Chapter 3

Smoking Prevalence and Lung Cancer Death Rates

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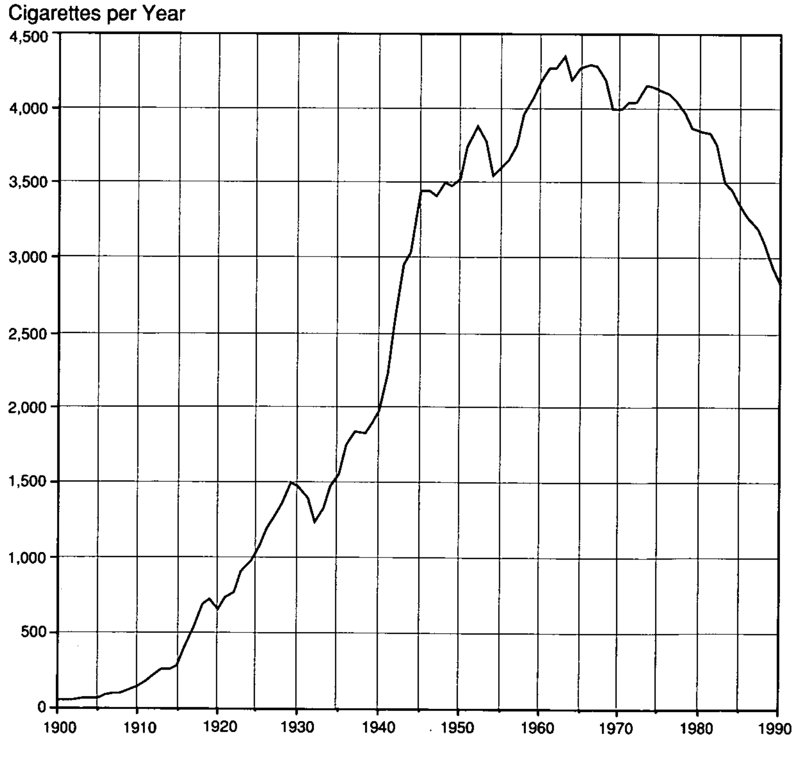
INTRODUCTION

The use of cigarettes, in contrast to other tobacco products, is a behavior that has developed relatively recently. Widespread use of cigarettes has been predominantly a 20th century phenomenon, with per capita consumption of cigarettes rising from 54 in 1900 to a peak of 4,345 in 1963 and then declining (Shopland et al., 1990) (see Figure 1). [Note: The data points used for plotting all figures in this chapter are listed in Appendix A.]

Figure 1
U.S. per capita cigarette consumption for adults, aged 18 and older (1900 to 1990)



Other chapters of this monograph address the social and environmental influences that have produced these changes in per capita consumption over time. This chapter describes the changes in smoking prevalence that occurred during this century and links them to observed changes in lung cancer death rates. A model for predicting future lung cancer death rates is presented also.

The prevalence of cigarette smoking is not spread uniformly across the U.S. population. There are marked differences in smoking prevalence across gender, racial, educational, and age groupings in the current population, and these differences have varied markedly across the first nine decades of this century. The risk of developing lung cancer is defined predominantly by past smoking exposure rather than by current smoking status. For these reasons, the data presented in this chapter are arranged by 10-year birth cohort. (A birth cohort is a group of individuals born during a specific span of calendar years.)

By following the changes in smoking behavior and lung cancer occurrence in a cohort as it ages, one is able to construct an accurate picture of the cumulative smoking history of the cohort and compare it with the resultant lung cancer occurrence in the same cohort. The more traditional approach, presenting data from multiple cross-sectional surveys done in different calendar years by the age of the individual surveyed at the time of the survey, leads to a biased impression of the changes in smoking prevalence that occur with age and an underestimation of the past smoking behavior of the older segments of the current population. When age-specific rates from multiple cross-sectional studies are compared to one another, the implicit assumption is that attained age (rather than calendar year of birth) is the dominant determinant of the rate being measured. For smoking behavior, however, calendar year of birth has a major influence on the possibility that an individual will become a cigarette smoker and on the duration of that smoking behavior. The individuals who constitute a given age group in cross-sectional samples drawn many years apart will belong to different birth cohorts. To compare the cross-sectional smoking prevalences at a given age without considering the peak prevalences of the birth cohorts that they represent distorts the true relationship between smoking behavior and age.

The excess death rates in cigarette smokers compared to nonsmokers lead to a diminishing fraction of ever-smokers being measured in a birth cohort as the population ages. Current measures of current and former smokers in older age groups will then underestimate the true prevalence of smoking of the same birth cohort several decades earlier. Since past rather than current smoking behavior causes lung cancer, and since the bulk of the U.S. lung cancer deaths occur among those same older segments of the current population, an accurate description of their smoking behavior is essential to the development of a model that relates smoking behavior to lung cancer death rates.

ANALYSIS OF SMOKING BEHAVIOR

This section characterizes smoking behavior in the United States between 1901 and 1987. Smoking prevalence is examined over time, by 10-year birth cohort, gender, and race. This information was produced from analyses of the National Health Interview Surveys (NHIS) conducted in 1970, 1978, 1979, 1980, and 1987. Because of its large sample size and high response rate (typically greater than 95 percent), the NHIS was used for estimates of smoking prevalence in the United States. The NHIS data sets used here are the only NHIS data sets available for computer analysis that include information regarding age of initiation and cessation of smoking—the two variables necessary to this analysis for constructing the past smoking behavior of a birth cohort from recent cross-sectional data.

Similar analyses have been reported previously in the Surgeon General's Reports (US DHHS, 1980 and 1985). The 1980 report included an analysis of the 1978 NHIS, with prevalence estimates through 1978. The 1985 report included analysis of the 1978, 1979, and 1980 NHIS combined, and also reported prevalence through 1978. The current analyses update the previous analyses by providing estimates through 1987 (an additional 9 years) and make use of the earlier 1970 data, which are likely to provide more accurate estimates of smoking behavior prior to 1970. This greater accuracy may be most applicable to earlier birth cohorts (e.g., people born from 1901 to 1910), which experienced significant mortality prior to 1978 (see discussion below). In addition, of all the NHIS samples, the 1970 NHIS is the largest, with 116,466 cases overall, including smoking data for 76,675 of these cases. The total number of cases for the other surveys used for this analysis were as follows: 1978, 12,111; 1979, 26,271; 1980, 11,333; and 1987, 22,043.

The analyses reported here rely mainly on responses to three questions: "How old were you when you first started smoking cigarettes fairly regularly?", "Do you smoke cigarettes now?", and "About how long has it been since you smoked cigarettes regularly?" The wording of these questions remained essentially identical across all surveys; however, the order of the questions and coding of responses may have resulted in slight differences in the categorization of smokers as *regular* versus *occasional* smokers. *Occasional* smokers typically are defined as those who *volunteer* that they never smoked cigarettes regularly, and thus they do not consistently report an age of onset and/or age of quitting. Because of the inconsistency of reporting, these respondents, when identifiable, were treated as *never-smokers* in these analyses.

Another difference among the five NHIS data sets used here is the source of responses—that is, self or respondent proxy. Of those responding to the smoking questions, the proxy response rates among those over age 17 in the surveys are: 1970, 39.0 percent; 1978 to 1980, 0.5 percent; and 1987, 22.2 percent. Proxy respondents typically are thought to report smoking status accurately but to underreport the number of cigarettes smoked per day and to be less knowledgeable about the age of onset and cessation of smoking (US DHHS, 1990).

Diagnostic analyses regarding the effects of using both proxy reports and self-reports in the 1970 NHIS demonstrate that estimates of age of initiation and age of cessation, by cohort and by cohort and gender, generally differ by less than 1 percentage point when based on proxy versus self-reports. In most cases, proxy reports result in slightly higher ages of initiation and cessation. This suggests that proxy reporting does not substantially affect cohort trends in smoking over time as reported here. Use of only self-reports for estimates of smoking prevalence results in smoking rates for females that are generally less than 2 percentage points higher than those reported here for all respondents (self and proxy). Among males, for whom the proportion of proxy reports is considerably higher, the use of only self-reports results in smoking prevalences between 0 and 6.2 percentage points higher, depending on the cohort. While part of the discrepancy is likely attributable to underreporting of smoking behavior by proxy respondents, those who respond by proxy have been noted to be generally younger, employed, and never married or married (as distinguished from divorced, separated, or widowed), and to have higher incomes and fewer health problems (Crane and Marcus, 1986). These characteristics suggest that those responding by proxy may indeed have lower smoking rates; thus, part of the difference between self-reports and all reports may reflect real differences in smoking status.

Because this analysis estimates smoking prevalence beginning in 1905, it relies on recall of smoking behavior many years before the surveys. In general, the data used are those collected closest to the year for which smoking prevalence is being estimated. Two assumptions guided this decision: First, recall of previous smoking behavior is likely to be better when the survey is conducted closer in time rather than further from the year being estimated; second, each cohort experiences mortality as time passes, with the earlier cohorts experiencing greater mortality. Using earlier data to estimate smoking behavior assures that more members of each cohort are available to provide a more accurate picture of the cohort's smoking behavior in years past. Since both current and former smokers have higher age-specific mortality rates than nonsmokers overall, a birth cohort has a progressively lower percentage of smokers and former smokers and a higher percentage of never-smokers as the individuals in the cohort grow older. Therefore, measurements of smoking behavior made earlier in time for the oldest cohorts provide a more accurate picture of their smoking behaviors during the middle part of the century than do current measurements.

In keeping with this, 1970 NHIS data were used for estimates of smoking prevalence for time points up to and including 1970; the 1978, 1979, and 1980 NHIS data were combined for estimates of smoking prevalence in 1975; the 1979 and 1980 NHIS data were combined for estimates of smoking prevalence in 1980 (with the assumption of no changes in smoking status in 1980 for those who responded in 1979); and the 1987 NHIS data were used for estimates of smoking prevalence in 1985 and 1987. There were two exceptions to this scheme. Because the 1951 to 1960 birth cohort includes members who were only 10 years of age in 1970 (and thus did not respond to the smoking questions), 1978 through 1980 data were used for estimates of smoking for this cohort prior to and including 1970. Similarly, the 1987 data were used to provide estimates of smoking for *all* time points for the 1961 to 1970 birth cohort.

In the 1980 Surgeon General's Report on smoking (US DHHS, 1980), there is an attempt to quantify the potential underestimation of smoking prevalence for earlier cohorts attributable to the differential mortality between smokers and nonsmokers. Applying the author's line of reasoning to this case, the group for which the mortality bias would have the most effect is the 1901 to 1910 cohort, which was aged 60 to 69 when surveyed in 1970. According to insurance life tables reported by Cowell and Hirst (1979), a male cigarette smoker at age 32 has an 80 percent chance of surviving to age 60, while a nonsmoker has a 93 percent chance. Data from the 1970 NHIS indicate that this cohort reached its peak smoking prevalence of 62 percent in 1940. Given the estimated mortality differences between smokers and nonsmokers, the actual smoking rate may have been as high as 66 percent. Thus, the estimated underreporting for this cohort is about 4 percentage points. The underestimate would be less for younger cohorts. The estimated survival rates to age 60 for female smokers and nonsmokers are 91 percent and 93 percent, respectively (Hammond, 1966), which would result in a negligible underestimation (less than 1 percentage point). These adjustments to the prevalence estimates assume that smokers remain continuous smokers and derive no survival advantage from cessation, which provides a worst-case estimate of bias.

As noted previously, the sample sizes of the data sets used for these analyses varied, so the confidence intervals for estimates vary. For most groups and time points reported, 95 percent confidence intervals are less than ± 2 percentage points (assuming a simple random sample; i.e., not taking into account the complex sampling strategy of the NHIS). However, estimates for the years 1985 and 1987 used the 1987 NHIS and are based on considerably fewer respondents than other estimates. Confidence intervals for estimates in 1985 and 1987 are in the range of ± 2 to 4 percentage points for most groups. These generalizations hold for smoking estimates for all males, all females, white males, and white females. Sample sizes for blacks of both sexes are considerably smaller, and confidence intervals for estimates are consequently much larger, in the range of ± 4 to 7 percentage points for time points prior to 1985, and in the range of ± 5 to 9 percentage points for estimates of smoking in 1985 and 1987. Sample sizes for the three major data sets—by cohort, gender, and race—are presented in Table 1.

SMOKING PREVALENCE

Figures 2 through 7 show changes in prevalence of cigarette smoking over time among successive birth cohorts for all males, all females, white males, black males, white females, and black females in the United States. As shown in Figure 2, among males, the 1911 to 1920 and 1921 to 1930 birth cohorts achieved the highest peak prevalences, at 65.9 percent and 66.1 percent, respectively. According to these data, the 1901 to 1910 cohort reached a peak smoking rate of 61.8 percent, which should be adjusted upward somewhat because of the differential mortality likely to have occurred between smokers and nonsmokers prior to the survey in 1970. The overall exposure to cigarettes appears to be different for these three cohorts, however, because of differences in the rates of cessation. For example, when the 1901 to 1910 cohort was aged 55 to 64 in 1965, its smoking rate was 45.0 percent. The comparable rate for the 1911 to 1920 cohort in 1975 was 39.8 percent, while for the 1921 to 1930 cohort, the rate in 1985 was 32.5 percent. Thus, although the three cohorts achieved similar peak rates, cessation was progressively greater for the later cohorts, resulting in fewer total years of exposure to cigarettes for the later cohorts at any given age. Birth cohorts after the 1931 to 1940 cohort experienced successively lower peak prevalence (52.3 percent, 39.6 percent, and 32.4 percent, respectively).

Figure 3 presents the smoking prevalence for successive birth cohorts of U.S. women and clearly demonstrates that women began to smoke in substantial numbers much later in the century than did men. The earliest birth cohort of men (1901 to 1910) showed marked initiation of smoking during adolescence (around 1915 to 1920) and had a high peak prevalence. In contrast, the same birth cohort of women took up smoking much more slowly (around 1925 to 1930) and had a

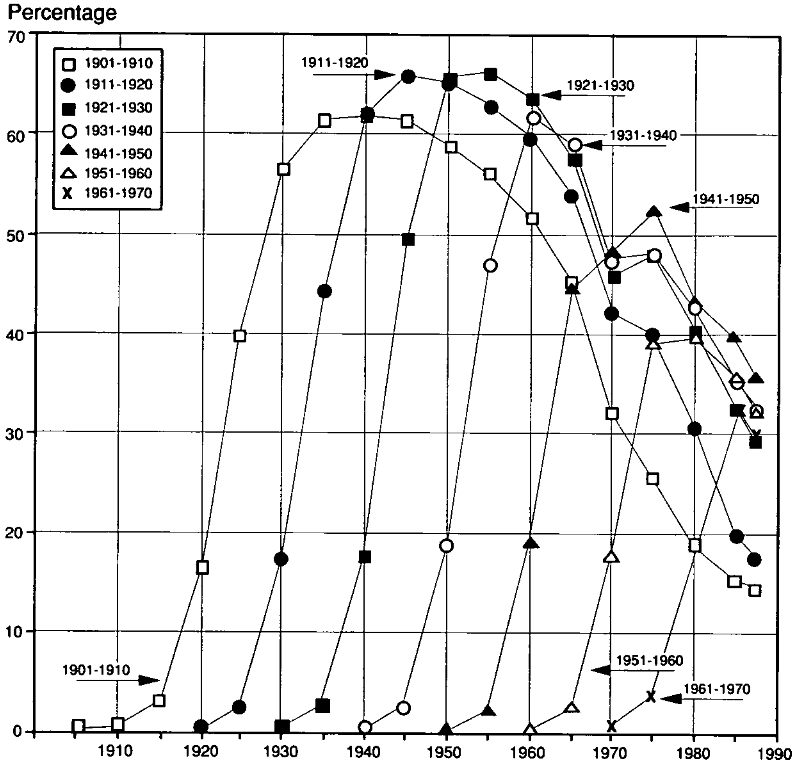
Table 1
Sample sizes for three major NHIS data sets, by birth cohort, gender, and race

	Male			Female		
	All	White	Black	All	White	Black
Birth Cohorts, 1970 NHIS						
1901-1910	3,363	3,065	256	4,677	4,215	440
1911-1920	4,715	4,331	334	5,934	5,350	525
1921-1930	5,484	4,991	419	6,884	6,129	696
1931-1940	5,188	4,663	438	6,532	5,662	762
1941-1950	6,690	6,008	586	8,409	7,332	941
Birth Cohorts, 1978-80 NHIS						
1901-1910	1,511	1,388	107	2,031	1,839	178
1911-1920	2,520	2,290	200	3,261	2,947	282
1921-1930	3,194	2,922	231	3,768	3,388	335
1931-1940	3,048	2,734	265	3,739	3,260	412
1941-1950	4,185	3,765	342	4,866	4,249	512
1951-1960	5,172	4,572	509	6,137	5,284	747
Birth Cohorts, 1987 NHIS						
1901-1910	331	289	37	831	754	74
1911-1920	833	731	96	1,412	1,240	159
1921-1930	1,084	937	135	1,583	1,345	220
1931-1940	1,125	957	134	1,399	1,145	221
1941-1950	1,757	1,501	205	2,198	1,821	324
1951-1960	2,144	1,839	242	2,936	2,318	528
1961-1970	1,548	1,305	187	2,033	1,581	376

Source: National Health Interview Survey (NHIS) 1970, 1978, 1979, 1980, 1987 Public Use Data tapes, National Center for Health Statistics.

very low peak prevalence. Clearly the increase in per capita consumption of cigarettes during the first part of the century was confined largely to males, while the rapid increase in per capita consumption that occurred just prior to and during World War II involved both men and women. The highest peak prevalence among women occurred for the 1931 to 1940 cohort, with a rate of 43.9 percent in 1965. The peak for the 1921 to 1930 cohort was only slightly lower (42.5 percent in 1960). Thus, the highest peak prevalence for women occurred about 10 years behind the peak prevalence for men. Notable among females is the considerably lower prevalence of smoking

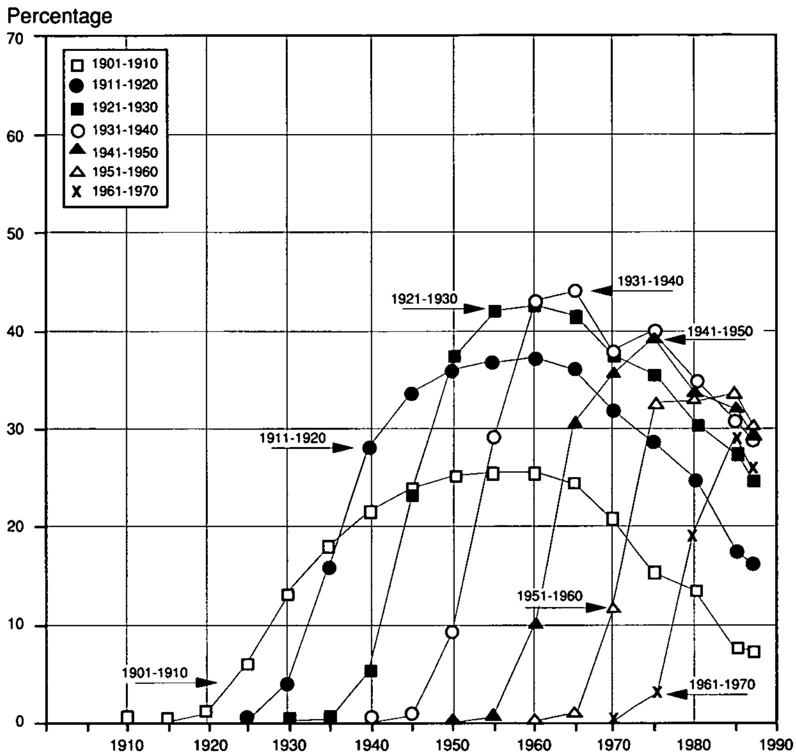
Figure 2
Changes in prevalence of cigarette smoking among successive birth cohorts of U.S. males, 1900 to 1987



in the 1901 to 1910 cohort than in all other cohorts (with a peak of only 25.4 percent in 1955). While the peak prevalence declined considerably for males among those cohorts after 1931 to 1940, the decline has been more modest for females (the peak was 39.3 percent for the 1941 to 1950 cohort, 33.6 percent for the 1951 to 1960 cohort, and 29.2 percent for the 1961 to 1970 cohort).

