it is between 0.53 and 0.78 years for females and between 0.67 and 0.90 for males. The corresponding intermediate cohort life expectancy values are 1.19 years and 1.61 years for a 35-year-old female and male, and are 0.63 years and 0.79 years for a 65-year-old male and female, respectively.

Note that this does not vary directly by cohort (even though the values are expressed in terms of cohort life expectancy), although illustrated life expectancy values are based on birth year 1980 and 1950 for ages 35 and 65. It assumes that the effects of a longer exposure period to obesity of younger cohorts approximately offset the effects of (1) lower hazard ratios at older attained ages and (2) the combined effects of a decreasing percentage of cardiovascular deaths compared with total deaths in the future, due to reductions in smoking and increases in obesity.

Net Effect of the Change in Smoking and Obesity

The estimated net effect of the changes in the two behaviors reviewed here on the cohort life expectancy of females and males who attained ages 35 and 65 in 2015 is shown in Table 13 compared with the

benchmark (the Trustees' assumptions). For the intermediate values, the estimated net effect at age 35 was a reduction of about 0.23 years for females and 0.62 years for males. At age 65, the net effect was a reduction of about 0.02 years for females and 0.18 for males.

Table 13. Estimated Effects on U.S. Cohort Life Expectancy of Smoking and Obesity

Effect of Change in Behavior	Age in 2015	Low		Intermediate		High	
		Females	Males	Females	Males	Females	Males
Smoking	35			0.96	0.99		
Obesity	35	–0.95	–1.34	–1.19	–1.61	–1.41	–1.84
Net	35			–0.23	–0.62		
Smoking	65			0.61	0.61		
Obesity	65	–0.53	–0.67	–0.63	–0.79	–0.78	–0.90
Net	65			–0.02	–0.18		

These effects do not represent the cohort life expectancy "cost" of these behaviors; rather, they represent the effect of the expected change in cohort life expectancy due to the change in these behaviors from baseline values—that is, the change in life expectancy at the applicable age (and recent mortality experience at that time).

The use of a model that incorporates a reduction or elimination of a driver or cause of death has sometimes been criticized because it ignores the existence of multiple ill-health conditions, especially at older ages, as well as the effect of aging itself. As a result, if a driver or cause of death is reduced or eliminated, the individual may die shortly thereafter of other causes—that is, the mortality rate from those other causes may increasing correspondingly. One advantage of studying two, somewhat offsetting factors, such as conducted in this paper, is that their combined effect reduces this type of concern.

Although a range of estimated values was developed to assess the effect of alternative obesity prevalence paths, only a single estimated value was developed for the effect of smoking. These selections do not imply that there is any less uncertainty regarding the future mortality impact of smoking, but just that it was thought that the scenarios for obesity served the purpose of illustrating the potential reasonable range associated with a specific set of obesity prevalence assumptions.

Interrelationships Between Smoking and Obesity

There are several significant sources of interrelationships between smoking and obesity. It is well known that one reason that some individuals smoke is to avoid gaining weight. As a result, after smoking cessation occurs, there tends to be an increase in BMI, which tends to offset somewhat the favorable effect on mortality of smoking cessation.

The joint effect of smoking and being obese is also significant. As seen in Table 14[4] according to Aune et al. (2016), their combination, expressed in terms of years since smoking cessation and BMI range, is greater than the sum of their two parts. In contrast, according to Mehta and Preston (2016) based on NHANES III (1988-94) and NHANES 1999-2010, linked to death records through December 31, 2011, the

[4] The mortality experience of the underweight population (BMI <18.5) is usually much greater than for those in the normal BMI category. However, since the percentage in this category has recently only been about 2 percent of the population (as shown in Table 10), the effect of this BMI category is ignored here.

relationship between mortality due to obesity and due to smoking was additive rather than multiplicative (that is, they are independent). Further analysis is called for.

Additional relationships are shown in Table 15. These interrelationships were not directly reflected in the above projections.

Table 14. **Hazard Ratios of the Mortality Effect of Combinations of Smoking and Obesity by BMI Category, by Gender and Time Since Smoking Cessation**

Smoking	Gender	BMI Range					
		< 18.5	18.5–23.4	23.5–24.9	25.0–29.9	30.0–34.9	35.0+
Never	**Males**	2.11	1.08	1.00	1.11	1.41	2.44
≥ 10 years	**Males**	2.96	2.45	2.15	2.22	2.67	3.51
< 10 years	**Males**	9.64	5.46	4.09	3.92	3.79	5.00
Current	**Males**	8.36	6.48	6.15	5.21	5.82	8.13
Never	**Females**	1.51	1.17	1.00	1.14	1.33	2.18
≥ 10 years	**Females**	3.01	2.09	1.85	2.20	2.71	3.86
< 10 years	**Females**	11.98	4.66	2.91	3.41	3.88	5.09
Current	**Females**	9.41	5.86	5.35	5.11	5.85	6.61

Source: Aune et al. (2016).

Table 15. Hazard Ratios of Mortality, by BMI, Smoking, and Age Groups

BMI	Smoking and Age Categories						
	All Participants	Current Smokers	Ever-Smokers	Healthy Non-smokers	Never-Smokers	<65 Years Old	≥65 Years Old
17.5	1.47	1.61	1.50	1.15	1.35	1.54	1.46
25.0	0.97	0.96	0.97	1.03	1.00	1.02	0.96
30.0	1.04	1.08	1.05	1.24	1.20	1.32	0.99
35.0	1.29	1.48	1.31	1.66	1.65	2.08	1.15
40.0	1.74	2.32	1.79	2.37	2.50	3.60	1.45

Source: Aune et al. (2016).

Limitations

Any projection of mortality is fraught with uncertainty. Those made in this paper are no exception. Although past patterns were examined for applicable trends that are expected to continue, the model used is by necessity somewhat simplistic. In addition, many other factors that contribute to the future level and pattern of mortality were not considered here.

Limitations of this analysis include uncertainties associated with four areas of research design. First, several sets of assumptions (the future trajectories in the prevalence of smoking and obesity and the future effects of these drivers on mortality) were developed through the application of judgment, as it is impossible to precisely predict the course of future smoking prevalence and BMI distribution and their resulting mortality hazard ratios. Second, the methodology uses as a baseline the mortality assumptions used by the Trustees of the Social Security system, although the assumptions made by the Trustees were developed with changes in behavior in mind. It is not possible to decompose the related changes the

Trustees have assumed from other drivers of future mortality. A third area of uncertainty is that the interrelationships both between smoking and obesity and between smoking and obesity and other causes of death have not been explicitly incorporated into the projections presented here. Finally, the period over which the estimated ultimate values are reached and the pattern of changes during this period also were selected by judgment.

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Appendix: Trends in Smoking-Related Diseases in the United States

This appendix provides additional data on mortality rates associated with selected smoking-related diseases in the United States. Tables A-1 through A-3 present mortality rate data for deaths due to lung, trachea and bronchus cancers; Tables A-4 through A-6 present data for deaths due to other pulmonary diseases (primarily COPD). For each series, the first table shows raw mortality rates, the second shows the percentage change in these rates, and the third shows the ratio of female to male mortality rates. The source for the data in these tables is the Human Mortality Data Base, Causes of Death for the United States.

Note that causes of death are classified according to the International Classification of Diseases (ICD) diagnosis coding applicable in the period reported. In the 1970s, the category for other pulmonary diseases was reclassified between ICD-8 and ICD-9, which is the reason this set of tables covers a shorter period. Another reclassification occurred in 1999 between ICD-9 and ICD-10, but its effect was relatively small for these causes of deaths.

For ease of comparison in the appendix, Table A-1 is a repeat of Table 5, and Table A-4 is a repeat of Table 6. Rates shown are for quinquennial age groups 35–39 through 95–99. Rates for ages younger than 35 are quite small, and the data by cause for ages over 99 may not be fully credible because, in part, of the high frequency of multiple causes of death and sparsity of experience at these ages. For projection purposes, no change is assumed to occur for centenarians. In any event, the effect of this assumption is quite minimal.

To provide additional perspective, corresponding data for mortality from all causes are shown in Tables A-7 through A-9. Finally, Tables A-10 through A-12 present corresponding data for diabetes, a major cause of death due to obesity, although this paper did not use this data.