One impact of this difference in the smoking behavior of the same birth cohorts of men and women is a difference in the current and future lung cancer death rates. Lung cancer occurrence is roughly proportional to the cumulative smoking experience of a cohort (the area under the prevalence curve for the cohort), but lung cancer occurs predominantly in the older age groups of the population. Therefore, overall lung cancer death rates for the U.S. population reflect largely deaths among individuals from ages 50 to 80. The men who are in this age group currently include those cohorts that have the highest peak prevalence of smoking and the greatest cumulative exposure to smoking. The cohorts now entering the 50 to 80 age range, when most lung cancers occur, have a lower peak

Figure 3
Changes in prevalence of cigarette smoking among successive birth cohorts of U.S. females, 1900 to 1987



and cumulative smoking exposure than the cohorts they are replacing. This should result in a decline in the number of lung cancers caused by smoking, and the timing of the projected decline is discussed later in this chapter.

The picture for women is substantially different. Peak and cumulative smoking exposures are substantially lower for those birth cohorts that are currently in the 50 to 80 age range, and so are lung cancer death rates. However, the women who are entering this age range (those cohorts born after 1930) have substantially greater peak and cumulative smoking exposure than those women whom they are replacing (the cohorts born from 1901 to 1930), and overall lung cancer death rates for women are continuing to increase steeply and will not begin to decline until much later than those for men.

Figures 4 and 5 present smoking data for the same cohorts of white and black males. There are several important differences between the smoking patterns for white males and black males that are evident from a comparison of these figures. First, the adoption of cigarette smoking in the early part of this century was somewhat slower among black males than among

Figure 4
Changes in prevalence of cigarette smoking among successive birth cohorts of white U.S. males, 1900 to 1987

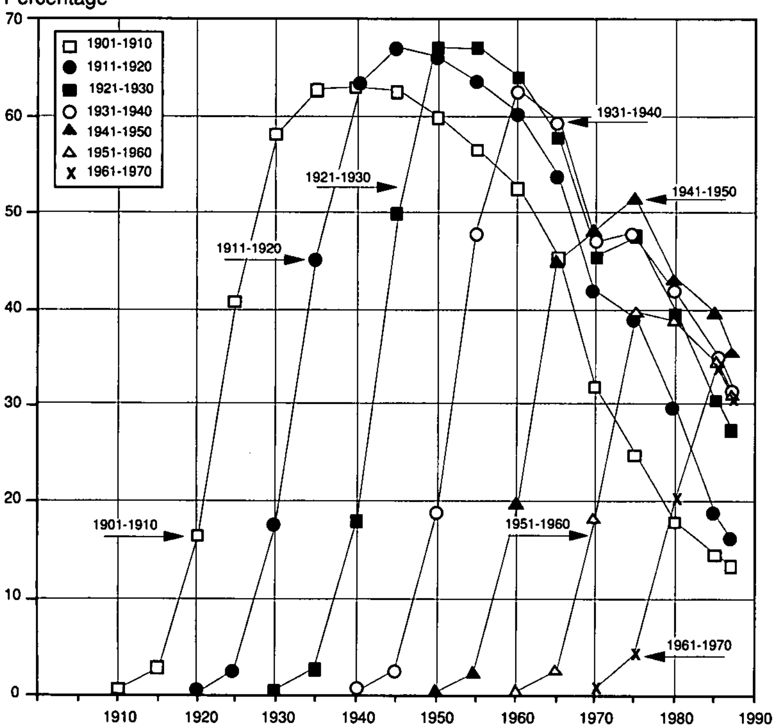
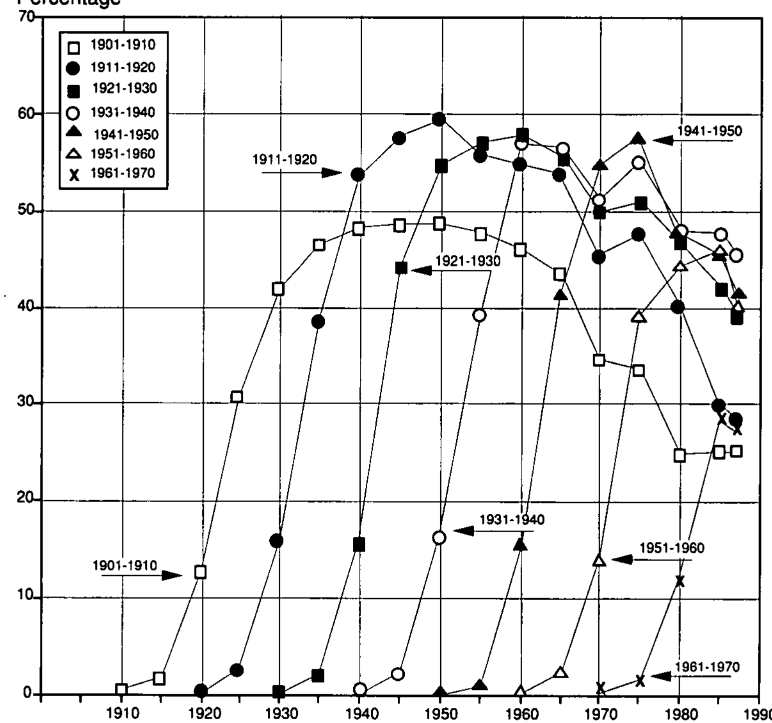


Figure 5
Changes in prevalence of cigarette smoking among successive birth cohorts of black U.S. males, 1900 to 1987



white males. The peak prevalence of smoking for the oldest cohort of black males is dramatically lower than that for the same cohort of white males, and the peak prevalence for each of the next two birth cohorts is also lower for black males. The peak prevalences for the 1931 to 1940 cohorts are similar and the peak prevalences for the cohorts born after 1940 are higher for black males than for white males. It is not until the 1951 to 1960 birth cohort that there is any evidence of a decline in peak prevalence. This suggests that the influences that drive the initiation of smoking occurred somewhat later in this century among the black male population; but among more contemporary cohorts, they have exerted a stronger influence on the black male population than on the white male population.

A second major difference between these two patterns is the width of the prevalence peaks. The number of years that a birth cohort spends at or close to its peak before beginning to decline is much greater for black males than for white males, resulting in the black male cohorts' having a greater cumulative smoking exposure than would be estimated from an examination of their peak prevalence alone. There appears to have been very little smoking cessation among black males until they reached a substantially greater age than their white birth-cohort peers. These two differences in the prevalence patterns are consistent with the lag in black male lung cancer death rates, compared to white male lung cancer death rates, that was observed early in this century, which has now reversed to produce current lung cancer death rates for black males that are substantially above those for white males.

A third difference relates somewhat to the longer duration of peak prevalence for black males. White males in all of the older birth cohorts began to quit in significant numbers in the mid-1950's, but cessation did not become evident among black male cohorts until the middle to late 1960's. A steep decline is evident in each of the three oldest white male cohorts (those that had already reached their peak) by the mid-1950's, and the onset of the steep part of the decline seems to be more closely related to the calendar year than to age. This timing coincides with the drop in per capita tobacco consumption that occurred during the mid-1950's and which has been attributed by Warner (1981) and others to the widespread publicity on smoking-related disease risks that occurred after publication of the first major prospective mortality studies on smoking risks. The same three cohorts of black males do not show a similar decline in prevalence until the 1970 data point, where all three cohorts show a steep decline from 1965. This time point also coincides with a drop in per capita cigarette consumption that occurred from 1967 to 1970 and which has been attributed to the antismoking advertisements that were on television at that time to counter cigarette commercials. This difference in the timing of the decline in prevalence between white and black males suggests that the knowledge of the disease risks associated with smoking may not have effectively penetrated into the black community until much later than it reached the white community.

Figure 6 shows smoking prevalence for white female cohorts and closely resembles Figure 3 (all females). Figure 7 (black females) shows some general similarities to the pattern for white females.

LUNG CANCER MORTALITY

From 1950 to the present, the age-adjusted cancer mortality rate for all sites combined has been increasing. However, when these rates are calculated for "all other cancers" (excluding lung cancer) the overall cancer death rate has been constant or declining, as shown in Figures 8 through 13. This decline is evident for the total male and female populations (Figures 8 and 11), and it is evident for the subgroups of white males, white females, and nonwhite females (Figures 9, 12, and 13); however, the death rates for "all other cancers" among nonwhite males are still increasing slightly. [Note: For all analyses in this chapter, the designations "black" and "nonwhite" may be considered interchangeable, as black men and women constitute about 90 percent of the nonwhite population studied.]

This section of Chapter 3 examines trends in mortality from primary cancers of the lung between 1950 and 1985. Its purpose is to review the changes in lung cancer death rates as a reflection of the changes in smoking prevalence described above.

Methodology

Data from the National Death Tapes, supplied by the National Center for Health Statistics, were used to calculate mortality rates. These rates were age-adjusted according to the direct method (Lilienfeld, 1967), with the 5-year age distribution of the total 1970 U.S. population as the standard. Except where noted, rates are presented as cases per 100,000 population. The analysis is based on the same birth cohorts as those used in the previous section on smoking prevalence.

Mortality Rates for Lung Cancer

Lung cancer mortality rates, by 10-year birth cohort, gender, and race, are presented in Tables 2 through 7. Lung cancer mortality becomes measurable when a cohort reaches a minimum age of 35, and it rises sharply as age increases. One can compare age-specific lung cancer death rates for different birth cohorts by using these tables and matching the death rate for one birth cohort with the death rate recorded 10 years earlier for the preceding birth cohort. Each birth cohort is 10 years younger than the preceding one, so the rates for the

Figure 6
Changes in prevalence of cigarette smoking among successive birth cohorts of white U.S. females, 1900 to 1987

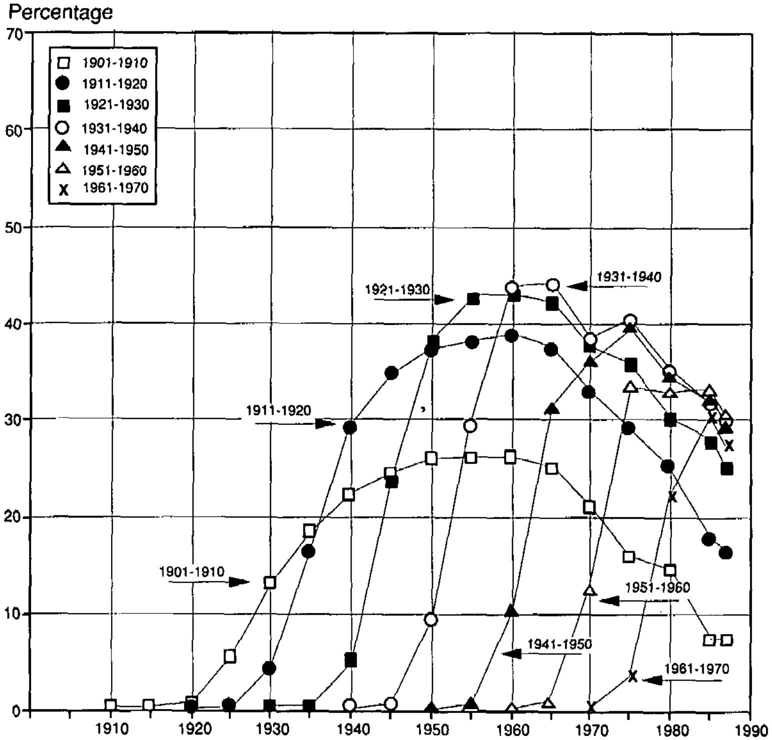


Figure 7
Changes in prevalence of cigarette smoking among successive birth cohorts of black U.S. females, 1900 to 1987

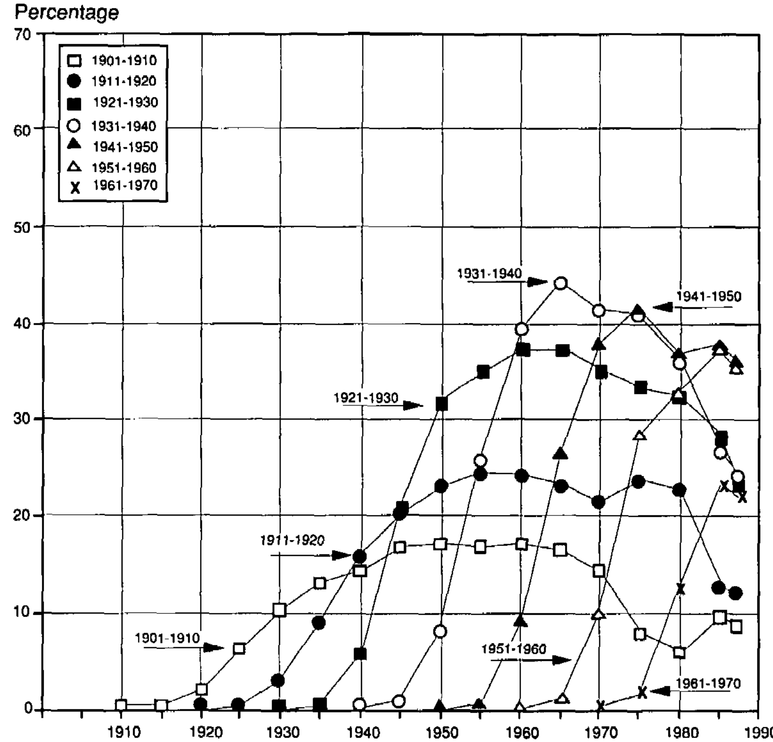
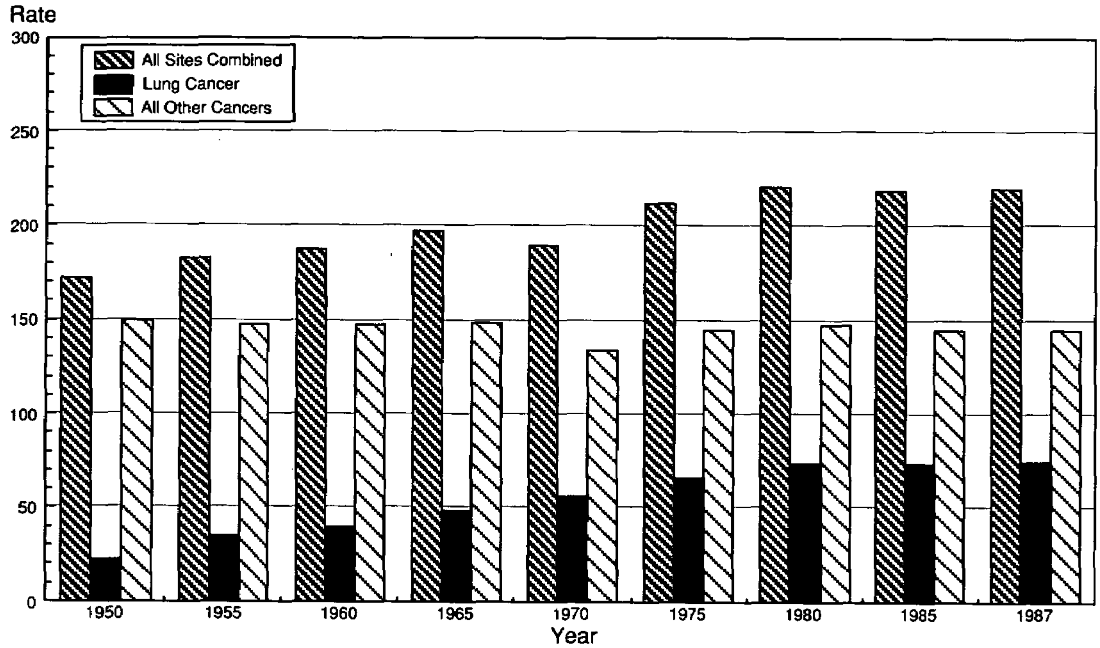


Figure 8
Age-adjusted cancer mortality rates,* all males



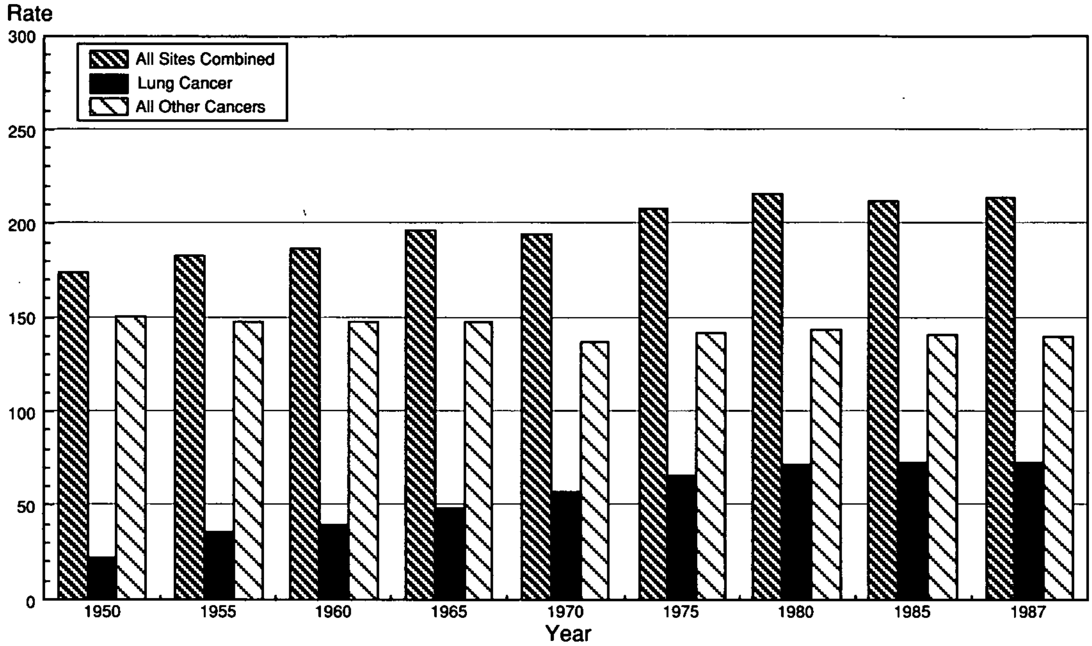
* Deaths per 100,000.

preceding cohort at a given age will have occurred 10 years earlier. The age-specific death rates are presented by birth cohort in Tables 8 through 13. Successive cohorts of males experienced higher age-specific mortality rates through the 1921 to 1930 cohort. However, beginning with the 1931 to 1940 cohort, the age-specific rates have been declining. This is a reflection of the downward trend in cigarette smoking that began with the 1931 to 1940 cohort of males in the United States.

Table 4 shows the mortality rates for lung cancer among nonwhite males. The rates for nonwhite males born during the period from 1901 through 1910 are somewhat lower than those for all U.S. males and for white males. However, for each subsequent cohort, the nonwhite male death rates from lung cancer are considerably higher than those for all males. The higher rates among nonwhites may be explained in part by the longer maintenance of the smoking habit and higher rates of smoking during the critical older ages.