Table A-1. U.S. Mortality Rates From Lung, Trachea and Bronchus Cancers, Deaths per 100,000

Females	35-39	40-44	45-49	50-54	55-59	60-64	65-69	70-74	75-79	80-84	85-89	90-94	95-99
1970-1974	2.53	8.05	17.41	27.99	44.27	51.92	56.90	62.45	65.36	64.65	70.67	74.37	53.10
1975-1979	2.29	9.08	19.91	37.33	53.47	78.17	89.67	94.79	92.36	91.43	85.82	90.15	89.05
1980-1984	1.99	7.31	20.99	43.28	71.67	98.86	127.63	146.58	137.13	128.16	119.05	108.33	109.49
1985-1989	1.77	6.50	20.26	45.59	75.93	121.23	154.78	196.56	199.46	182.43	150.64	132.40	124.52
1990-1994	2.02	5.68	16.94	40.20	77.82	127.92	184.36	234.09	261.41	259.06	216.79	169.19	147.47
1995-1999	1.95	6.20	13.63	33.45	71.09	122.95	186.80	257.29	289.67	322.48	277.46	225.83	157.38
2000-2004	1.73	5.75	15.27	28.79	58.73	113.46	180.34	259.23	326.35	355.22	325.15	266.51	197.74
2005-2009	1.25	4.56	14.49	29.43	49.29	91.76	163.23	243.70	324.86	370.02	356.00	292.12	238.71
2010-2014	0.98	2.85	10.22	27.54	50.53	77.53	129.73	217.52	292.64	354.50	359.18	299.08	240.89
Males													
1970-1974	5.52	18.86	45.13	84.19	155.13	236.89	333.40	413.91	447.46	419.25	328.99	238.17	198.80
1975-1979	4.15	16.13	43.06	94.24	161.33	260.95	357.53	471.94	507.93	510.19	435.72	310.81	271.41
1980-1984	2.96	13.33	38.93	91.64	170.03	271.03	384.70	504.69	585.60	605.80	551.31	409.73	350.27
1985-1989	2.86	10.93	33.38	83.49	163.64	282.03	392.87	530.83	622.45	667.94	629.31	514.72	386.01
1990-1994	2.58	8.20	25.36	68.15	144.99	260.18	394.99	522.88	621.97	713.72	692.73	581.80	453.65
1995-1999	2.21	8.17	20.66	50.23	114.17	219.11	347.37	502.12	589.27	701.40	713.05	610.51	525.93
2000-2004	1.64	6.55	20.74	42.78	91.37	181.92	297.14	450.92	581.75	677.22	689.83	608.35	530.68
2005-2009	1.43	4.43	16.34	39.18	74.92	142.79	251.43	387.18	517.45	645.30	673.35	615.81	517.38
2010-2014	1.06	3.30	11.21	31.55	70.44	119.27	199.52	316.87	441.75	554.26	618.75	559.42	454.94

Table A-2. Change in U.S. Mortality Rates From Lung, Trachea and Bronchus Cancer, Deaths per 100,000

Females		35-39	40-44	45-49	50-54	55-59	60-64	65-69	70-74	75-79	80-84	85-89	90-94	95-99
1970-1974	**1975-1979**	-0.24	1.03	2.50	9.34	9.20	26.25	32.77	32.34	27.00	26.78	15.15	15.78	35.95
1975-1979	**1980-1984**	-0.30	-1.77	1.08	5.95	18.20	20.69	37.96	51.79	44.77	36.73	33.23	18.18	20.44
1980-1984	**1985-1989**	-0.22	-0.81	-0.73	2.31	4.26	22.37	27.15	49.98	62.33	54.27	31.59	24.07	15.03
1985-1989	**1990-1994**	0.25	-0.82	-3.32	-5.39	1.89	6.69	29.58	37.53	61.95	76.63	66.15	36.79	22.95
1990-1994	**1995-1999**	-0.07	0.52	-3.31	-6.75	-6.73	-4.97	2.44	23.20	28.26	63.42	60.67	56.64	9.91
1995-1999	**2000-2004**	-0.22	-0.45	1.64	-4.66	-12.36	-9.49	-6.46	1.94	36.68	32.74	47.69	40.68	40.36
2000-2004	**2005-2009**	-0.48	-1.19	-0.78	0.64	-9.44	-21.70	-17.11	-15.53	-1.49	14.80	30.85	25.61	40.97
2005-2009	**2010-2014**	-0.27	-1.71	-4.27	-1.89	1.24	-14.23	-33.50	-26.18	-32.22	-15.52	3.18	6.96	2.18
Males														
1970-1974	**1975-1979**	-1.37	-2.73	-2.07	10.05	6.20	24.06	24.13	58.03	60.47	90.94	106.73	72.64	72.61
1975-1979	**1980-1984**	-1.19	-2.80	-4.13	-2.60	8.70	10.08	27.17	32.75	77.67	95.61	115.59	98.92	78.86
1980-1984	**1985-1989**	-0.10	-2.40	-5.55	-8.15	-6.39	11.00	8.17	26.14	36.85	62.14	78.00	104.99	35.74
1985-1989	**1990-1994**	-0.28	-2.73	-8.02	-15.34	-18.65	-21.85	2.12	-7.95	-0.48	45.78	63.42	67.08	67.64
1990-1994	**1995-1999**	-0.37	-0.03	-4.70	-17.92	-30.82	-41.07	-47.62	-20.76	-32.70	-12.32	20.32	28.71	72.28
1995-1999	**2000-2004**	-0.57	-1.62	0.08	-7.45	-22.80	-37.19	-50.23	-51.20	-7.52	-24.18	-23.22	-2.16	4.75
2000-2004	**2005-2009**	-0.21	-2.12	-4.40	-3.60	-16.45	-39.13	-45.71	-63.74	-64.30	-31.92	-16.48	7.46	-13.30
2005-2009	**2010-2014**	-0.37	-1.13	-5.13	-7.63	-4.48	-23.52	-51.91	-70.31	-75.70	-91.04	-54.60	-56.39	-62.44