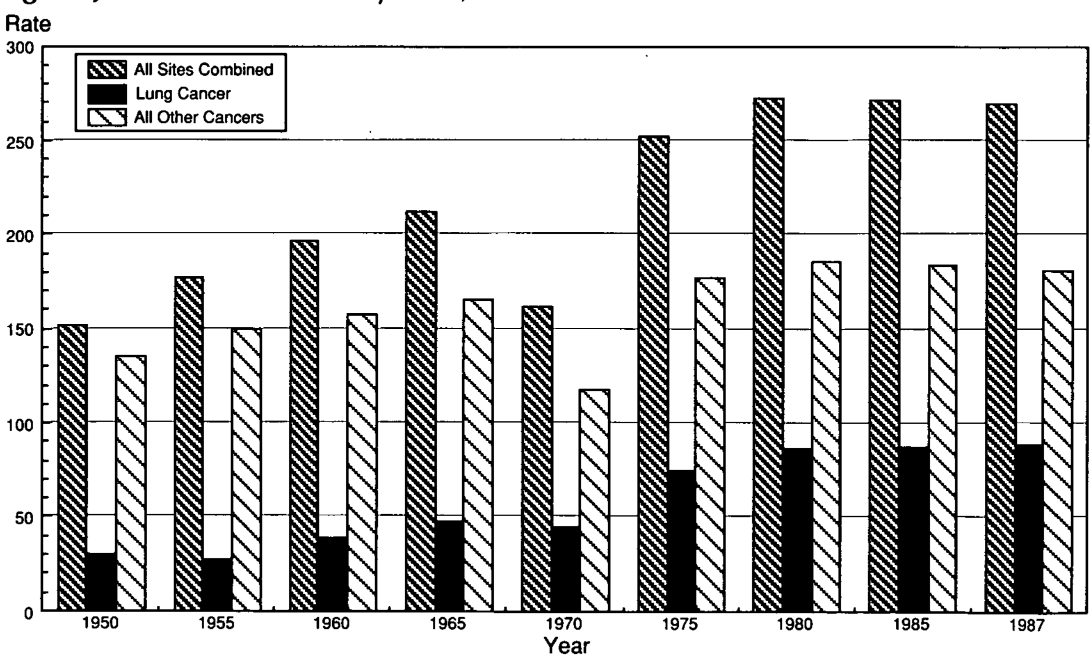
The lung cancer death rates for women, first measurable at age 35, are considerably lower than those for males and rise more slowly with age in the older birth cohorts (Table 5). While the rates for males began to decline with the 1931 to 1940 cohort, the rates continued to rise among women for successive cohorts through 1931 to 1940.

Figure 9
Age-adjusted cancer mortality rates,* white males



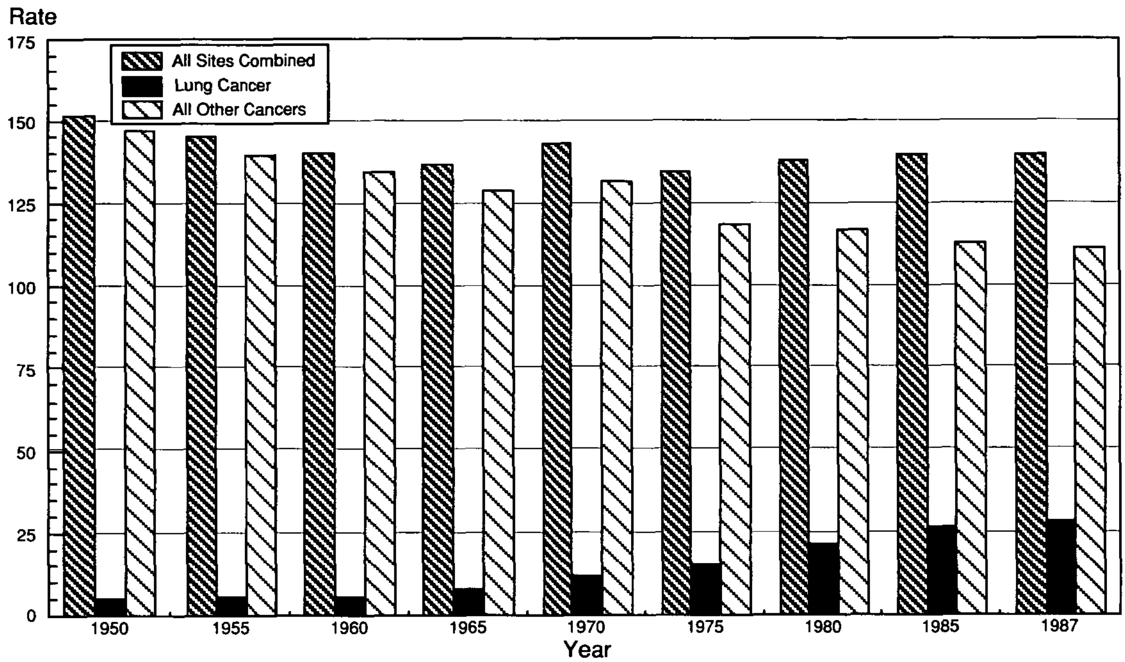
* Deaths per 100,000.

Figure 10
Age-adjusted cancer mortality rates,* nonwhite males



* Deaths per 100,000.

Figure 11
Age-adjusted cancer mortality rates,* all females

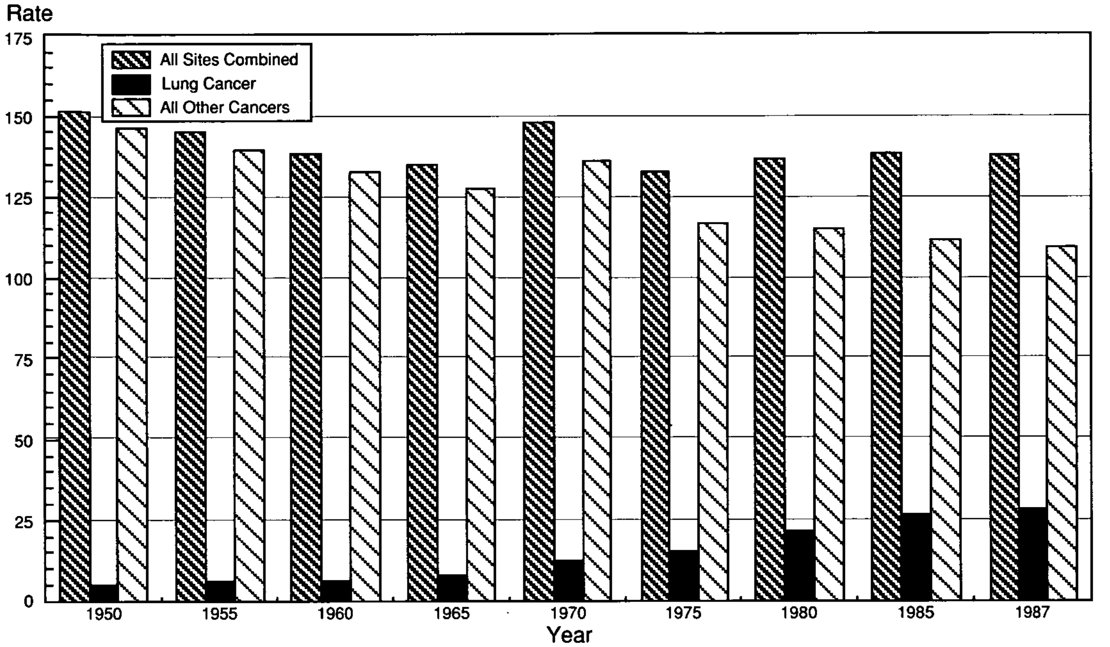


* *Deaths per 100,000.*

The U.S. white female lung cancer mortality rates (Table 6) are very close to those for all females (Table 5). The lung cancer mortality rates among the nonwhite female cohorts before 1921 to 1930 (Table 7) were generally, though not consistently, lower than among the whites; however, at that point they seem to catch up and then slightly surpass the white females. Smoking prevalence data suggest that lung cancer mortality would be lower for nonwhites than for whites in the earliest two cohorts.

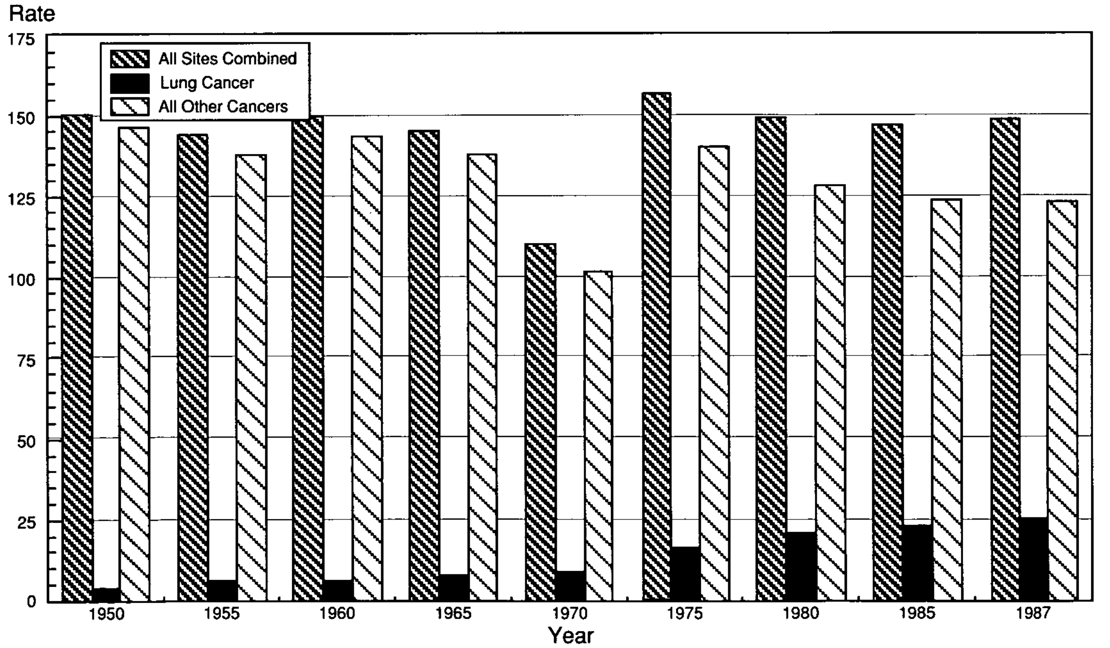
Tables 8 through 13 provide a retabulation of data from Tables 2 through 7, as age-specific rates with percentage of change between cohorts. This allows a ready comparison of the lung cancer experience of the different cohorts at the same ages. For example, when males in the 1911 to 1920 cohort were aged 40 to 49, their lung cancer mortality rate was higher than that of the 1901 to 1910 cohort at the same age. The rates continued to rise as the 1921 to 1930 cohort reached age 40 to 49; however, the rates declined slightly for the 1931 to 1940 cohort. This pattern is seen for all males, regardless of race. At ages 50 to 59, the rates rose considerably less between the 1911 to 1920 and 1921 to 1930 cohorts than they did between the 1901 to 1910 and 1911 to 1920 cohorts (for all males, 13 percent compared with 32 percent), suggesting a leveling off of lung cancer mortality among this age group.

Figure 12
Age-adjusted cancer mortality rates,* white females



* Deaths per 100,000.

Figure 13
Age-adjusted cancer mortality rates,* nonwhite females



* Deaths per 100,000.

Table 2
Lung cancer mortality rates, 1950 to 1985, for all males born 1901 through 1950, by birth cohort

	Lung Cancer Mortality,* by Birth Cohort				
	1901-1910	1911-1920	1921-1930	1931-1940	1941-1950
Year					
1950	17.0				
1955	47.6				
1960	91.1	24.0			
1965	159.3	58.7	13.2		
1970	259.7	120.1	35.4		
1975	363.4	200.5	74.3	14.0	
1980	470.7	308.2	135.3	33.9	
1985	543.0	415.9	220.3	67.0	9.9

** Deaths per 100,000.*

Table 3
Lung cancer mortality rates, 1950 to 1985, for white males born 1901 through 1950, by birth cohort

	Lung Cancer Mortality,* by Birth Cohort				
	1901-1910	1911-1920	1921-1930	1931-1940	1941-1950
Year					
1950	17.1				
1955	46.9				
1960	90.2	22.6			
1965	159.4	56.8	12.2		
1970	259.9	115.2	32.7		
1975	365.2	193.9	69.3	12.6	
1980	473.5	301.1	128.4	30.9	
1985	546.4	409.5	211.9	62.2	9.0

** Deaths per 100,000.*

Smoking Prevalence And Lung Cancer Mortality

Figures 14 through 33 offer a closer look at the effect of smoking and at trends in lung cancer mortality, by birth cohort. For each gender and race group by birth cohort, the figures show changes over time in the percentage of those currently smoking, percentage of those who have ever smoked, and rates of lung cancer mortality, expressed as number of deaths per 10,000 population.

Table 4
Lung cancer mortality rates, 1950 to 1985, for nonwhite males born 1901 through 1950, by birth cohort

	Lung Cancer Mortality,* by Birth Cohort				
	1901-1910	1911-1920	1921-1930	1931-1940	1941-1950
Year					
1950	16.1				
1955	54.1				
1960	99.8	36.7			
1965	158.7	77.0	22.3		
1970	257.8	166.2	59.0		
1975	347.6	262.2	117.1	24.1	
1980	445.1	374.5	194.7	54.8	
1985	511.6	475.3	288.7	99.4	16.5

** Deaths per 100,000.*

Table 5
Lung cancer mortality rates, 1950 to 1985, for all females born 1901 through 1950, by birth cohort

	Lung Cancer Mortality,* by Birth Cohort				
	1901-1910	1911-1920	1921-1930	1931-1940	1941-1950
Year					
1950	3.5				
1955	7.2				
1960	12.0	6.1			
1965	21.9	13.9	4.4		
1970	40.0	30.1	12.1		
1975	65.8	54.4	26.6	7.0	
1980	101.6	91.5	52.1	16.9	
1985	133.3	141.8	91.2	34.8	5.6

** Deaths per 100,000.*

Small sample sizes create some difficulty in interpreting findings in smoking behavior among the black male cohorts (Figures 15, 17, 19, 21, and 23). For example, estimates for the 1901 to 1910 cohort in 1985 and 1987 are based on only 37 respondents. This results in a 95 percent confidence interval of approximately ± 14 percentage points (assuming a random sample). Regardless, the following trends appear: For the four oldest cohorts (1901 to 1940), there is an apparent rise

Table 6
Lung cancer mortality rates, 1950 to 1985, for white females born 1901 through 1950, by birth cohort

	Lung Cancer Mortality,* by Birth Cohort				
	1901-1910	1911-1920	1921-1930	1931-1940	1941-1950
Year					
1950	3.5				
1955	6.8				
1960	11.8	6.0			
1965	21.7	13.8	4.2		
1970	40.5	30.1	11.7		
1975	64.7	55.4	26.5	6.8	
1980	103.4	92.8	51.6	16.5	
1985	136.4	145.6	91.7	35.1	5.5

** Deaths per 100,000.*

Table 7
Lung cancer mortality rates, 1950 to 1985, for nonwhite females born 1901 through 1950, by birth cohort

	Lung Cancer Mortality,* by Birth Cohort				
	1901-1910	1911-1920	1921-1930	1931-1940	1941-1950
Year					
1950	3.6				
1955	10.5				
1960	13.1	7.2			
1965	23.8	14.5	5.9		
1970	35.0	29.7	14.9		
1975	79.3	45.8	28.1	8.0	
1980	83.8	79.6	55.8	19.5	
1985	101.2	108.7	87.7	33.0	6.2

** Deaths per 100,000.*

between 1970 and 1985 in the number who have ever smoked. In addition to the small sample size, slight changes in survey methodology over the different years of administration (as described previously) could cause these results. Still, these increases deserve further exploration.

Also of note are the rates of lung cancer relative to white males. Although the prevalence of current smokers and ever-smokers is lower among black males through the 1931 to 1940

Table 8
Age-specific lung cancer death rates,* 1950 to 1980, for all males born 1901 through 1940, by birth cohort

	1901-1910 Cohort	1911-1920 Cohort	Percent Change	1921-1930 Cohort	Percent Change	1931-1940 Cohort	Percent Change
Age							
40-49	17.0	24.0	(41.2)	35.4	(47.5)	33.9	(-4.2)
50-59	91.0	120.1	(31.8)	135.3	(12.7)		
60-69	259.7	308.2	(18.7)				
70-79	470.7						

** Per 100,000 population.*

Table 9
Age-specific lung cancer death rates,* 1950 to 1980, for white males born 1901 through 1940, by birth cohort

	1901-1910 Cohort	1911-1920 Cohort	Percent Change	1921-1930 Cohort	Percent Change	1931-1940 Cohort	Percent Change
Age							
40-49	17.1	22.6	(32.2)	32.7	(44.6)	30.9	(-5.5)
50-59	90.2	115.2	(27.7)	128.4	(11.5)		
60-69	259.9	301.1	(15.8)				
70-79	473.5						

** Per 100,000 population.*

cohort, lung cancer death rates are similar between the races for the 1901 to 1910 cohort, and they are noticeably higher for black males in each successive cohort. For example, for the 1921 to 1930 cohort (Figure 19) in 1985, the lung cancer death rate for black males was more than 36 percent higher than for white males, even though the peak prevalence of smoking among black males in that cohort never achieved that of white males, and the ever-smokers rate matched that of whites only since 1970 (see Figure 18). The reason for this disparity in lung cancer death rates is not clear. Differences in smoking behavior other than prevalence may play a role, such as the type of cigarette smoked and the amount of each cigarette smoked. However, consumption in terms of the number of cigarettes smoked is considerably *lower* among blacks (US DHHS, 1988).

Table 10
Age-specific lung cancer death rates,* 1950 to 1980, for nonwhite males born 1901 through 1940, by birth cohort

	1901-1910 Cohort	1911-1920 Cohort	Percent Change	1921-1930 Cohort	Percent Change	1931-1940 Cohort	Percent Change
Age							
40-49	16.1	36.7	(128.0)	59.0	(60.8)	54.8	(-7.1)
50-59	99.8	166.2	(66.5)	194.7	(17.1)		
60-69	257.8	374.5	(45.3)				
70-79	445.1						

** Per 100,000 population.*

Table 11
Age-specific lung cancer death rates,* 1950 to 1980, for all females born 1901 through 1940, by birth cohort

	1901-1910 Cohort	1911-1920 Cohort	Percent Change	1921-1930 Cohort	Percent Change	1931-1940 Cohort	Percent Change
Age							
40-49	3.5	6.1	(74.3)	12.1	(98.4)	16.9	(39.7)
50-59	12.0	30.1	(150.8)	52.1	(73.1)		
60-69	40.0	91.5	(128.8)				
70-79	101.6						

**Per 100,000 population.*

Also to be considered is the shorter life expectancy of black males compared with white males—approximately 8 to 10 years for males born between 1920 and 1950 (Hoffman, 1987). The mortality rate for black males in that age group may result in considerable underestimation of past smoking behavior of the earlier cohorts, more so than for white males, because estimates are based on the behavior of survivors only. Thus, it is possible that there were higher rates of smoking than those reported for those cohorts, resulting in the observed lung cancer mortality rates.

White females (Figures 24, 26, 28, 30, and 32) are similar to white males in that, in later cohorts, there is considerably more initiation of smoking after the peak prevalence than for earlier cohorts, as indicated by differences between the current smoker and ever-smoker curves. For white females, as with

Table 12
Age-specific lung cancer death rates,* 1950 to 1980, for white females born 1901 through 1940, by birth cohort

	1901-1910 Cohort	1911-1920 Cohort	Percent Change	1921-1930 Cohort	Percent Change	1931-1940 Cohort	Percent Change
Age							
40-49	3.5	6.0	(71.4)	11.7	(95.0)	16.5	(41.0)
50-59	11.8	30.1	(155.1)	51.6	(71.4)		
60-69	40.5	92.8	(129.1)				
70-79	103.4						

** Per 100,000 population.*

Table 13
Age-specific lung cancer death rates,* 1950 to 1980, for nonwhite females born 1901 through 1940, by birth cohort

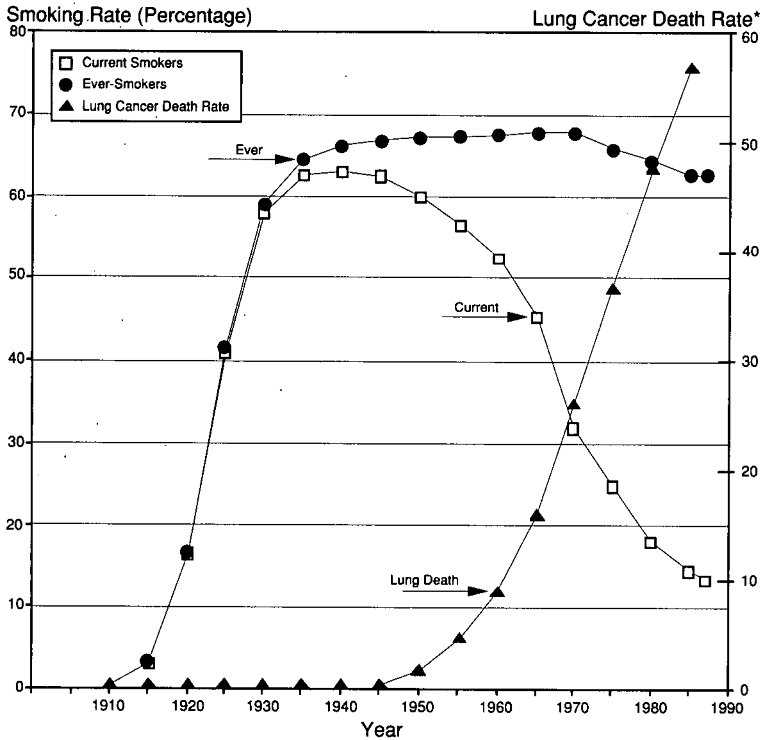
	1901-1910 Cohort	1911-1920 Cohort	Percent Change	1921-1930 Cohort	Percent Change	1931-1940 Cohort	Percent Change
Age							
40-49	3.6	7.2	(100.0)	14.9	(106.9)	19.5	(30.9)
50-59	13.1	29.7	(126.7)	55.8	(87.9)		
60-69	35.0	79.6	(127.4)				
70-79	83.8						

** Per 100,000 population.*

white males, this becomes apparent for the 1941 to 1950 cohort (Figure 32). The lower overall smoking rates for white females compared with white males for all cohorts shown are borne out in considerably lower lung cancer death rates for women. It can be expected, however, that as later cohorts (e.g., 1951 to 1960) enter the ages at which lung cancer death rates increase rapidly, the lung cancer death rate differential between males and females will begin to disappear because of the narrowing gap in smoking behavior.

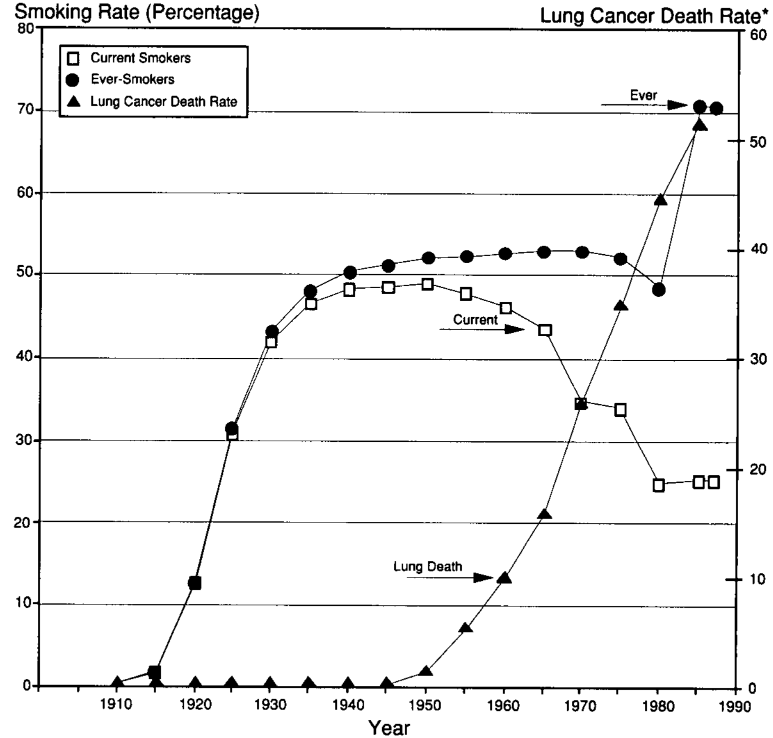
Starting with the 1931 to 1940 cohort (Figure 31), the pattern of both current smokers and ever-smokers for black women is similar to that for white women. Prior to 1931 (Figures 25, 27, and 29), black women had lower rates of current smokers and ever-smokers than did white women, with one exception. In the 1921 to 1930 cohort (Figures 28 and 29),

Figure 14
Changes in current smokers, ever-smokers, and lung cancer deaths, for white U.S. males born 1901 to 1910



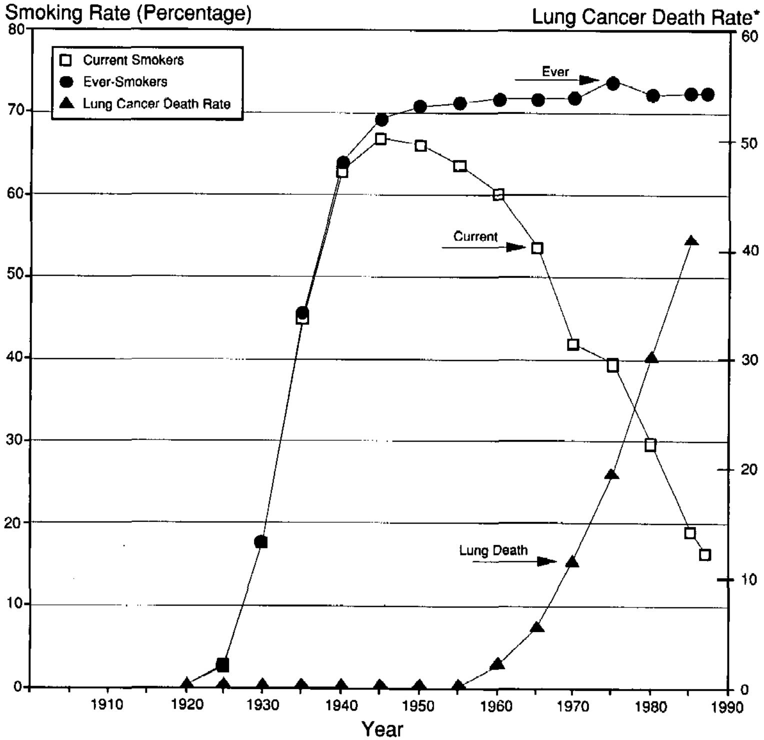
*Deaths per 10,000

Figure 15
Changes in current smokers, ever-smokers, and lung cancer deaths, for black U.S. males born 1901 to 1910



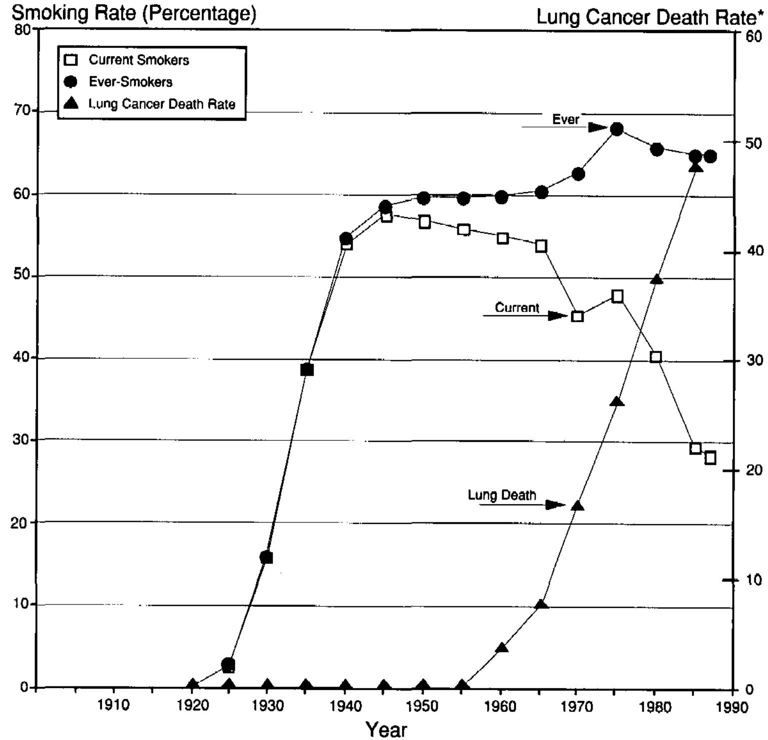
*Deaths per 10,000

Figure 16
Changes in current smokers, ever-smokers, and lung cancer deaths, for white U.S. males born 1911 to 1920



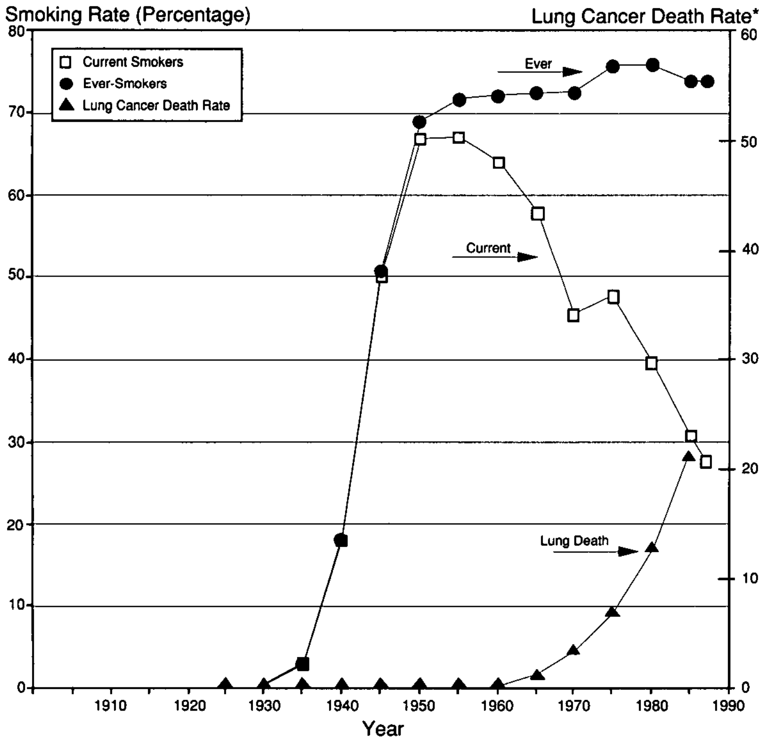
*Deaths per 10,000

Figure 17
Changes in current smokers, ever-smokers, and lung cancer deaths, for black U.S. males born 1911 to 1920



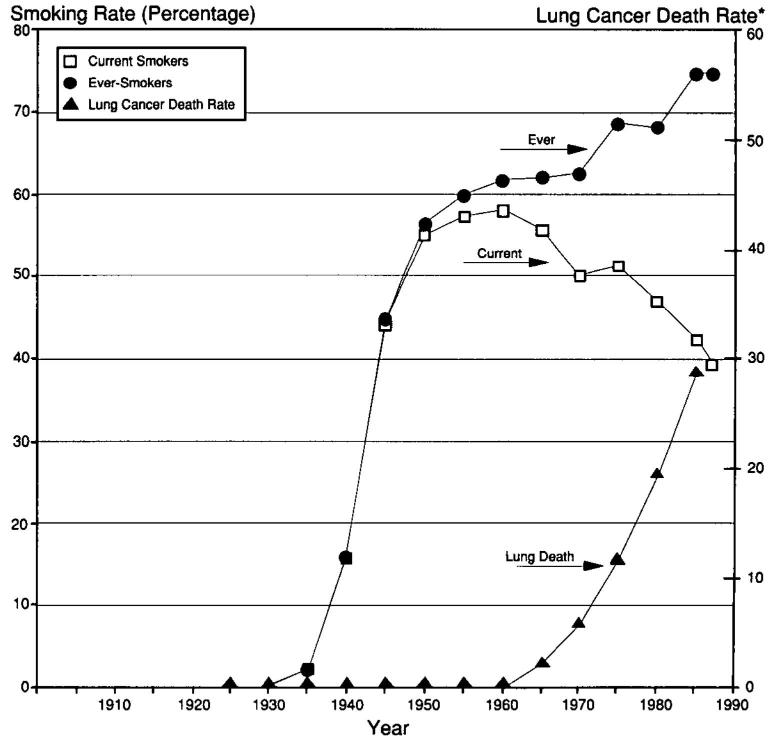
*Deaths per 10,000

Figure 18
Changes in current smokers, ever-smokers, and lung cancer deaths, for white U.S. males born 1921 to 1930



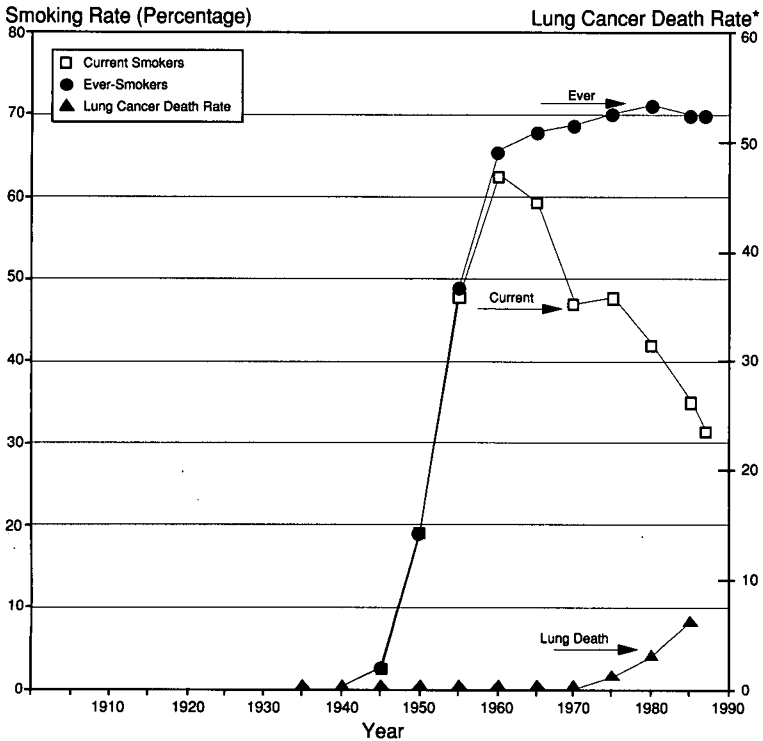
*Deaths per 10,000

Figure 19
Changes in current smokers, ever-smokers, and lung cancer deaths, for black U.S. males born 1921 to 1930



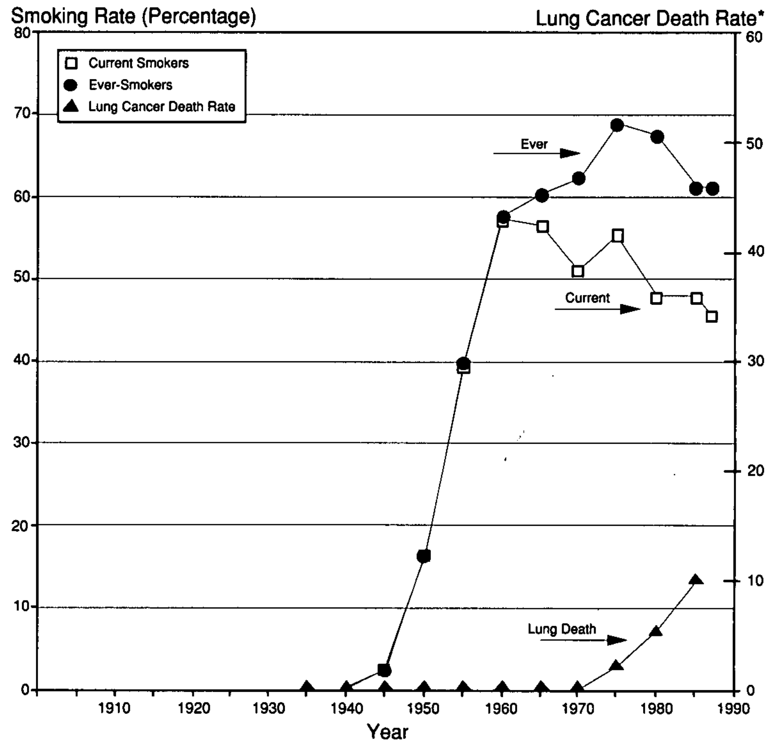
*Deaths per 10,000

Figure 20
Changes in current smokers, ever-smokers, and lung cancer deaths, for white U.S. males born 1931 to 1940



*Deaths per 10,000

Figure 21
Changes in current smokers, ever-smokers, and lung cancer deaths, for black U.S. males born 1931 to 1940



*Deaths per 10,000

Figure 22
Changes in current smokers, ever-smokers, and lung cancer deaths, for white U.S. males born 1941 to 1950

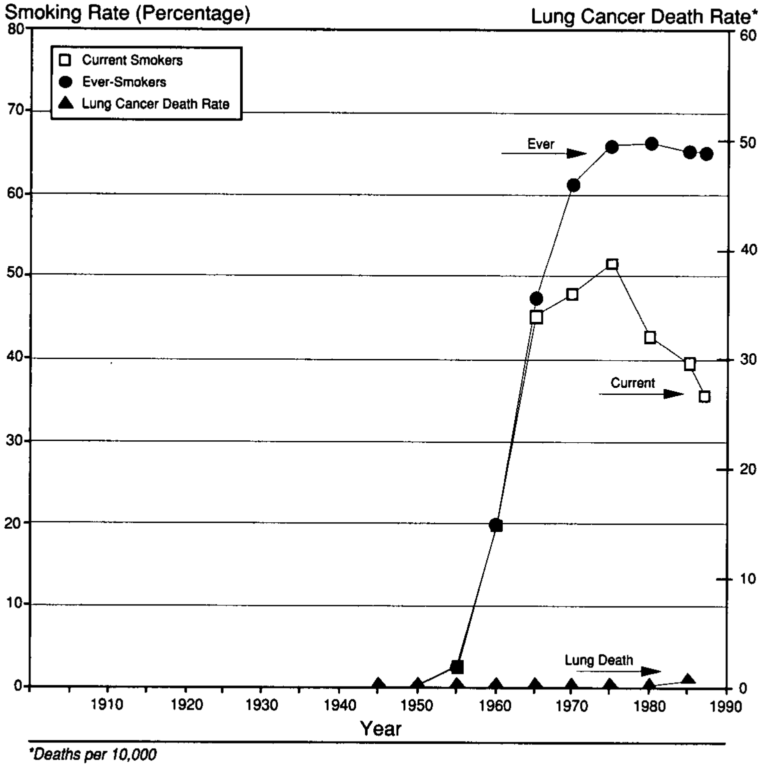


Figure 23
Changes in current smokers, ever-smokers, and lung cancer deaths, for black U.S. males born 1941 to 1950