Table A-3. Ratio of Female Mortality to Male Mortality From Lung, Trachea and Bronchus Cancer

	35-39	40-44	45-49	50-54	55-59	60-64	65-69	70-74	75-79	80-84	85-89	90-94	95-99
1970-1974	46%	43%	39%	33%	29%	22%	17%	15%	15%	15%	21%	31%	27%
1975-1979	55%	56%	46%	40%	33%	30%	25%	20%	18%	18%	20%	29%	33%
1980-1984	67%	55%	54%	47%	42%	36%	33%	29%	23%	21%	22%	26%	31%
1985-1989	62%	59%	61%	55%	46%	43%	39%	37%	32%	27%	24%	26%	32%
1990-1994	78%	69%	67%	59%	54%	49%	47%	45%	42%	36%	31%	29%	33%
1995-1999	88%	76%	66%	67%	62%	56%	54%	51%	49%	46%	39%	37%	30%
2000-2004	105%	88%	74%	67%	64%	62%	61%	57%	56%	52%	47%	44%	37%
2005-2009	87%	103%	89%	75%	66%	64%	65%	63%	63%	57%	53%	47%	46%
2010-2014	92%	86%	91%	87%	72%	65%	65%	69%	66%	64%	58%	53%	53%

Note: Ratios calculated from data in Table A-1.

Table A-4. U.S. Mortality Rates From Other Pulmonary Diseases (Mostly COPD), Deaths per 100,000

Females	35-39	40-44	45-49	50-54	55-59	60-64	65-69	70-74	75-79	80-84	85-89	90-94	95-99
1980-1984	0.23	1.02	2.83	7.02	15.61	31.14	56.53	87.72	109.08	132.96	144.01	157.83	161.20
1985-1989	0.22	0.51	2.56	7.57	19.36	40.38	70.30	119.53	169.92	208.48	227.61	239.28	262.78
1990-1994	0.21	0.55	1.82	7.08	19.04	44.94	84.48	138.49	218.51	287.64	325.87	341.17	353.31
1995-1999	0.23	0.76	2.11	6.84	19.87	47.72	91.72	162.68	248.86	369.87	448.89	485.03	517.76
2000-2004	0.50	1.05	3.01	7.01	18.37	49.44	98.80	176.85	275.85	420.89	571.52	659.44	738.43
2005-2009	0.35	1.27	3.83	9.59	18.12	43.19	92.87	174.64	285.51	437.32	594.24	733.53	873.08
2010-2014	0.38	1.03	3.68	11.39	22.27	41.03	83.94	170.51	280.77	432.13	605.52	768.03	939.64
Males													
1980-1984	0.37	1.24	3.41	11.09	29.34	64.71	132.61	253.92	392.23	543.38	661.28	664.81	663.71
1985-1989	0.47	1.12	3.47	9.95	28.44	68.68	134.76	253.05	414.30	615.80	801.33	844.72	909.61
1990-1994	0.35	1.06	2.63	8.99	25.77	61.77	134.94	234.67	392.75	622.91	838.24	966.37	1,164.40
1995-1999	0.30	1.08	2.92	8.56	24.52	59.34	123.76	242.83	390.04	643.18	925.79	1,141.26	1,369.01
2000-2004	0.36	1.29	3.62	8.97	22.13	56.91	116.15	230.02	388.94	625.30	943.24	1,261.58	1,537.43
2005-2009	0.32	1.17	4.00	10.22	22.81	50.71	108.62	207.59	361.50	589.57	855.69	1,169.30	1,489.30
2010-2014	0.25	1.11	2.99	9.94	24.55	49.43	97.53	200.81	330.55	540.08	819.32	1,103.06	1,511.19

Table A-5. Change in U.S. Mortality Rates From Other Pulmonary Diseases (Mostly COPD), Deaths per 100,000

Females		35-39	40-44	45-49	50-54	55-59	60-64	65-69	70-74	75-79	80-84	85-89	90-94	95-99
1980-1984	**1985-1989**	-0.01	-0.51	-0.27	0.55	3.75	9.24	13.77	31.81	60.84	75.52	83.60	81.45	101.58
1985-1989	**1990-1994**	-0.01	0.04	-0.74	-0.49	-0.32	4.56	14.18	18.96	48.59	79.16	98.26	101.89	90.53
1990-1994	**1995-1999**	0.02	0.21	0.29	-0.24	0.83	2.78	7.24	24.19	30.35	82.23	123.02	143.86	164.45
1995-1999	**2000-2004**	0.27	0.29	0.90	0.17	-1.50	1.72	7.08	14.17	26.99	51.02	122.63	174.41	220.67
2000-2004	**2005-2009**	-0.15	0.22	0.82	2.58	-0.25	-6.25	-5.93	-2.21	9.66	16.43	22.72	74.09	134.65
2005-2009	**2010-2014**	0.03	-0.24	-0.15	1.80	4.15	-2.16	-8.93	-4.13	-4.74	-5.19	11.28	34.50	66.56
Males														
1980-1984	**1985-1989**	0.10	-0.12	0.06	-1.14	-0.90	3.97	2.15	-0.87	22.07	72.42	140.05	179.91	245.90
1985-1989	**1990-1994**	-0.12	-0.06	-0.84	-0.96	-2.67	-6.91	0.18	-18.38	-21.55	7.11	36.91	121.65	254.79
1990-1994	**1995-1999**	-0.05	0.02	0.29	-0.43	-1.25	-2.43	-11.18	8.16	-2.71	20.27	87.55	174.89	204.61
1995-1999	**2000-2004**	0.06	0.21	0.70	0.41	-2.39	-2.43	-7.61	-12.81	-1.10	-17.88	17.45	120.32	168.42
2000-2004	**2005-2009**	-0.04	-0.12	0.38	1.25	0.68	-6.20	-7.53	-22.43	-27.44	-35.73	-87.55	-92.28	-48.13
2005-2009	**2010-2014**	-0.07	-0.06	-1.01	-0.28	1.74	-1.28	-11.09	-6.78	-30.95	-49.49	-36.37	-66.24	21.89

Table A-6. Ratio of Female Mortality to Male Mortality From Other Pulmonary Diseases (Mostly COPD)

	35-39	40-44	45-49	50-54	55-59	60-64	65-69	70-74	75-79	80-84	85-89	90-94	95-99
1980-1984	62%	82%	83%	63%	53%	48%	43%	35%	28%	24%	22%	24%	24%
1985-1989	47%	46%	74%	76%	68%	59%	52%	47%	41%	34%	28%	28%	29%
1990-1994	60%	52%	69%	79%	74%	73%	63%	59%	56%	46%	39%	35%	30%
1995-1999	77%	70%	72%	80%	81%	80%	74%	67%	64%	58%	48%	42%	38%
2000-2004	139%	81%	83%	78%	83%	87%	85%	77%	71%	67%	61%	52%	48%
2005-2009	109%	109%	96%	94%	79%	85%	85%	84%	79%	74%	69%	63%	59%
2010-2014	152%	93%	123%	115%	91%	83%	86%	85%	85%	80%	74%	70%	62%

Note: Ratios calculated from data in Table A-4.