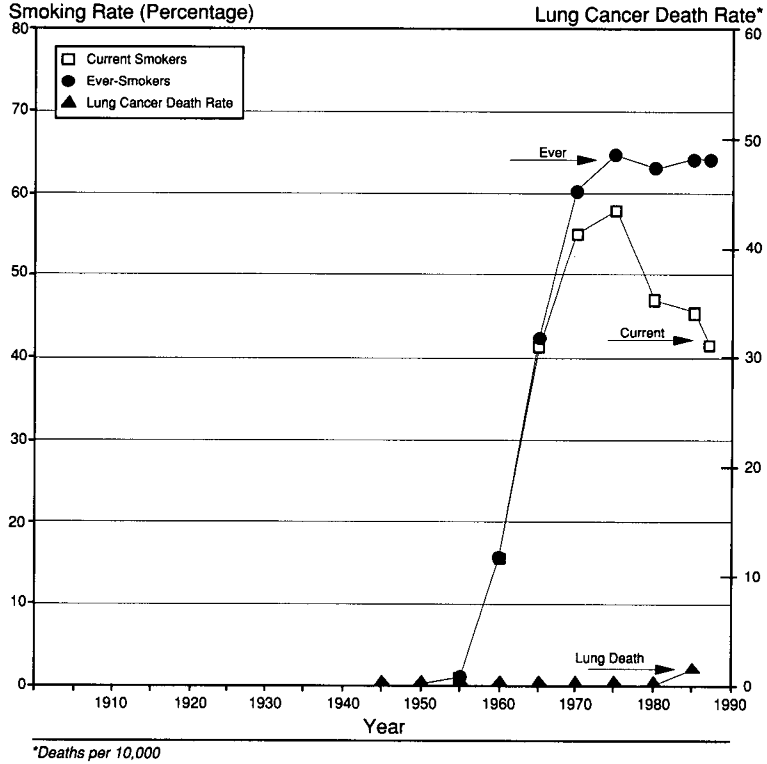
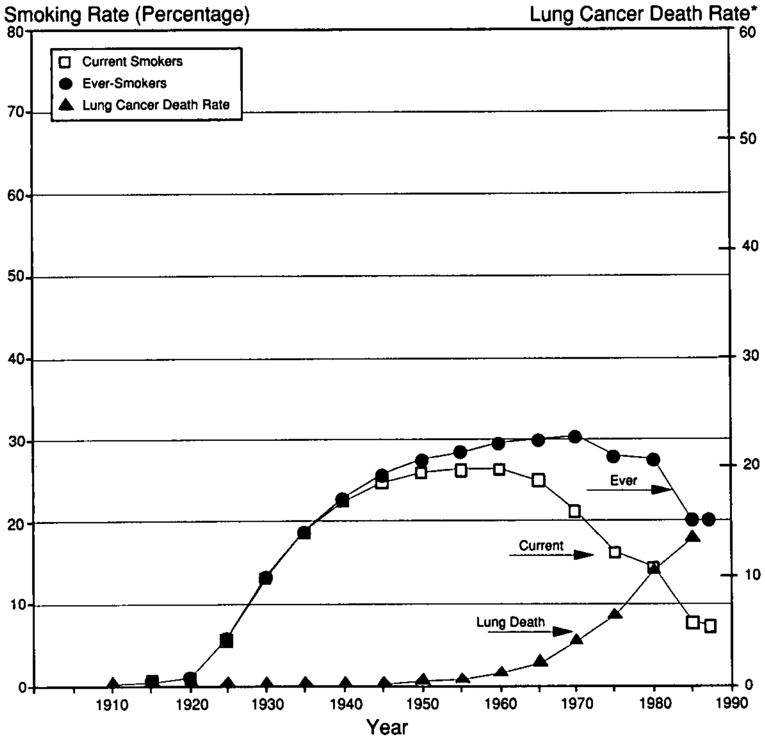
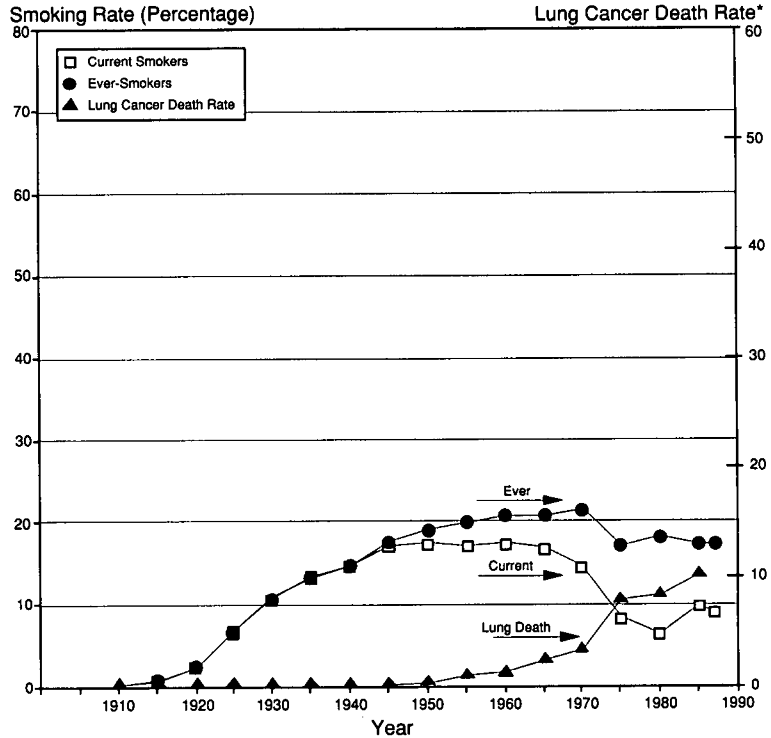


Figure 24
Changes in current smokers, ever-smokers, and lung cancer deaths, for white U.S. females born 1901 to 1910



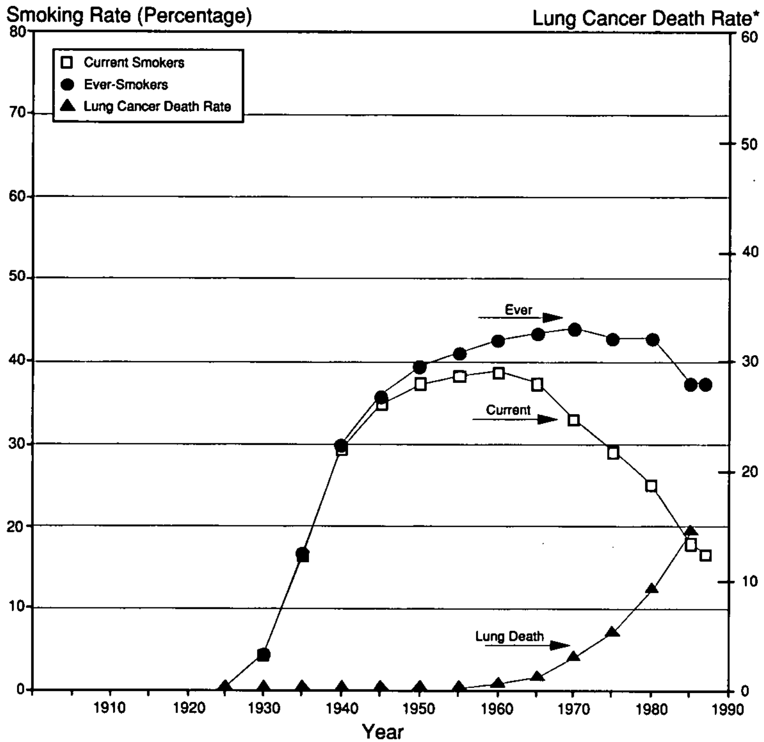
*Deaths per 10,000

Figure 25
Changes in current smokers, ever-smokers, and lung cancer deaths, for black U.S. females born 1901 to 1910



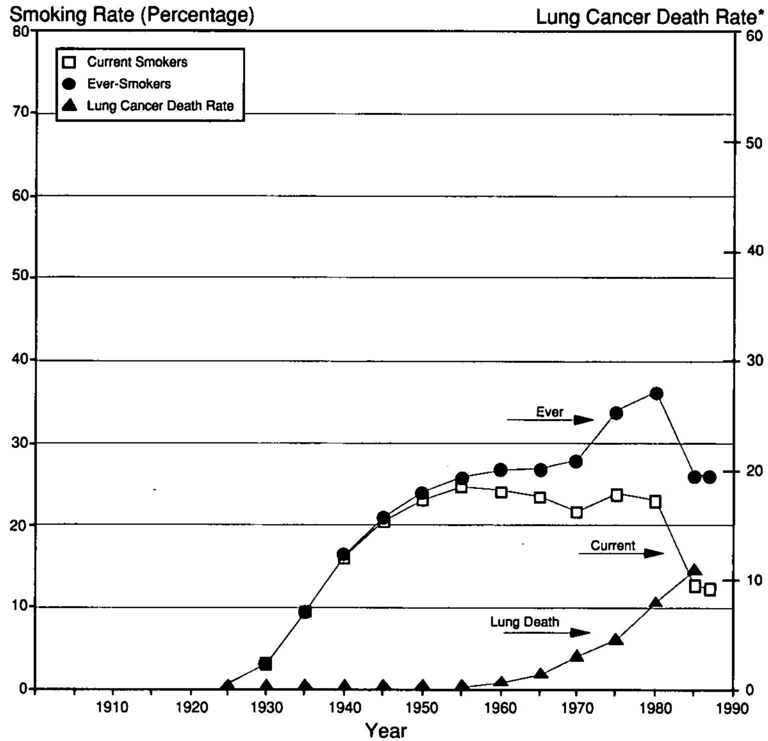
*Deaths per 10,000

Figure 26
Changes in current smokers, ever-smokers, and lung cancer deaths, for white U.S. females born 1911 to 1920



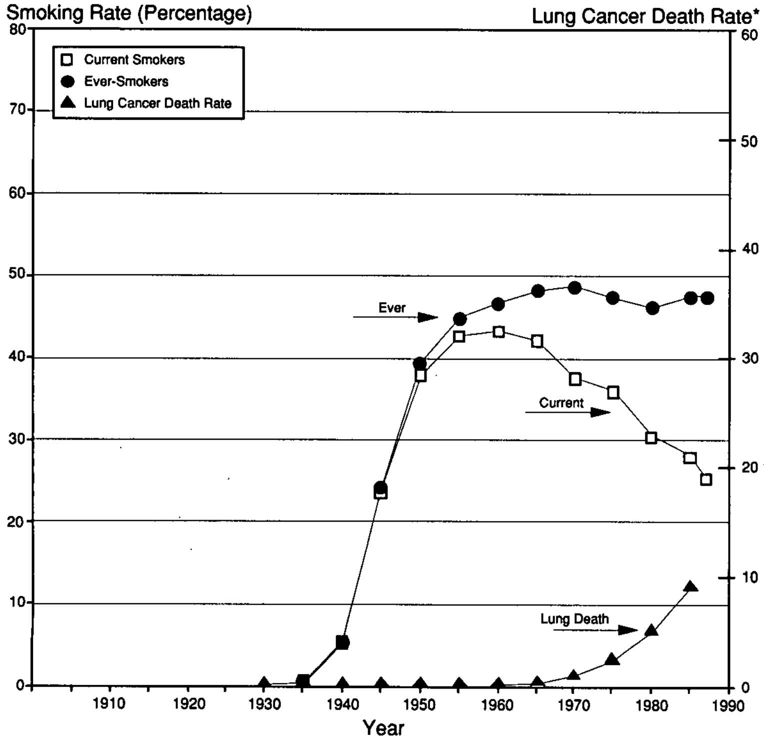
*Deaths per 10,000

Figure 27
Changes in current smokers, ever-smokers, and lung cancer deaths, for black U.S. females born 1911 to 1920



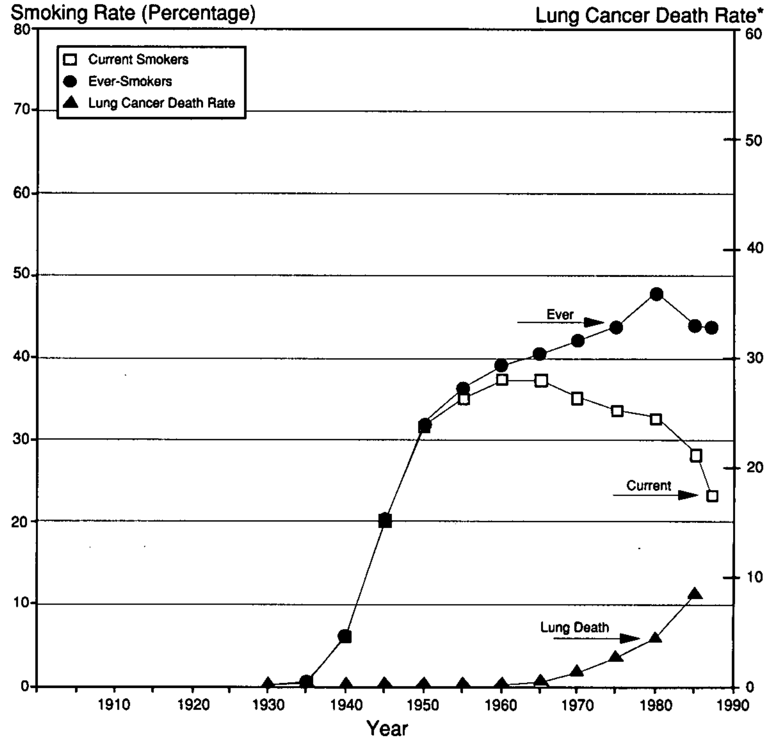
*Deaths per 10,000

Figure 28
Changes in current smokers, ever-smokers, and lung cancer deaths, for white U.S. females born 1921 to 1930



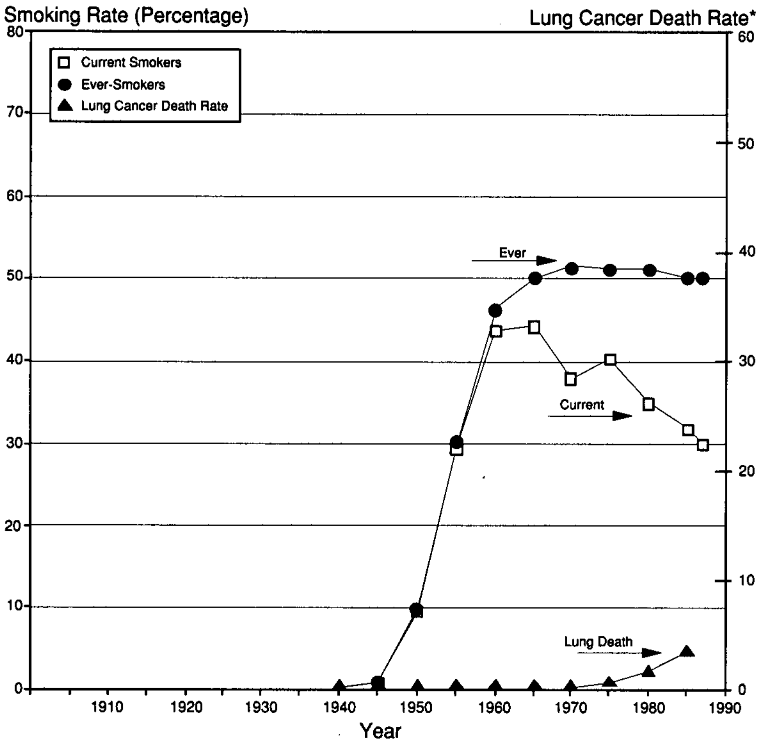
Deaths per 10,000

Figure 29
Changes in current smokers, ever-smokers, and lung cancer deaths, for black U.S. females born 1921 to 1930



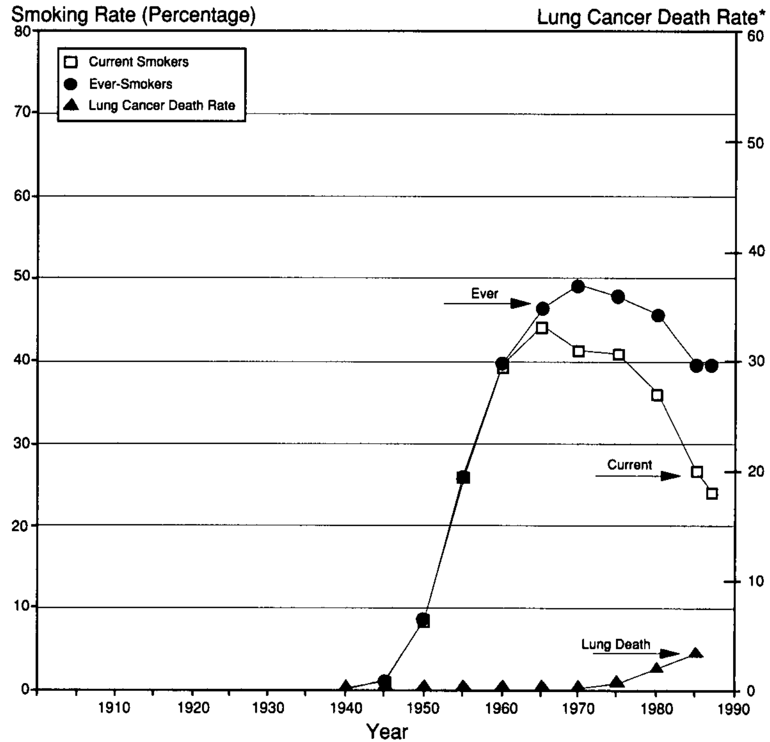
Deaths per 10,000

Figure 30
Changes in current smokers, ever-smokers, and lung cancer deaths, for white U.S. females born 1931 to 1940



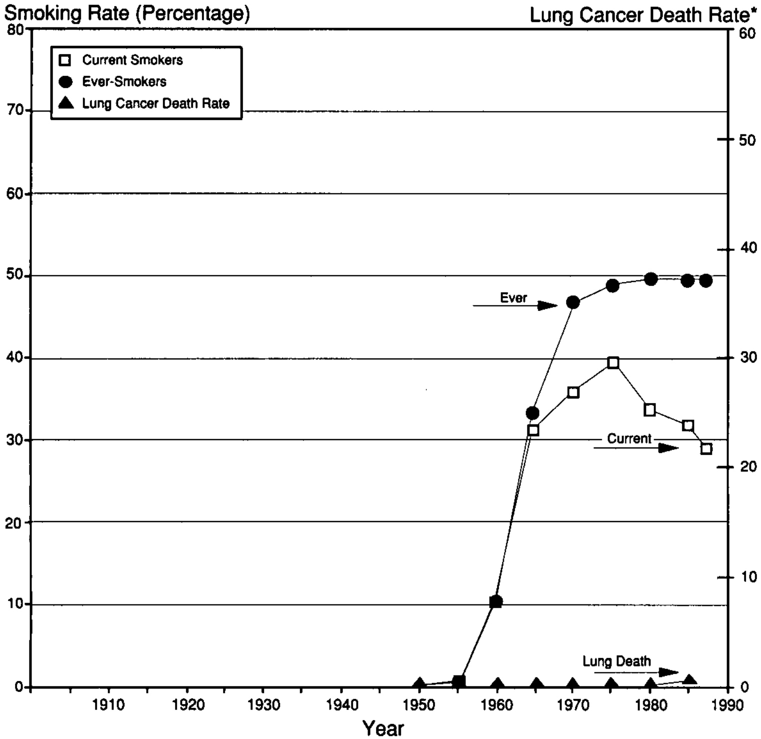
*Deaths per 10,000

Figure 31
Changes in current smokers, ever-smokers, and lung cancer deaths, for black U.S. females born 1931 to 1940



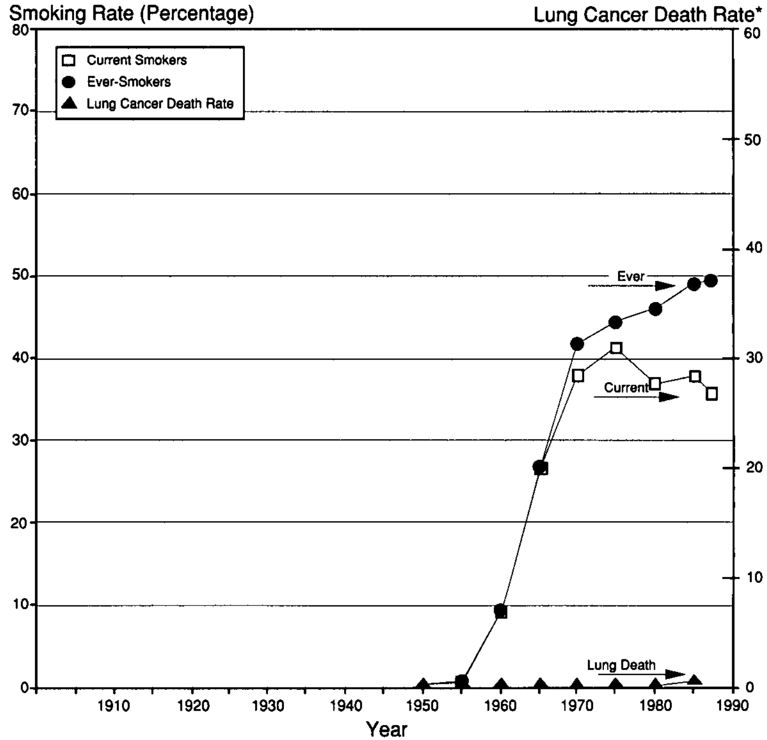
*Deaths per 10,000

Figure 32
Changes in current smokers, ever-smokers, and lung cancer deaths, for white U.S. females born 1941 to 1950



*Deaths per 10,000

Figure 33
Changes in current smokers, ever-smokers, and lung cancer deaths, for black U.S. females born 1941 to 1950



*Deaths per 10,000

the percentages of ever-smokers reached comparable levels for black women and white women. Lung cancer death rates for all cohorts are approximately the same for white and black females, even though smoking rates are lower for black females in the earliest two cohorts. As smoking rates converged for white and black females in later cohorts, lung cancer death rates remained approximately equivalent for the two races. The equivalent lung cancer rates for white and black females in earlier cohorts, despite lower smoking rates among black females, may again suggest a lung cancer risk that is not attributable to smoking.

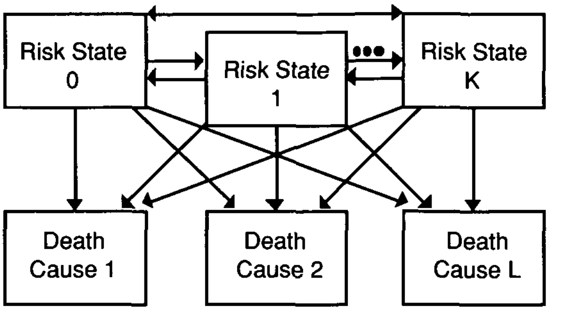
Use of Birth Cohort Smoking Behaviors To Predict Lung Cancer Death Rates

Understanding the effects that shifts in the distribution of risk factors (such as smoking patterns) have on disease occurrence and associated health care costs is fundamental to evaluating trends and formulating public policy. In the public policy domain, the determination of which health care programs or projects receive what proportion of limited resources requires analysis of the future costs and benefits of those programs. In assessing health trend effects, changes in either risk factor exposure or the treatment of disease may affect the incidence of disease, the prevalence of chronic conditions, and/or the mortality rates.

The efficacy of a health program in preventing a disease with a long latency period may not be quickly manifest by the usual morbidity and mortality estimates. Primary prevention programs are directed at reducing risk factor exposures, and for many diseases the benefits of altering a risk factor as measured by reductions in mortality or disability require time to emerge. Individuals who already have a disease, including those at preclinical stages, may not benefit from alteration of risk factors and will often continue to progress through the disease course. Thus, intervention studies frequently require 5 to 10 years to show significantly reduced morbidity and mortality risks. During these lengthy periods, the demographic profile of the beneficiary population may shift (e.g., the population may become younger with time) or those with adverse risk factor values may die earlier. In such cases, some of the observed benefits are not the result of interventions but of population shifts in the distribution of risk factors. A health program may reduce the age-specific mortality rates, but this reduction would only partly offset the increase in death rates that accompanies the aging of individuals. Thus, determining the benefits of a risk factor management program requires separating benefits attributable to risk factor modification from benefits attributable to demographic shifts, changes in susceptibility, and mortality selection.

To assess the effects of risk factor interventions on health trends, standard increment-decrement life-table models are generalized to "compartment" models (i.e., discrete state-discrete

Figure 34
Compartment model schematic of morbidity-mortality process with discrete risk states



time models of health processes) to represent movement between risk factor states. The states in the compartment model can represent death, disability, or an adverse (or beneficial) risk factor status. In the current analysis, the primary risk factor is duration of smoking. Interventions are represented by changes in risk factor states; that is, interventions modify transition rates between certain risk factor and mortality states and change the number of individuals in those states. For example, decreases in the initiation of smoking rates and/or increases in the smoking cessation rates could represent effects of a health intervention in the population. The benefits of this intervention are calculated from incidence and prevalence rates calculated for each compartment and summed across the population.

A DISCRETE STATE MODEL OF HEALTH INTERVENTION

A compartment model of morbidity-mortality processes is illustrated in Figure 34. An individual resides in only one risk factor state, although he or she can move to any other state at time *t*. The risk factor states can represent chronic illness, disability, and risk factor exposure (e.g., smoker versus nonsmoker, hypertensive versus not hypertensive). The "well" state is defined as the state with no risk factors. Though an individual can be in only one state at any time, the *definitions* of states need not be exclusive; e.g., an individual may be in a hypertensive state, a smoking state, or a hypertensive *and* smoking state. We define the following terms:

t	=	time measured in years ($t = 1, 2, \ldots, T$).
K	=	number of risk factor states (besides the well state). Risk factor state 0 is the "well" state.

L	=	number of causes of death ($l = 1, 2, \ldots, L$).
a	=	index for age groups.
$n_k(a,t)$	=	number of individuals in age group a at beginning of t in state k.
$q_{kl}(a,t)$	=	probability that a person in age group a state at t will die of cause l during the year.
$q_l(a,t)$	=	probability that a person in age group a at t dies of cause l,
	=	$\Sigma q_{k2}(a,t)n_k(a,t) \,/\, \Sigma n_k(a,t)$ (1)

The Markov Assumption

Multiple increment-decrement life tables are special cases of the compartment model seen in Figure 34. Consequently, methods to estimate multiple decrement life-table parameters are easily extended to the compartment model. However, applying those methods for many risk factor states and causes of death requires a huge quantity of data. Problems in evaluating mortality functions arise because (1) all possible pathways that result in the contingent event of interest must be determined, and (2) the probabilities associated with each of these pathways must be assessed. The problems are simplified if the model in Figure 34 can be assumed to be Markovian; i.e., the probability of changing states depends only on the two states (the state the individual is coming from and the state he or she is going to) and not on any previous states the individual has been in or length of time in the current state.

The Markov assumption seems unreasonable, since a person's age and the length of time he or she smoked are determinants of the risks of many causes of death and disease. The Markov assumption can be made more reasonable by defining risk factor states as length of time with a particular risk factor. For example, a person enters the "smoked 0 to 5 years" risk state when smoking begins. In 5 years, the individual moves to a "smoked 5 to 10 years" risk state if he or she still smokes and has not died. Or, the person may enter a "hypertensive *and* smoked 5 to 10 years" state if the blood pressure rises and he or she continues to smoke. Alternatively, the person who stops smoking may enter the "smoked only 5 years" state. Age can be treated similarly; that is, Figure 34 can be viewed as applicable to a specific age group with risk factor states defined for each subsequent age group. Individuals move between states as they age.

Assuming that the Markov assumption holds for Figure 34, movement between states can be described by a matrix of transition probabilities. If π_{ij} is the probability of moving from state i to state j in a year, the transition matrix is

$$\Pi = \begin{pmatrix} \pi_{00} & \pi_{01} & \cdots & \pi_{0R} \\ \cdot & & & \\ \cdot & & & \\ \cdot & & & \\ \pi_{R0} & \pi_{R1} & \cdots & \pi_{RR} \end{pmatrix}, \qquad (2)$$

where the total number of states is $R + l = K + L + l$, including the "well" and death states. The π_{ij} are determined from $n_k(a,t)$ and $q_{kl}(a,t)$. To determine the population in each state after m years, let n_i be the number of individuals in state i at time 0. The row vector $\mathrm{N} = (n_0, n_1, \ldots, n_r)$ of these counts is called the state vector. The vector $\mathrm{N}^{(m)}$of counts in each state after t years is

$$\mathrm{N}^{(t)} = \mathrm{N}\Pi^{t} \qquad (3)$$

where Π^t is the product of Π with itself t - 1 times (i.e., the "t^{th}" power of Π). The vector $\mathrm{N}^{(t)}$, $t = 1, 2, \ldots,$ is the basis for all discrete survival functions where $\mathrm{N}^{(t)} = (N_0(t), N_1(t), \ldots, N_R(t))$. The model is useful for forecasting future contingent outcomes and evaluating functions associated with morbidity and mortality outcomes under various interventions or changes in the population.

Because the current model is more biologically plausible than simply "alive-dead" and "standard-substandard risk" classifications, forecast estimates will be more accurate. By selecting a sufficient number of risk factor and mortality states, one can model any finite combination of risk factors. A model representing the interactions of risk factors and chronic conditions is more defensible than risk scoring methods that do not represent those interactions (see Cummins et al., 1983). In this chapter, the above model is used to forecast lung cancer mortality patterns.

Previous Forecast Methods

Several researchers have presented models for forecasting mortality patterns for lung cancer. The simplest method is to assume that the age-specific mortality rates will remain constant and then predict the number of deaths in the future from the number of individuals expected in each age group. A sophisticated version of this model is given by Brown and Kessler (1988), in which the differential cohort effects and differential smoking patterns are included in estimating the age-specific lung cancer mortality rate. The Brown and Kessler model also used the number of cigarettes and the tar per cigarette as regressor variables for the period effects. The model does not explicitly include the length of time that people smoked. Forecasts are based on estimated effects of cohort, age, smoking status, and "dose" (as measured by two variables, average cigarettes and tar levels). The model adjusts for smoking duration and for any competing risks of deaths only implicitly; that is, insofar as these two variables are reflected in the mortality risks of lung cancer in the observed data used to fit the model, this same relationship is maintained in the forecasting formula.

Hakulinen and Pukkala (1981) use a similar method but make explicit adjustments for subjects' length of smoking and time since they last smoked. Although this model is more sophisticated in the use of smoking duration, it does not estimate the cohort effects from observed lung cancer mortality over time as the Brown and Kessler model does. The model also adjusts for the competing risks implicitly, by assuming that the mortality risks used contained the appropriate adjustment.

The model proposed in this chapter extends these models in two ways. First, explicit adjustment of the competing risks is taken into account. Because current and past smoking patterns have a differential effect on both lung cancer and other competing risks, forecasting the effects of changes in the smoking patterns over the last 10 years and the anticipated smoking patterns on future lung cancer mortality requires "unbundling" the different mortality risks. Second, the model uses the mortality risk explicitly as a function of smoking initiation and cessation rates in a Markov model. Explicit identification of these components provides the forecaster more freedom in altering the constituent parts of the model to examine the long-term effects of interventions and health promotion programs on mortality outcome. As in the models described above, the current model does provide a cohort-specific, smoking-duration-based model. However, rather than examine the trends of the mortality risks over the last two decades, as Brown and Kessler have done, this model assumes that the underlying causes of these trends are represented by the risk factor and population dynamics used in the model.

Building the Model

To build a model, estimates of the transition probabilities are required. Tolley and Manton (in press) have described how the various types of health statistics can be used to determine estimates. In this section, the estimation of these transition probabilities is briefly described, and the data sources for making the estimates are presented.

The Risk Factor States

The first step in the estimation is to determine the number of individuals in each of the risk factor states. Naturally, the primary risk factor state here is smoking status: whether or not the individual is or has been a smoker and, if a smoker, the duration of smoking. The initiation and cessation rates over time for birth cohorts of black and white males and females can be estimated from the NHIS data presented in the first part of this chapter. From these estimates, estimates of the number of individuals who are current smokers with a smoking duration of 5 years, 10 years, and so forth, can be obtained for both races and sexes for the entire Nation. In addition, estimates of the number of individuals who have never smoked, and the number of ex-smokers who smoked 5 years, 10 years, and so on, can be obtained. All of these estimates of smoking duration are specific to various birth cohorts beginning with the 1901 to 1910 cohort and including birth cohorts up to the 1951 to 1960 cohort.

Table 14 gives the distribution of each cohort in terms of their current smoking status in 1980. Naturally, these three smoking states can be subdivided. For the current model, the risk factor states for smoking are "never smoked," "current smoker" (divided into 5-year duration intervals up to "smoked over 70 years"), and "ex-smoker," which also is divided into 5-year duration intervals. This gives 31 smoking states.

The data given in the first section of this chapter show different patterns of initiation and cessation in various birth cohorts; therefore, the model here is developed through separate treatment of each of the 10-year birth cohorts. The oldest cohort considered in this study is the 1901 to 1910 cohort, and the youngest is the 1951 to 1960 cohort.

Although risk factors such as hypertension, elevated blood cholesterol, alcohol consumption, and obesity are also important in the assessment of the future mortality patterns, current data on these patterns and how these patterns are expected to change in the future are limited. Therefore, these risk factors are disregarded in the current model, reflecting an assumption that, whatever the current patterns are, they will remain unchanged in the next three decades.

Causes of Death

The reason for including causes of death other than lung cancer is to adjust for their competing effects. Those causes of death that have smoking as a major risk factor must be considered as separate states in the model. Changes in smoking patterns will then be adjusted for in each such competing risk. All causes of death that do not have smoking as a primary risk factor can be grouped together as a "death by all other causes" state. Table 15 lists all causes other than lung cancer that are assumed (in this model) to have smoking as a major risk factor.

Relative Risks

The second step is to determine the relative risk associated with each risk factor level. For all causes of death except lung cancer, this model assumes that the relative risk is independent of the length of time that subjects smoked. Models relating smoking duration to coronary heart disease death and chronic obstructive pulmonary disease death are less established; therefore, they have not been included. Relative risks for current smokers and ex-smokers, both males and females, have been given in the Surgeon General's Report (US DHHS, 1989).

Table 14
Distribution of nonsmokers, smokers, and ex-smokers in 1980, by race, gender, and birth cohort

	Never-Smokers	Current Smokers	Ex-Smokers
Born 1901-1910			
White male	.36	.19	.45
White female	.72	.15	.13
Black male	.52	.22	.26
Black female	.82	.06	.12
Born 1911-1920			
White male	.28	.30	.42
White female	.57	.26	.17
Black male	.34	.40	.26
Black female	.64	.23	.13
Born 1921-1930			
White male	.24	.40	.36
White female	.54	.31	.15
Black male	.32	.47	.21
Black female	.52	.34	.14
Born 1931-1940			
White male	.29	.42	.29
White female	.49	.35	.16
Black male	.33	.49	.18
Black female	.54	.36	.10
Born 1941-1950			
White male	.34	.43	.23
White female	.50	.34	.16
Black male	.37	.47	.16
Black female	.54	.37	.07
Born 1951-1960			
White male	.49	.39	.12
White female	.56	.33	.11
Black male	.46	.45	.09
Black female	.62	.33	.05

Estimates of relative risks, reproduced in Tables 15 and 16, are used here. Note that since these risks are not race-specific, the same relative risks are used for both blacks and whites.

Table 15
Relative risks of death for current and former smokers (males)

	ICD Code[a]	Age	Current Smokers	Former Smokers
Cause of Death[b]				
CHD	(410-414)	35 - 64	2.81	1.75
		65+	1.62	1.29
Other heart	(390-398, 401-405)		1.85	1.32
CVD	(430-438)	35 - 64	3.67	1.38
		65+	1.94	1.27
Other vascular	(440-448)		4.06	2.33
COPD	(490-492, 496)		9.65	8.75
Other pulmonary	(010-012, 480-489, 493)		1.99	1.56
Oral cancers	(140-149)		27.48	8.80
Bladder cancer	(188)		2.86	1.10
Kidney cancer	(189)		2.95	1.95
Pancreatic cancer	(157)		2.14	1.12
Esophageal cancer	(150)		7.60	5.83

[a]*ICD, International Classification of Disease.*
[b]*CHD, coronary heart disease; CVD, cerebrovascular disease; COPD, chronic obstructive pulmonary disease.*

Several authors have posited models relating the mortality from lung cancer to age and duration of smoking. Peto (1986) proposed a model that related smoking duration to risk of lung cancer. Peto's model included smoking dose in two ways: first, there is a specific model for heavy smokers and moderate smokers; second, the cumulative dose, as measured by smoking duration, is explicitly included in determination of the risk. The models by Gaffney and Altshuler (1988) and those by Moolgavkar et. al (1989) are more sophisticated in their use of dose in determining relative risks of lung cancer instantiation. Although this second set of dose-related models seems to offer many strengths, the data available from the NHIS set sample provide good information on duration of smoking only and not explicitly on dose.

Because of data limitations, the model used here for determining risk of lung cancer is that given by Peto. The probability of death by lung cancer for a person aged "a" who has smoked for "y" years is given by

$$\text{Prob (of death by lung cancer)} = 10^{-11}a^4 + 10^{-9}y^4.$$

Table 16
Relative risks of death for current and former smokers (females)

	ICD Code[a]	Age	Current Smokers	Former Smokers
Cause of Death[b]				
CHD	(410-414)	35 - 64	3.00	1.43
		65+	1.60	1.29
Other heart	(390-398, 401-405)		1.69	1.16
CVD	(430-438)	35 - 64	4.80	1.41
		65+	1.47	1.01
Other vascular	(440-448)		3.00	1.34
COPD	(490-492, 496)		10.47	7.04
Other pulmonary	(010-012, 480-489, 493)		2.18	1.38
Oral cancers	(140-149)		5.59	2.88
Bladder cancer	(188)		2.58	1.85
Kidney cancer	(189)		1.41	1.16
Pancreatic cancer	(157)		2.33	1.78
Esophageal cancer	(150)		10.25	3.16

[a]*ICD, International Classification of Disease.*
[b]*CHD, coronary heart disease; CVD, cerebrovascular disease; COPD, chronic obstructive pulmonary disease.*

Before using the Peto model, we must modify it for several reasons: First, the aggregation of moderate and heavy smokers into the same group, necessitated by the NHIS data format, is problematic; we expect that the "average" probability of lung cancer death would be higher than predicted by the model. Second, since the model was derived from a subpopulation of smokers in Britain, the toxicity of the smoked material and the method of smoking may differ from those characteristics in the United States. Third, the more prevalent use of filters on cigarettes in the last two decades may cause the model to estimate incorrectly the likelihood of death for more recent birth cohorts.

The adjustment of the Peto model is as follows: We assume that for each gender- and race-specific birth cohort, the model for the probability of lung cancer can be determined from the Peto model by a scaling equation (4) as follows:

Prob(of death by lung cancer for nonsmoker) = $S10^{-11}a^4$
Prob(of death by lung cancer for a current smoker)
$= S10^{-11}a^4 + S10^{-8}y^5$
Prob(of death by lung cancer for a former smoker)
$= S10^{-11}a^4 + 5S10^{-9}y^4$

In these equations, the unknown parameter S is a scale parameter. This parameter is determined by calculation of the observed number of deaths by lung cancer in 1980 for each birth cohort-gender-race combination, and comparison to the number predicted from the above equations. The value of S for each cohort-gender-race combination is the value that equates the predicted with the observed number of deaths.

Calculating Transition Probabilities

The probability of transitioning to one of the cause-of-death states (except death by lung cancer) from the never-smoked state for a particular age group is given by the following equation:

$$q_{01}(a,0) = \frac{[\text{Number of observed deaths from cause } l]}{[n_0(a,0) + R1_{k1}n_{kl}(a,0) + R2_{k2}n_{k2}(a,0)]}$$

In this equation, $R1$ is the relative risk of the current smokers for the particular cause of death, and $R2$ is the relative risk of the ex-smokers for the same cause of death. The indexes k_1 and k_2 refer to current smoker and ex-smoker states, respectively. The transition probabilities for the particular cause of death for current smokers and ex-smokers are given by

$$q_{11}(a,0) = R1\ q_{01}(a,0)$$
$$q_{21}(a,0) = R2\ q_{01}(a,0).$$

Calculation of the probability of transition from the "never-smoked" state to death by lung cancer is calculated similarly; however, in this case, each of the smoking levels has a different relative risk, as calculated by the modified Peto model (above).