Table A-7. U.S. Mortality Rates From All Causes, Deaths per 100,000

Females	35-39	40-44	45-49	50-54	55-59	60-64	65-69	70-74	75-79	80-84	85-89	90-94	95-99
1970-1974	171.28	266.68	406.74	589.09	875.95	1,280.61	1,928.61	3,169.75	5,127.62	8,395.86	13,753.45	21,255.00	30,467.94
1975-1979	134.83	219.89	345.69	525.32	771.68	1,174.66	1,686.70	2,764.89	4,352.51	7,341.80	12,014.79	18,977.75	27,932.91
1980-1984	115.51	185.87	303.56	482.59	740.52	1,127.04	1,685.32	2,607.35	4,085.45	6,976.49	11,500.50	18,255.38	27,315.23
1985-1989	113.42	170.32	276.73	453.99	710.59	1,111.30	1,656.34	2,563.46	3,994.99	6,729.14	11,296.51	18,408.11	28,146.07
1990-1994	118.30	166.71	260.59	416.72	669.51	1,049.67	1,588.56	2,436.30	3,783.11	6,390.46	10,655.24	17,630.12	27,487.49
1995-1999	117.71	170.72	250.09	388.63	625.59	1,005.64	1,536.05	2,403.10	3,739.68	6,464.50	10,977.72	18,403.23	29,116.66
2000-2004	114.66	177.12	259.88	377.51	584.36	930.00	1,445.41	2,273.13	3,648.97	6,350.60	11,093.82	18,954.51	30,398.39
2005-2009	106.32	169.56	261.56	377.54	537.53	831.41	1,282.17	2,040.98	3,323.24	5,732.48	10,193.53	17,829.74	28,977.48
2010-2014	103.99	155.54	247.39	377.46	535.95	773.63	1,180.88	1,871.55	3,085.11	5,285.83	9,529.30	16,919.13	27,857.10
Males													
1970-1974	303.39	460.51	737.83	1,127.77	1,782.88	2,693.20	3,950.96	5,854.08	8,487.35	12,358.01	18,180.62	25,811.23	35,062.30
1975-1979	257.07	391.53	631.64	1,005.08	1,522.94	2,394.46	3,484.09	5,321.39	7,589.70	11,445.84	16,752.01	24,069.94	32,955.76
1980-1984	230.36	339.04	547.31	894.00	1,410.19	2,143.67	3,250.51	4,914.83	7,242.81	11,095.96	16,432.18	23,642.27	33,341.94
1985-1989	260.14	335.32	502.50	806.75	1,296.12	2,025.01	3,013.06	4,659.00	6,940.40	10,827.91	16,288.09	24,082.52	34,271.05
1990-1994	284.14	359.39	486.21	729.47	1,159.76	1,834.35	2,778.95	4,157.37	6,308.01	10,186.74	15,570.69	23,409.51	34,341.43
1995-1999	235.99	328.61	460.80	660.10	1,035.36	1,654.26	2,527.22	3,902.15	5,895.14	9,829.99	15,636.10	24,121.88	35,493.26
2000-2004	206.04	303.51	454.45	649.36	948.38	1,465.41	2,235.76	3,471.46	5,429.96	9,034.22	15,013.42	24,166.80	36,632.27
2005-2009	188.59	280.49	428.43	647.51	915.03	1,322.81	1,958.32	3,003.59	4,768.65	7,913.75	13,371.38	22,419.66	34,999.28
2010-2014	179.25	246.67	390.17	611.85	912.26	1,282.05	1,813.49	2,758.44	4,355.82	7,206.41	12,228.52	20,792.53	33,013.90

Table A-8. Change in U.S. Mortality Rates From All Causes, Deaths per 100,000

Females		35-39	40-44	45-49	50-54	55-59	60-64	65-69	70-74	75-79	80-84	85-89	90-94	95-99
1970-1974	**1975-1979**	-36.45	-46.79	-61.05	-63.77	-104.27	-105.95	-241.91	-404.86	-775.11	-1054.06	-1738.66	-2277.25	-2535.03
1975-1979	**1980-1984**	-19.32	-34.02	-42.13	-42.73	-31.16	-47.62	-1.38	-157.54	-267.06	-365.31	-514.29	-722.37	-617.68
1980-1984	**1985-1989**	-2.09	-15.55	-26.83	-28.60	-29.93	-15.74	-28.98	-43.89	-90.46	-247.35	-203.99	152.73	830.84
1985-1989	**1990-1994**	4.88	-3.61	-16.14	-37.27	-41.08	-61.63	-67.78	-127.16	-211.88	-338.68	-641.27	-777.99	-658.58
1990-1994	**1995-1999**	-0.59	4.01	-10.50	-28.09	-43.92	-44.03	-52.51	-33.20	-43.43	74.04	322.48	773.11	1629.17
1995-1999	**2000-2004**	-3.05	6.40	9.79	-11.12	-41.23	-75.64	-90.64	-129.97	-90.71	-113.90	116.10	551.28	1281.73
2000-2004	**2005-2009**	-8.34	-7.56	1.68	0.03	-46.83	-98.59	-163.24	-232.15	-325.73	-618.12	-900.29	-1124.77	-1420.91
2005-2009	**2010-2014**	-2.33	-14.02	-14.17	-0.08	-1.58	-57.78	-101.29	-169.43	-238.13	-446.65	-664.23	-910.61	-1120.38
Males														
1970-1974	**1975-1979**	-46.32	-68.98	-106.19	-122.69	-259.94	-298.74	-466.87	-532.69	-897.65	-912.17	-1428.61	-1741.29	-2106.54
1975-1979	**1980-1984**	-26.71	-52.49	-84.33	-111.08	-112.75	-250.79	-233.58	-406.56	-346.89	-349.88	-319.83	-427.67	386.18
1980-1984	**1985-1989**	29.78	-3.72	-44.81	-87.25	-114.07	-118.66	-237.45	-255.83	-302.41	-268.05	-144.09	440.25	929.11
1985-1989	**1990-1994**	24.00	24.07	-16.29	-77.28	-136.36	-190.66	-234.11	-501.63	-632.39	-641.17	-717.40	-673.01	70.38
1990-1994	**1995-1999**	-48.15	-30.78	-25.41	-69.37	-124.40	-180.09	-251.73	-255.22	-412.87	-356.75	65.41	712.37	1151.83
1995-1999	**2000-2004**	-29.95	-25.10	-6.35	-10.74	-86.98	-188.85	-291.46	-430.69	-465.18	-795.77	-622.68	44.92	1139.01
2000-2004	**2005-2009**	-17.45	-23.02	-26.02	-1.85	-33.35	-142.60	-277.44	-467.87	-661.31	-1120.47	-1642.04	-1747.14	-1632.99
2005-2009	**2010-2014**	-9.34	-33.82	-38.26	-35.66	-2.77	-40.76	-144.83	-245.15	-412.83	-707.34	-1142.86	-1627.13	-1985.38

Table A-9. Ratio of Female All-Cause Mortality to Male All-Cause Mortality

	35-39	40-44	45-49	50-54	55-59	60-64	65-69	70-74	75-79	80-84	85-89	90-94	95-99
1970-1974	56%	58%	55%	52%	49%	48%	49%	54%	60%	68%	76%	82%	87%
1975-1979	52%	56%	55%	52%	51%	49%	48%	52%	57%	64%	72%	79%	85%
1980-1984	50%	55%	55%	54%	53%	53%	52%	53%	56%	63%	70%	77%	82%
1985-1989	44%	51%	55%	56%	55%	55%	55%	55%	58%	62%	69%	76%	82%
1990-1994	42%	46%	54%	57%	58%	57%	57%	59%	60%	63%	68%	75%	80%
1995-1999	50%	52%	54%	59%	60%	61%	61%	62%	63%	66%	70%	76%	82%
2000-2004	56%	58%	57%	58%	62%	63%	65%	65%	67%	70%	74%	78%	83%
2005-2009	56%	60%	61%	58%	59%	63%	65%	68%	70%	72%	76%	80%	83%
2010-2014	58%	63%	63%	62%	59%	60%	65%	68%	71%	73%	78%	81%	84%

Note: Ratios calculated from data in Table A-7.

Table A-10. U.S. Mortality Rates (United States) From Diabetes, Deaths per 100,000

Females	35-39	40-44	45-49	50-54	55-59	60-64	65-69	70-74	75-79	80-84	85-89	90-94	95-99
1980-1984	2.71	3.54	6.03	10.02	17.42	30.80	50.59	77.65	114.29	173.11	230.47	275.17	296.86
1985-1989	1.99	3.83	6.09	11.18	19.82	32.47	51.55	77.79	114.16	161.99	241.51	279.74	303.98
1990-1994	2.45	3.80	7.16	13.69	23.83	38.78	64.14	91.01	130.25	190.10	251.96	326.46	372.91
1995-1999	2.25	3.68	7.38	13.56	25.14	44.56	67.97	103.48	144.15	209.62	293.82	356.30	441.83
2000-2004	2.66	3.93	7.10	13.22	24.09	39.44	67.67	101.45	148.00	225.20	323.94	417.44	502.03
2005-2009	2.43	4.19	6.99	11.73	20.43	34.55	53.65	81.59	126.91	195.07	289.59	381.26	446.66
2010-2014	2.74	3.94	7.73	11.60	18.34	30.30	48.79	69.06	111.30	170.41	249.84	353.60	424.18
Males													
1980-1984	3.62	5.12	7.64	12.25	20.23	31.91	48.54	76.39	118.48	167.53	207.19	277.82	294.96
1985-1989	3.75	5.71	9.33	13.55	22.83	34.98	53.03	83.43	116.12	170.63	220.46	286.27	314.12
1990-1994	3.24	5.82	9.54	16.81	28.01	45.12	66.13	96.00	141.72	208.32	282.88	345.08	399.12
1995-1999	3.81	6.09	10.72	18.43	30.63	52.34	79.41	118.42	169.11	256.32	343.84	397.34	491.96
2000-2004	3.74	7.15	11.10	18.76	33.22	55.49	84.99	123.95	178.59	268.61	384.49	492.74	546.29
2005-2009	3.58	7.09	11.61	19.74	31.43	53.54	75.38	113.81	166.27	244.14	352.60	482.95	546.13
2010-2014	3.32	6.62	12.97	20.08	32.20	48.63	73.79	104.28	155.46	224.16	324.55	448.91	558.03