The transition probabilities for transitioning from the "never-smoked" to the "smoked-5-years-or-less" state are determined from the past initiation patterns. These probabilities are assumed to be age-dependent and cohort-dependent; however, because forecasting what pattern the younger cohorts will follow in the future is difficult, a single table for all cohorts for future initiation as a function of age was estimated. Table 17 is estimated from the initiation rates of the older cohorts and gives the estimated initiation rates, by age group. How current awareness of the detrimental effects of smoking will reduce these initiation rates can only be guessed.

Future cessation patterns, like future initiation patterns, are affected by the recent health trends in the United States. The estimated cessation rates, as a function of duration of smoking, are given in Table 18. These rates are determined by the experience of older cohorts and modified by recent trends toward better health.

Table 17
Probability of initiating smoking in future as a function of age (5-year rate)

	White Male	White Female	Black Male	Black Female
Age Group				
20 - 24 years	.20	.05	.16	.09
25 - 29	.37	.20	.30	.18
30 - 34	.30	.17	.25	.20
35 - 39	.10	.08	.10	.08
40 - 44	.03	.05	.05	.07
45 - 49	.02	.03	.04	.05
50 - 54	.01	.015	.02	.03
55 - 59	.01	.015	.01	.01
60 - 64	.005	.005	.005	.01
65 +	0	0	0	0

Table 18
Probability of termination of smoking during 5-year period, by 5-year duration

	White Male	White Female	Black Male	Black Female
Duration of Smoking				
< 5 years	.05	.05	.05	.08
5 - 10	.08	.10	.08	.07
10 - 15	.10	.10	.08	.06
15 - 20	.10	.08	.06	.05
20 - 25	.10	.10	.05	.04
25 - 30	.15	.08	.05	.04
30 - 35	.15	.05	.04	.03
35 - 40	.10	.05	.03	.03
40 - 45	.05	.05	.03	.03
45 +	.05	.05	.03	.03

Results and Forecasts

The parameters estimated above can now be placed in the model described previously, to forecast mortality outcomes for each race and gender. These forecasts are summarized in Tables 19 through 22 for each race and gender combination. Entries in the tables are the age-specific annual mortality rates per 100,000 individuals.

Examining the values in these tables, we see several important points. One point of interest is that, for white males and white females, the age-specific lung cancer mortality rate drops

Table 19
Forecast mortality rates* for select causes of death, white males, ages 55 to 84

Year	Lung Cancer	Other Cancers	Coronary Heart Disease	All Other Causes
		Age group 55 - 64		
1980	208.76	78.98	585.48	858.48
1985	181.34	81.56	602.48	873.19
1995	100.69	74.89	563.55	854.46
2005	26.91	70.62	536.02	831.36
2015	14.97	77.45	578.38	856.19
		Age group 65 - 74		
1980	375.79	162.06	1,384.57	2,088.08
1985	385.37	169.00	1,412.82	2,124.37
1995	321.03	175.53	1,443.87	2,163.87
2005	178.69	162.94	1,399.21	2,115.59
2015	49.13	155.46	1,357.07	2,056.93
		Age group 75 - 84		
1980	476.60	242.20	2,554.47	4,169.47
1985	508.34	393.92	3,246.97	5,966.54
1995	516.52	429.99	3,350.83	6,192.03
2005	451.04	458.14	3,440.06	6,403.72
2015	254.08	421.76	3,348.47	6,195.09

** Deaths per 100,000; 1980 data are actual, not forecast.*

rather quickly for the younger age groups because of the low peak prevalence rates in more recent cohorts. For older age groups, this reduction occurs much more slowly. Note that the forecast model begins with the actual data for 1980; however, the values for 1985 and subsequent years are predicted from 1980 mortality rates combined with the estimated smoking rates and the relative risks—as calculated with the Peto model.

Although the mortality risks from coronary heart disease and from cancers other than lung are notably higher for smokers, as evidenced in Tables 15 and 16, the observed mortality rates for these causes are forecast to change very little over the next 25 years. One reason for this is that the age-specific mortality rates for different years are determined by the experience of different birth cohorts. Although the age-specific mortality rate for the "never-smoked" individuals is constant over time, the percentage of the population in each smoking state differs for each cohort. As a consequence, the number of individuals who are current smokers and ex-smokers and the

Table 20
Forecast mortality rates* for select causes of death, white females, ages 55 to 84

Year	Lung Cancer	Other Cancers	Coronary Heart Disease	All Other Causes
		Age group 55 - 64		
1980	71.29	34.62	177.87	591.89
1985	77.82	35.74	185.10	601.68
1995	67.28	36.53	186.19	600.72
2005	30.57	35.82	178.18	588.91
2015	14.80	38.80	193.10	605.65
		Age group 65 - 74		
1980	98.11	70.75	597.32	1,293.86
1985	126.22	76.04	623.35	1,324.53
1995	150.88	78.17	637.81	1,343.84
2005	130.33	80.32	640.43	1,341.47
2015	60.00	79.60	624.12	1,313.48
		Age group 75 - 84		
1980	104.40	106.11	1,410.84	2,571.00
1985	126.22	140.30	1,972.20	3,465.08
1995	199.74	160.30	2,096.18	3,619.20
2005	239.28	165.62	2,145.72	3,689.71
2015	208.90	170.37	2,155.74	3,681.28

** Deaths per 100,000; 1980 data are actual, not forecast.*

number in each duration state are different. Differential effects of lung cancer as a competing risk and the differences in the number of smokers both will alter the mortality rates for these other causes.

The forecast of the overall lung cancer rate is given in Table 23, where the age-standardized rate per 100,000 population between the ages of 55 and 84 is given for each of the four general causes of death. The rates in this table are substantially higher than the overall age-adjusted death rates because they are only for those between the ages of 55 and 84 rather than being age-standardized for the entire population. The population used for age standardization is the 1980 U.S. population. Note that although the lung cancer mortality rate for white males is forecast to increase through 2005 for older ages and decrease for younger ages, the age-standardized rate is forecast to decrease. However this decrease is relatively slower than age-specific decreases in younger ages, being almost constant

Table 21
Forecast mortality rates* for select causes of death, black males, ages 55 to 84

Year	Lung Cancer	Other Cancers	Coronary Heart Disease	All Other Causes
		Age group 55 - 64		
1980	314.76	168.86	588.33	1,794.73
1985	328.73	170.68	597.34	1,810.84
1995	259.30	165.37	580.66	1,790.37
2005	113.31	162.05	564.10	1,756.58
2015	95.30	176.18	601.21	1,793.03
		Age group 65 - 74		
1980	452.74	224.42	1,195.15	3,244.99
1985	554.03	242.24	1,232.01	3,309.03
1995	600.65	244.18	1,238.17	3,325.57
2005	473.81	236.98	1,221.15	3,289.64
2015	215.75	233.29	1,202.22	3,226.78
		Age group 75 - 84		
1980	488.59	239.95	1,956.85	5,409.63
1985	523.15	394.34	2,438.00	6,794.00
1995	759.31	471.70	2,575.20	7,104.08
2005	823.01	475.54	2,589.97	7,142.38
2015	652.22	458.10	2,559.84	7,062.83

** Deaths per 100,000; 1980 data are actual, not forecast.*

until 1995. For all other gender-race combinations, the age-standardized lung cancer mortality rates increase until around 2000 and then decrease. Thus, the decreases in smoking patterns that have occurred prior to the current time will have little effect on decreasing age-standardized rates until 2005 for all but white males.

Potential Reduction In Lung Cancer

The mortality rates forecast by the model assume that current patterns of initiation and cessation will continue over the next 25 years. The impact of improved smoking control strategies can be estimated with this model. If one assumes that implementation of the comprehensive smoking control strategies described in this volume would double current rates of cessation, then the impact of these improvements can be calculated, as presented in Table 24. The lung cancer mortality estimates in Table 24 can be compared with those in the first columns of Tables 19 through 22.

Table 22
Forecast mortality rates* for select causes of death, black females, ages 55 to 84

Year	Lung Cancer	Other Cancers	Coronary Heart Disease	All Other Causes
		Age group 55 - 64		
1980	73.32	62.40	315.95	1,102.76
1985	94.79	67.65	339.88	1,126.56
1995	95.99	68.35	343.61	1,129.22
2005	38.66	70.55	349.36	1,125.35
2015	45.73	76.99	376.51	1,155.40
		Age group 65 - 74		
1980	85.69	99.60	729.56	2,140.22
1985	115.24	115.82	779.26	2,217.30
1995	183.92	127.46	806.21	2,238.60
2005	186.36	128.32	807.08	2,239.14
2015	77.84	132.42	808.50	2,217.33
		Age group 75 - 84		
1980	86.81	127.68	1,381.49	3,657.17
1985	96.44	150.15	1,759.85	4,449.39
1995	178.13	185.61	1,916.42	4,671.24
2005	288.34	203.44	1,974.39	4,722.32
2015	292.83	205.21	1,977.33	4,727.77

** Deaths per 100,000; 1980 data are actual, not forecast.*

For white males, there is a dramatic change in the predicted lung cancer mortality pattern, with approximately a 50 percent reduction in age-specific lung cancer death rates for all age groups by the year 2015. It is important that this reduction is *in addition to* the benefits to be expected from current smoking control efforts.

The results for the other racial and gender groups are more modest but still impressive. The more modest reductions reflect the lower current rates of cessation in those groups and, therefore, dramatically underestimate the benefits that could be achieved if the cessation patterns occurring among white males can be replicated in the other racial and gender groups.

CONCLUSIONS

- Males born early in this century became cigarette smokers earlier in life and in greater percentages than females. The pattern of initiation and peak prevalence of smoking is similar for males and females born into the most recent birth cohorts.

Table 23
Forecast age-standardized mortality rates,* based on 1980 population

Year	Lung Cancer	Other Cancers	Coronary Heart Disease	Other Causes
		White male		
1980	310.6154	134.8752	1,192.714	1,841.914
1985	305.7283	164.9100	1,331.260	2,174.659
1995	245.9573	170.0526	1,340.338	2,217.751
2005	150.9946	168.6916	1,327.521	2,227.296
2015	67.95557	163.2606	1,318.622	2,183.843
		White female		
1980	88.18845	63.94307	616.6047	1,305.564
1985	105.5464	74.50172	765.1922	1,537.934
1995	127.0899	80.41854	800.6575	1,581.471
2005	114.2955	82.12020	810.1826	1,592.848
2015	77.01571	84.31496	813.6352	1,588.735
		Black male		
1980	389.3818	199.0883	1,016.176	2,874.051
1985	435.8217	231.4099	1,112.363	3,131.886
1995	455.4529	242.1545	1,128.678	3,178.280
2005	350.4382	238.7241	1,117.134	3,155.673
2015	227.2963	241.7119	1,124.491	3,139.918
		Black female		
1980	80.22296	88.16579	671.2568	1,970.012
1985	102.0179	100.6025	775.6823	2,167.45
1995	142.2724	112.0328	818.2055	2,220.809
2005	139.0346	116.9478	832.8903	2,229.558
2015	106.6173	121.6528	846.4619	2,237.143

**Deaths per 100,000; 1980 data are actual, not forecast.*

- White males began to quit smoking in substantial numbers during the 1950's, but black males, white females, and black females did not begin to quit in substantial numbers until the late 1960's.
- In general, the birth cohort pattern of cigarette smoking closely matches the pattern of lung cancer death rates within each racial and gender grouping, but black males and females appear to have higher rates of lung cancer than white males and females, even after consideration of the differences in their smoking behaviors.

Table 24
Forecast age-specific lung cancer mortality rates,* assuming cessation rates are doubled

Year	White Male	White Female	Black Male	Black Female
		Age group 55 - 64		
1980	208.76	71.29	314.76	73.32
1985	170.67	75.04	321.54	92.82
1995	73.49	57.46	235.19	88.38
2005	15.49	21.60	91.20	32.29
2015	7.30	8.58	65.24	33.26
		Age group 65 - 74		
1980	375.79	98.11	452.74	85.69
1985	376.39	122.73	544.93	113.27
1995	276.21	134.41	559.70	171.67
2005	115.14	101.44	404.11	162.25
2015	24.66	38.41	162.14	61.03
		Age group 75 - 84		
1980	476.60	104.40	488.59	86.81
1985	502.75	123.99	517.38	95.38
1995	485.26	185.24	721.70	168.96
2005	364.44	201.04	732.67	257.39
2015	150.83	152.14	525.41	242.49

**Deaths per 100,000; 1980 data are actual, not forecast.*

- A model of future lung cancer death rates based on trends in smoking behavior presented in this chapter predicts that the lung cancer death rates for white males will begin to fall by 1995, with declines in lung cancer death rates occurring later among the other racial and gender groups.
- A doubling of the effectiveness of current smoking control programs could result, by the year 2015, in up to a 50 percent reduction in lung cancer death rates from those that will occur if current trends continue.

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Appendix A

Data Points for Figures in Chapter 3

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Figure 1. U.S. per capita cigarette consumption for adults, aged 18 and older (1900 to 1990)

Year	Per Capita	Year	Per Capita
1900	54	1945	3,449
1901	53	1946	3,446
1902	60	1947	3,416
1903	64	1948	3,505
1904	66	1949	3,480
1905	70	1950	3,522
1906	86	1951	3,744
1907	99	1952	3,886
1908	105	1953	3,778
1909	125	1954	3,546
1910	151	1955	3,597
1911	173	1956	3,650
1912	223	1957	3,755
1913	260	1958	3,953
1914	267	1959	4,073
1915	285	1960	4,171
1916	395	1961	4,266
1917	551	1962	4,265
1918	697	1963	4,345
1919	727	1964	4,195
1920	665	1965	4,259
1921	742	1966	4,287
1922	770	1967	4,280
1923	911	1968	4,186
1924	982	1969	3,993
1925	1,085	1970	3,985
1926	1,191	1971	4,037
1927	1,279	1972	4,043
1928	1,366	1973	4,148
1929	1,504	1974	4,141
1930	1,485	1975	4,123
1931	1,399	1976	4,092
1932	1,245	1977	4,051
1933	1,334	1978	3,967
1934	1,483	1979	3,861
1935	1,564	1980	3,851
1936	1,754	1981	3,840
1937	1,847	1982	3,753
1938	1,830	1983	3,502
1939	1,900	1984	3,461
1940	1,976	1985	3,370
1941	2,236	1986	3,274
1942	2,585	1987	3,197
1943	2,956	1988	3,096
1944	3,039	1989	2,926
		1990	2,828

Figure 2. Changes in prevalence of cigarette smoking among successive birth cohorts of U.S. males, 1900 to 1987

X Data	1901-1910	1911-1920	1921-1930	1931-1940	1941-1950	1951-1960	1961-1970
1900	0	0	0	0	0	0	0
1905	0	0	0	0	0	0	0
1910	0.4	0	0	0	0	0	0
1915	2.9	0	0	0	0	0	0
1920	16.2	0.2	0	0	0	0	0
1925	39.9	2.6	0	0	0	0	0
1930	56.7	17.4	0.4	0	0	0	0
1935	61.3	44.3	2.8	0	0	0	0
1940	61.8	62.0	17.8	0.3	0	0	0
1945	61.3	65.9	49.4	2.6	0	0	0
1950	58.9	65.2	65.8	18.7	0.1	0	0
1955	55.8	62.8	66.1	47.0	2.3	0	0
1960	51.8	59.6	63.5	61.8	19.1	0.2	0
1965	45.0	53.6	57.7	59.0	44.7	2.6	0
1970	32.0	42.1	45.9	47.4	48.5	17.7	0.3
1975	25.4	39.8	48.1	48.1	52.3	39.4	3.7
1980	18.6	30.5	40.3	42.5	43.3	39.6	18.7
1985	15.3	19.8	32.5	35.7	39.5	36.1	32.4
1987	14.3	17.3	29.5	32.3	35.7	32.1	30.0

Figure 3. Changes in prevalence of cigarette smoking among successive birth cohorts of U.S. females, 1900 to 1987

X Data	1901-1910	1911-1920	1921-1930	1931-1940	1941-1950	1951-1960	1961-1970
1900	0	0	0	0	0	0	0
1905	0	0	0	0	0	0	0
1910	0.4	0	0	0	0	0	0
1915	0.1	0	0	0	0	0	0
1920	0.9	0	0	0	0	0	0
1925	5.7	0.2	0	0	0	0	0
1930	13.0	4.0	0.1	0	0	0	0
1935	18.0	15.8	0.4	0	0	0	0
1940	21.5	28.2	5.4	0	0	0	0
1945	23.9	33.5	23.1	0.8	0	0	0
1950	25.1	35.9	37.2	9.4	0	0	0
1955	25.4	36.8	41.8	28.9	0.6	0	0
1960	25.4	37.2	42.5	42.9	10.1	0.1	0
1965	24.3	36.0	41.6	43.9	30.5	1.1	0
1970	20.7	31.8	37.3	38.0	35.8	12.0	0.3
1975	15.4	28.5	35.5	40.0	39.3	32.7	3.2
1980	13.6	24.9	30.5	34.9	33.6	32.7	20.1
1985	7.6	17.6	27.5	30.7	32.0	33.6	29.2
1987	7.3	16.3	24.7	28.8	29.4	30.5	25.9

Figure 4. Changes in prevalence of cigarette smoking among successive birth cohorts of white U.S. males, 1900 to 1987

X Data	1901-1910	1911-1920	1921-1930	1931-1940	1941-1950	1951-1960	1961-1970
1900	0	0	0	0	0	0	0
1905	0	0	0	0	0	0	0
1910	0.4	0	0	0	0	0	0
1915	3.0	0	0	0	0	0	0
1920	16.5	0.2	0	0	0	0	0
1925	40.8	2.6	0	0	0	0	0
1930	58.0	17.5	0.5	0	0	0	0
1935	62.6	45.0	2.9	0	0	0	0
1940	62.9	62.9	18.1	0.3	0	0	0
1945	62.4	66.8	50.0	2.6	0	0	0
1950	59.9	66.0	66.8	19.0	0.2	0	0
1955	56.5	63.5	67.0	47.9	2.5	0	0
1960	52.4	60.2	64.0	62.4	19.7	0.2	0
1965	45.3	53.6	57.9	59.3	45.3	2.6	0
1970	31.8	41.9	45.5	47.1	48.0	18.3	0.4
1975	24.8	39.3	47.7	47.7	51.6	39.6	4.2
1980	18.0	29.7	39.5	42.0	42.9	39.0	20.2
1985	14.5	19.0	30.7	35.0	39.5	34.4	33.7
1987	13.5	16.4	27.6	31.4	35.6	30.8	31.0

Figure 5. Changes in prevalence of cigarette smoking among successive birth cohorts of black U.S. males, 1900 to 1987

X Data	1901-1910	1911-1920	1921-1930	1931-1940	1941-1950	1951-1960	1961-1970
1900	0	0	0	0	0	0	0
1905	0	0	0	0	0	0	0
1910	0.5	0	0	0	0	0	0
1915	1.7	0	0	0	0	0	0
1920	12.7	0.2	0	0	0	0	0
1925	30.9	2.7	0	0	0	0	0
1930	42.1	15.8	0.2	0	0	0	0
1935	46.6	38.7	2.2	0	0	0	0
1940	48.3	54.1	15.8	0.2	0	0	0
1945	48.6	57.6	44.3	2.5	0	0	0
1950	48.9	59.6	55.0	16.3	0	0	0
1955	47.8	55.8	57.2	39.4	1.0	0	0
1960	46.1	54.9	58.0	57.1	15.5	0.3	0
1965	43.6	54.0	55.7	56.5	41.3	2.2	0
1970	34.7	45.3	50.0	51.0	55.0	14.1	0
1975	33.9	47.8	51.1	55.3	57.9	39.2	1.5
1980	24.8	40.4	46.9	47.8	47.0	44.6	12.0
1985	25.3	29.4	42.3	47.8	45.5	46.1	28.5
1987	25.3	28.3	39.3	45.5	41.6	40.3	28.4

Figure 6. Changes in prevalence of cigarette smoking among successive birth cohorts of white U.S. females, 1900 to 1987

X Data	1901-1910	1911-1920	1921-1930	1931-1940	1941-1950	1951-1960	1961-1970
1900	0	0	0	0	0	0	0
1905	0	0	0	0	0	0	0
1910	0	0	0	0	0	0	0
1915	0.1	0	0	0	0	0	0
1920	0.8	0	0	0	0	0	0
1925	5.6	0.2	0	0	0	0	0
1930	13.2	4.2	0.1	0	0	0	0
1935	18.5	16.5	0.4	0	0	0	0
1940	22.2	29.5	5.4	0	0	0	0
1945	24.6	34.9	23.5	0.8	0	0	0
1950	25.9	37.4	38.0	9.6	0	0	0
1955	26.2	38.2	42.7	29.5	0.6	0	0
1960	26.2	38.8	43.3	43.7	10.3	0.1	0
1965	25.0	37.4	42.2	44.2	31.2	1.1	0
1970	21.2	33.0	37.7	37.9	35.9	12.4	0.4
1975	16.1	29.2	35.9	40.3	39.5	33.6	3.6
1980	14.5	25.3	30.5	35.0	33.7	33.0	22.0
1985	7.5	17.9	28.0	31.9	31.8	33.4	30.4
1987	7.5	16.6	25.3	30.0	29.1	30.1	26.9

Figure 7. Changes in prevalence of cigarette smoking among successive birth cohorts of black U.S. females, 1900 to 1987

X Data	1901-1910	1911-1920	1921-1930	1931-1940	1941-1950	1951-1960	1961-1970
1900	0	0	0	0	0	0	0
1905	0	0	0	0	0	0	0
1910	0	0	0	0	0	0	0
1915	0.6	0	0	0	0	0	0
1920	2.4	0	0	0	0	0	0
1925	6.6	0.6	0	0	0	0	0
1930	10.7	3.2	0.1	0	0	0	0
1935	13.2	9.4	0.4	0	0	0	0
1940	14.6	16.1	6.1	0	0	0	0
1945	17.0	20.4	20.3	1.0	0	0	0
1950	17.3	23.1	31.7	8.4	0.1	0	0
1955	17.0	24.6	35.0	25.9	0.5	0	0
1960	17.3	24.1	37.4	39.4	9.3	0.2	0
1965	16.7	23.3	37.4	44.3	26.6	0.9	0
1970	14.5	21.6	35.2	41.3	37.9	9.8	0.1
1975	8.1	23.8	33.6	41.0	41.3	28.5	1.7
1980	6.2	22.9	32.7	36.0	36.9	32.7	12.7
1985	9.7	12.7	28.3	26.7	37.8	37.4	23.5
1987	8.9	12.2	23.3	24.1	35.7	35.4	22.3

Figure 8. Age-adjusted cancer mortality rates, all males

X Data	All Sites Combined	Lung Cancer	All Other Cancers
1950	171.9	22.2	149.7
1955	182.9	34.6	148.3
1960	187.9	39.3	148.5
1965	197.8	48.7	149.1
1970	190.2	55.9	134.3
1975	212.2	66.7	145.5
1980	221.3	73.3	148.0
1985	218.8	73.9	144.9
1987	219.4	74.9	144.5

Figure 9. Age-adjusted cancer mortality rates, white males

X Data	All Sites Combined	Lung Cancer	All Other Cancers
1950	173.3	22.6	150.7
1955	183.1	35.2	147.9
1960	186.8	39.3	147.5
1965	196.2	48.8	147.4
1970	194.4	57.5	136.9
1975	207.7	65.7	142.0
1980	215.6	71.8	143.8
1985	212.5	72.2	140.3
1987	213.4	73.2	140.2

Figure 10. Age-adjusted cancer mortality rates, nonwhite males

X Data	All Sites Combined	Lung Cancer	All Other Cancers
1950	151.7	16.2	135.5
1955	176.9	27.3	149.6
1960	196.3	38.7	157.6
1965	211.9	47.0	164.9
1970	161.7	44.6	117.1
1975	252.0	74.9	177.2
1980	271.7	85.7	186.0
1985	271.3	87.3	184.0
1987	269.2	88.5	180.6

Figure 11. Age-adjusted cancer mortality rates, all females

X Data	All Sites Combined	Lung Cancer	All Other Cancers
1950	151.7	5.06	146.7
1955	145.6	5.92	139.7
1960	140.0	5.83	134.2
1965	136.4	7.78	128.7
1970	143.2	11.80	131.5
1975	134.2	15.60	118.6
1980	138.0	21.40	116.6
1985	139.3	26.40	112.9
1987	139.5	28.20	111.3

Figure 12. Age-adjusted cancer mortality rates, white females

X Data	All Sites Combined	Lung Cancer	All Other Cancers
1950	151.2	5.0	146.1
1955	145.1	5.8	139.2
1960	138.6	5.8	132.8
1965	135.1	7.6	127.5
1970	148.0	12.2	135.8
1975	132.3	15.6	116.6
1980	136.4	21.5	115.0
1985	138.2	26.8	111.4
1987	138.1	28.5	109.6

Figure 13. Age-adjusted cancer mortality rates, nonwhite females

X Data	All Sites Combined	Lung Cancer	All Other Cancers
1950	150.4	4.10	146.4
1955	144.1	6.10	137.9
1960	149.6	6.10	143.5
1965	145.2	7.50	137.7
1970	110.1	8.82	101.2
1975	156.5	16.00	140.5
1980	149.0	20.50	128.5
1985	146.9	23.20	123.7
1987	148.6	25.50	123.1

Figure 14. Changes in current smokers, ever-smokers, and lung cancer deaths, for white U.S. males born 1901 to 1910

X Data	Current	Ever	Lung Death
1900	0	0	0
1905	0	0	0
1910	0.4	0.4	0
1915	3.0	3.0	0
1920	16.5	16.7	0
1925	40.8	41.4	0
1930	58.0	59.2	0
1935	62.6	64.5	0
1940	62.9	66.1	0
1945	62.4	66.9	0
1950	59.9	67.1	1.7
1955	56.5	67.2	4.7
1960	52.4	67.4	9.0
1965	45.3	67.7	15.9
1970	31.8	67.8	26.0
1975	24.8	65.7	36.5
1980	18.0	64.3	47.4
1985	14.5	62.6	56.8
1987	13.4	62.6	

Figure 15. Changes in current smokers, ever-smokers, and lung cancer deaths, for black U.S. males born 1901 to 1910

X Data	Current	Ever	Lung Death
1900	0	0	0
1905	0	0	0
1910	0.5	0.5	0
1915	1.7	1.7	0
1920	12.7	12.7	0
1925	30.9	31.5	0
1930	42.1	43.3	0
1935	46.6	48.2	0
1940	48.3	50.3	0
1945	48.6	51.1	0
1950	48.9	52.1	1.6
1955	47.8	52.3	5.4
1960	46.1	52.7	10.0
1965	43.6	53.0	15.9
1970	34.7	53.0	25.8
1975	33.9	52.1	34.8
1980	24.8	48.4	44.5
1985	25.3	70.8	51.2
1987	25.3	70.8	

Figure 16. Changes in current smokers, ever-smokers, and lung cancer deaths, for white U.S. males born 1911 to 1920

X Data	Current	Ever	Lung Death
1900	0	0	0
1905	0	0	0
1910	0	0	0
1915	0	0	0
1920	0.2	0.2	0
1925	2.6	2.6	0
1930	17.5	17.7	0
1935	45.0	45.5	0
1940	62.9	64.0	0
1945	66.8	69.2	0
1950	66.0	70.7	0
1955	63.5	71.1	0
1960	60.2	71.3	2.3
1965	53.6	71.5	5.7
1970	41.9	71.6	11.5
1975	39.3	73.8	19.4
1980	29.7	72.2	30.1
1985	19.0	72.3	41.0
1987	16.4	72.3	

Figure 17. Changes in current smokers, ever-smokers, and lung cancer deaths, for black U.S. males born 1911 to 1920

X Data	Current	Ever	Lung Death
1900	0	0	0
1905	0	0	0
1910	0	0	0
1915	0	0	0
1920	0.2	0.2	0
1925	2.7	2.7	0
1930	15.8	15.8	0
1935	38.7	38.7	0
1940	54.1	54.7	0
1945	57.6	58.7	0
1950	56.8	59.6	0
1955	55.8	59.6	0
1960	54.9	60.0	3.7
1965	54.0	60.5	7.7
1970	45.3	62.7	16.6
1975	47.8	68.0	26.2
1980	40.4	65.7	37.5
1985	29.4	65.0	47.5
1987	28.3	65.0	

Figure 18. Changes in current smokers, ever-smokers, and lung cancer deaths, for white U.S. males born 1921 to 1930

X Data	Current	Ever	Lung Death
1900	0	0	0
1905	0	0	0
1910	0	0	0
1915	0	0	0
1920	0	0	0
1925	0	0	0
1930	0.5	0.5	0
1935	2.9	2.9	0
1940	18.1	18.2	0
1945	50.0	50.6	0
1950	66.8	69.0	0
1955	67.0	71.5	0
1960	64.0	72.0	0
1965	57.9	72.3	1.2
1970	45.5	72.5	3.3
1975	47.7	75.7	6.9
1980	39.5	75.8	12.8
1985	30.7	73.8	21.2
1987	27.6	73.9	

Figure 19. Changes in current smokers, ever-smokers, and lung cancer deaths, for black U.S. males born 1921 to 1930

X Data	Current	Ever	Lung Death
1900	0	0	0
1905	0	0	0
1910	0	0	0
1915	0	0	0
1920	0	0	0
1925	0	0	0
1930	0.2	0.2	0
1935	2.2	2.2	0
1940	15.8	15.7	0
1945	44.3	44.8	0
1950	55.0	56.4	0
1955	57.2	60.0	0
1960	58.0	61.6	0
1965	55.7	62.0	2.2
1970	50.0	62.5	5.9
1975	51.1	68.6	11.7
1980	46.9	68.1	19.5
1985	42.3	74.7	28.9
1987	39.3	74.7	

Figure 20. Changes in current smokers, ever-smokers, and lung cancer deaths, for white U.S. males born 1931 to 1940

X Data	Current	Ever	Lung Death
1900	0	0	0
1905	0	0	0
1910	0	0	0
1915	0	0	0
1920	0	0	0
1925	0	0	0
1930	0	0	0
1935	0	0	0
1940	0.3	0.3	0
1945	2.6	2.6	0
1950	19.0	19.2	0
1955	47.9	48.9	0
1960	62.4	65.4	0
1965	59.3	67.8	0
1970	47.1	68.5	0
1975	47.7	69.9	1.3
1980	42.0	70.9	3.1
1985	35.0	69.8	6.2
1987	31.4	69.8	

Figure 21. Changes in current smokers, ever-smokers, and lung cancer deaths, for black U.S. males born 1931 to 1940

X Data	Current	Ever	Lung Death
1900	0	0	0
1905	0	0	0
1910	0	0	0
1915	0	0	0
1920	0	0	0
1925	0	0	0
1930	0	0	0
1935	0	0	0
1940	0.2	0.2	0
1945	2.5	2.5	0
1950	16.3	16.3	0
1955	39.4	39.8	0
1960	57.1	57.6	0
1965	56.5	60.2	0
1970	51.0	62.1	0
1975	55.3	68.7	2.4
1980	47.8	67.4	5.5
1985	47.8	61.0	10.0
1987	45.5	61.0	

Figure 22. Changes in current smokers, ever-smokers, and lung cancer deaths, for white U.S. males born 1941 to 1950

X Data	Current	Ever	Lung Death
1900	0	0	0
1905	0	0	0
1910	0	0	0
1915	0	0	0
1920	0	0	0
1925	0	0	0
1930	0	0	0
1935	0	0	0
1940	0	0	0
1945	0	0	0
1950	0.2	0.2	0
1955	2.5	2.5	0
1960	19.7	19.9	0
1965	45.3	47.4	0
1970	48.0	61.4	0
1975	51.6	65.9	0
1980	42.9	66.2	0
1985	39.5	65.2	0.9
1987	35.6	65.3	

Figure 23. Changes in current smokers, ever-smokers, and lung cancer deaths, for black U.S. males born 1941 to 1950

X Data	Current	Ever	Lung Death
1900	0	0	0
1905	0	0	0
1910	0	0	0
1915	0	0	0
1920	0	0	0
1925	0	0	0
1930	0	0	0
1935	0	0	0
1940	0	0	0
1945	0	0	0
1950	0	0	0
1955	1	1	0
1960	15.5	15.6	0
1965	41.3	42.4	0
1970	55.0	60.3	0
1975	57.9	64.7	0
1980	47.0	63.1	0
1985	45.5	64.1	1.7
1987	41.6	64.1	

Figure 24. Changes in current smokers, ever-smokers, and lung cancer deaths, for white U.S. females born 1901 to 1910

X Data	Current	Ever	Lung Death
1900	0	0	0
1905	0	0	0
1910	0	0	0
1915	0.1	0.1	0
1920	0.8	0.9	0
1925	5.6	5.7	0
1930	13.2	13.4	0
1935	18.5	18.8	0
1940	22.2	22.8	0
1945	24.6	25.6	0
1950	25.9	27.5	0.35
1955	26.2	28.4	0.68
1960	26.2	29.4	1.2
1965	25.0	29.8	2.2
1970	21.2	30.2	4.1
1975	16.1	27.9	6.5
1980	14.5	27.5	10.3
1985	7.5	20.1	13.6
1987	7.2	20.1	

Figure 25. Changes in current smokers, ever-smokers, and lung cancer deaths, for black U.S. females born 1901 to 1910

X Data	Current	Ever	Lung Death
1900	0	0	0
1905	0	0	0
1910	0	0	0
1915	0.6	0.6	0
1920	2.4	2.4	0
1925	6.6	6.6	0
1930	10.7	10.7	0
1935	13.2	13.2	0
1940	14.6	14.6	0
1945	17.0	17.2	0
1950	17.3	18.9	0.4
1955	17.0	19.7	1.1
1960	17.3	20.5	1.3
1965	16.7	20.6	2.4
1970	14.5	21.3	3.5
1975	8.1	17.0	7.9
1980	6.2	18.1	8.4
1985	9.7	17.2	10.1
1987	8.9	17.2	

Figure 26. Changes in current smokers, ever-smokers, and lung cancer deaths, for white U.S. females born 1911 to 1920

X Data	Current	Ever	Lung Death
1900	0	0	0
1905	0	0	0
1910	0	0	0
1915	0	0	0
1920	0	0	0
1925	0.2	0.2	0
1930	4.2	4.2	0
1935	16.5	16.6	0
1940	29.5	30.0	0
1945	34.9	35.9	0
1950	37.4	39.3	0
1955	38.2	41.0	0
1960	38.8	42.6	0.6
1965	37.4	43.4	1.4
1970	33.0	44.0	3.0
1975	29.2	42.9	5.5
1980	25.3	42.8	9.3
1985	17.9	37.4	14.6
1987	16.6	37.4	

Figure 27. Changes in current smokers, ever-smokers, and lung cancer deaths, for black U.S. females born 1911 to 1920

X Data	Current	Ever	Lung Death
1900	0	0	0
1905	0	0	0
1910	0	0	0
1915	0	0	0
1920	0	0	0
1925	0.6	0.6	0
1930	3.2	3.2	0
1935	9.4	9.6	0
1940	16.1	16.5	0
1945	20.4	20.9	0
1950	23.1	24.0	0
1955	24.6	25.9	0
1960	24.1	26.7	0.7
1965	23.3	26.8	1.5
1970	21.6	27.7	3.0
1975	23.8	33.7	4.6
1980	22.9	36.1	8.0
1985	12.7	26.0	10.9
1987	12.2	26.0	

Figure 28. Changes in current smokers, ever-smokers, and lung cancer deaths, for white U.S. females born 1921 to 1930

X Data	Current	Ever	Lung Death
1900	0	0	0
1905	0	0	0
1910	0	0	0
1915	0	0	0
1920	0	0	0
1925	0	0	0
1930	0.1	0.1	0
1935	0.4	0.4	0
1940	5.4	5.4	0
1945	23.5	24.1	0
1950	38.0	39.4	0
1955	42.7	44.8	0
1960	43.3	46.8	0
1965	42.2	48.2	0.4
1970	37.7	48.8	1.2
1975	35.9	47.3	2.7
1980	30.5	46.3	5.2
1985	28.0	47.5	9.2
1987	25.3	47.5	

Figure 29. Changes in current smokers, ever-smokers, and lung cancer deaths, for black U.S. females born 1921 to 1930

X Data	Current	Ever	Lung Death
1900	0	0	0
1905	0	0	0
1910	0	0	0
1915	0	0	0
1920	0	0	0
1925	0	0	0
1930	0.1	0.1	0
1935	0.4	0.4	0
1940	6.1	6.1	0
1945	20.3	20.3	0
1950	31.7	32.0	0
1955	35.0	36.3	0
1960	37.3	39.1	0
1965	37.4	40.5	0.6
1970	35.2	42.2	1.5
1975	33.6	43.7	2.8
1980	32.7	47.8	5.6
1985	28.3	43.9	8.8
1987	23.3	43.9	

Figure 30. Changes in current smokers, ever-smokers, and lung cancer deaths, for white U.S. females born 1931 to 1940

X Data	Current	Ever	Lung Death
1900	0	0	0
1905	0	0	0
1910	0	0	0
1915	0	0	0
1920	0	0	0
1925	0	0	0
1930	0	0	0
1935	0	0	0
1940	0	0	0
1945	0.8	0.8	0
1950	9.6	9.7	0
1955	29.5	30.2	0
1960	43.7	46.3	0
1965	44.2	50.0	0
1970	37.9	51.5	0
1975	40.3	51.1	0.7
1980	35.0	51.2	1.7
1985	31.9	50.1	3.5
1987	30.0	50.1	

Figure 31. Changes in current smokers, ever-smokers, and lung cancer deaths, for black U.S. females born 1931 to 1940

X Data	Current	Ever	Lung Death
1900	0	0	0
1905	0	0	0
1910	0	0	0
1915	0	0	0
1920	0	0	0
1925	0	0	0
1930	0	0	0
1935	0	0	0
1940	0	0	0
1945	1.0	1.0	0
1950	8.4	8.5	0
1955	25.9	26.0	0
1960	39.4	39.9	0
1965	44.3	46.4	0
1970	41.3	49.1	0
1975	41.0	47.8	0.8
1980	36.0	45.7	2.0
1985	26.7	39.5	3.3
1987	24.1	39.5	

Figure 32. Changes in current smokers, ever-smokers, and lung cancer deaths, for white U.S. females born 1941 to 1950

X Data	Current	Ever	Lung Death
1900	0	0	0
1905	0	0	0
1910	0	0	0
1915	0	0	0
1920	0	0	0
1925	0	0	0
1930	0	0	0
1935	0	0	0
1940	0	0	0
1945	0	0	0
1950	0	0	0
1955	0.6	0.6	0
1960	10.3	10.5	0
1965	31.2	33.3	0
1970	35.9	46.9	0
1975	39.5	49.0	0
1980	33.7	49.7	0
1985	31.8	49.4	0.6
1987	29.1	49.5	

Figure 33. Changes in current smokers, ever-smokers, and lung cancer deaths, for black U.S. females born 1941 to 1950

X Data	Current	Ever	Lung Death
1900	0	0	0
1905	0	0	0
1910	0	0	0
1915	0	0	0
1920	0	0	0
1925	0	0	0
1930	0	0	0
1935	0	0	0
1940	0	0	0
1945	0	0	0
1950	0.1	0.1	0
1955	0.5	0.5	0
1960	9.3	9.3	0
1965	26.6	26.9	0
1970	37.9	41.8	0
1975	41.3	44.4	0
1980	36.9	46.0	0
1985	37.8	49.1	0.6
1987	35.7	49.4	