Table A-11. Change in U.S. Mortality Rates From Diabetes, Deaths per 100,000

Females		35-39	40-44	45-49	50-54	55-59	60-64	65-69	70-74	75-79	80-84	85-89	90-94	95-99
1980-1984	**1985-1989**	-0.72	0.29	0.06	1.16	2.40	1.67	0.96	0.14	-0.13	-11.12	11.04	4.57	7.12
1985-1989	**1990-1994**	0.46	-0.03	1.07	2.51	4.01	6.31	12.59	13.22	16.09	28.11	10.45	46.72	68.93
1990-1994	**1995-1999**	-0.20	-0.12	0.22	-0.13	1.31	5.78	3.83	12.47	13.90	19.52	41.86	29.84	68.92
1995-1999	**2000-2004**	0.41	0.25	-0.28	-0.34	-1.05	-5.12	-0.30	-2.03	3.85	15.58	30.12	61.14	60.20
2000-2004	**2005-2009**	-0.23	0.26	-0.11	-1.49	-3.66	-4.89	-14.02	-19.86	-21.09	-30.13	-34.35	-36.18	-55.37
2005-2009	**2010-2014**	0.31	-0.25	0.74	-0.13	-2.09	-4.25	-4.86	-12.53	-15.61	-24.66	-39.75	-27.66	-22.48
Males														
1980-1984	**1985-1989**	0.13	0.59	1.69	1.30	2.60	3.07	4.49	7.04	-2.36	3.10	13.27	8.45	19.16
1985-1989	**1990-1994**	-0.51	0.11	0.21	3.26	5.18	10.14	13.10	12.57	25.60	37.69	62.42	58.81	85.00
1990-1994	**1995-1999**	0.57	0.27	1.18	1.62	2.62	7.22	13.28	22.42	27.39	48.00	60.96	52.26	92.84
1995-1999	**2000-2004**	-0.07	1.06	0.38	0.33	2.59	3.15	5.58	5.53	9.48	12.29	40.65	95.40	54.33
2000-2004	**2005-2009**	-0.16	-0.06	0.51	0.98	-1.79	-1.95	-9.61	-10.14	-12.32	-24.47	-31.89	-9.79	-0.16
2005-2009	**2010-2014**	-0.26	-0.47	1.36	0.34	0.77	-4.91	-1.59	-9.53	-10.81	-19.98	-28.05	-34.04	11.90

Table A-12. Ratio of Female All-Cause Mortality to Male Diabetes Mortality

	35-39	40-44	45-49	50-54	55-59	60-64	65-69	70-74	75-79	80-84	85-89	90-94	95-99
1980-1984	75%	69%	79%	82%	86%	97%	104%	102%	96%	103%	111%	99%	101%
1985-1989	53%	67%	65%	83%	87%	93%	97%	93%	98%	95%	110%	98%	97%
1990-1994	76%	65%	75%	81%	85%	86%	97%	95%	92%	91%	89%	95%	93%
1995-1999	59%	60%	69%	74%	82%	85%	86%	87%	85%	82%	85%	90%	90%
2000-2004	71%	55%	64%	70%	73%	71%	80%	82%	83%	84%	84%	85%	92%
2005-2009	68%	59%	60%	59%	65%	65%	71%	72%	76%	80%	82%	79%	82%
2010-2014	83%	60%	60%	58%	57%	62%	66%	66%	72%	76%	77%	79%	76%

Note: Ratios calculated from data in Table A-10.