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Mortality attributable to cigarette smoking in the United States

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Abstract

Cigarette smoking is a particularly pernicious behavior because of its high prevalence and mortality risk. We use the powerful methodology of life tables with covariates and employ the National Health Interview Survey-Multiple Cause of Death file to illuminate the interrelations of smoking with other risk factors, and with the combined influences of smoking prevalence and population size on smoking-attributable mortality. We find that the smoking-mortality gap is only modestly affected by other risk factors and excess deaths due to smoking among U.S. adults in the year 2000 were as great as 340,000. Better knowledge of the prevalence and mortality risk associated with cigarette smoking statuses enhances the future health and longevity prospects of the U.S. population.

Keywords

Cigarette smoking; Mortality risks; Life tables

The Harm of Cigarette Smoking for Mortality

Over 50 years of research and thousands of studies on the relative risks of death for smokers and nonsmokers have demonstrated that cigarette smoking is the single most preventable cause of premature mortality in the United States (U.S. Department of Health and Human Services [DHHS] 2000). Smoking substantially increases the risks of death for causes that include cancer (especially of the lung, larynx, esophagus, pharynx, mouth, bladder, pancreas, kidney, and cervix), cardiovascular disease (hypertension, ischemic heart disease, cerebrovascular disease, and atherosclerosis), and respiratory diseases (pneumonia,

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influenza, bronchitis, emphysema, and chronic airway obstruction) (Centers for Disease Control [CDC] 1989; DHHS 2001). Given the high mortality rates for these smoking-related diseases, the relatively widespread prevalence of cigarette use has much potential to diminish life expectancy.

This potential persists despite a major decline in the level of smoking since 1964 when the Surgeon General's report first highlighted the negative consequences of cigarette use. In 1965, 42% of U.S. adults aged 20 and over smoked, 14% formerly smoked, and 44% never smoked (CDC 2002c). By 2000, the figures had improved to 23% current smokers, 23% former smokers, and 54% never smokers. While encouraging, the trends nonetheless leave a large population vulnerable to the harmful effects of smoking. Moreover, the rate of decline in cigarette use has stalled. The adoption rates by youth increased during the 1990s (Mendez and Courant 1998), and slower rates of decline among females relative to males have narrowed the traditional female advantage in lung cancer mortality and life expectancy (Pampel 2002).

The stubborn resistance of cigarette use to efforts of eradication means that it will remain a major source of premature mortality in years to come. Public warnings about the harm to health of smoking are so well known that the U.S. public actually overestimates the risks (Viscusi 1992); higher cigarette prices due to taxes and lawsuits against tobacco companies create a financial disincentive to smoke; prohibitions against smoking in office buildings, public facilities, and even restaurants and bars force smokers into outside streets, alleyways, and quarantined rooms; and nonsmokers feel free to criticize smokers as a public nuisance and shame them for their inability to stop a destructive habit. Still, about 44 million persons ages 20 and over in the year 2000 were at risk of early death from current cigarette smoking and about another 44 million were at risk from former cigarette smoking (CDC 2002c).

Attempting to present a concrete figure that summarizes the harm of smoking for health, the 1989 Surgeon General's Report (CDC 1989) calculated the number of deaths attributed to cigarette smoking to be about 400,000 a year – a number that has received much publicity. Building on the method used in the report, CDC (2002a) has created a web-page that allows users to calculate the same figure for more recent years (and, if desired, for particular states and demographic subgroups). In 1999, CDC calculations estimated 404,750 deaths due to smoking, or about 16.9% of all U.S. deaths during the year.

Problems in Determining the Implications of Cigarette Smoking for Mortality and Life Expectancy

The 400,000 plus figure, the data on which it is based, and the methods used to calculate it have produced some controversy (Levy and Marimont 1998). Several limitations of the procedures used to determine smoking-attributable deaths have been noted in the literature. First, the calculations are based on relative risks of death for smokers and nonsmokers obtained from a non-random sample of the U.S. population (Sterling, Rosenbaum, and Weinkam 1993). The American Cancer Society's (ACS) prospective Cancer Prevention Study II (Garfinkel 1980) of one million Americans aged 30 and older from 1982 to 1992 provides a sample large enough to reliably estimate the mortality of current, former, and

never smokers by age, sex, and cause of death. But the sample relies on volunteers, who tend on average to have higher education than the population as a whole. With high status healthy nonsmokers overrepresented, the sample tends to overstate the benefits of nonsmoking and exaggerate the risks of smoking. Malarcher et al. (2000) thus find evidence that the smoking-attributed mortality calculated from relative risks rates in the ACS data are 19% higher than those from a representative sample of the U.S. population.

Second, studies typically rely on crude categories of smoking status and age, as well as an incomplete set of causes of death (CDC 2002b). By distinguishing among never, former, and current smokers, but without attending to different numbers of cigarettes smoked by former and current smokers, efforts to identify the harm of smoking miss critical information. Measuring the amount of smoking is crucial because a dose-response relationship exists between smoking and mortality: for both former and current smokers, the risk of death increases as cigarette consumption increases (DHHS 1989). At exceptionally low levels, smoking has modest effects. More seriously, heavy current and former smokers have significantly higher risks than nonsmokers, but also light and moderate current and former smokers (Rogers, Hummer, and Nam 2000).

Other measurement problems appear in the treatment of age and cause of death. Calculations sometimes group persons 35-64 together (CDC 2002a), but smoking prevalence and mortality risks vary substantially between those 35-40 and those 60-64. The calculations also ignore those under age 35, but individuals who begin in early adolescence could smoke for 17 years before turning 30 – time enough to develop smoking-related mortality risks. Similarly, calculations sometimes concentrate on only the four most common smoking-related causes of death (Malarcher et al. 2000), but many persons die from other smoking-related diseases. Studies require both precision when measuring age and breadth when considering causes of death related to smoking.

Third, the calculation of excess or smoking-attributable deaths alone fails to draw out the implications for potential years of life lost and life expectancy (Nam, Hummer, and Rogers 1996). Deaths from smoking have different consequences for life expectancy depending on the age at which they occur. Deaths at the younger ages do more to reduce life expectancy than deaths at older ages. Moreover, smoking prevalence varies with age. To illustrate, Figure 1 presents smoking prevalence by age and sex (see also Appendix Table A) in the United States in 2000. The figure displays a curvilinear pattern with age; there are low rates of ever smokers at young adult ages, higher rates of current smokers at middle ages, and low rates of current female smokers and high rates of former male smokers at older ages. These age-specific smoking patterns translate into varied rates of smoking-related deaths across the life course and have diverse consequences for life expectancy. Fully understanding the mortality consequences of smoking thus requires attending to age patterns of smoking and mortality and their implications for life expectancy rather than the number of deaths alone. But such calculations are not commonly made (see Rogers and Powell-Griner 1991, for an exception).

Fourth, calculations that are based on relative risks of mortality for smokers and nonsmokers rarely adjust for confounding factors. Compared to nonsmokers, smokers are more likely to

be poor, obtain fewer years of schooling, be exposed to workplace carcinogens, experience less social integration, and have other chronic health conditions, thereby reducing their chances for survival (Levy and Marimont 1998; Link and Phelan 1995; Mirowsky 1999). Similarly, smokers tend to engage in a variety of other risky behaviors that increase their chance of death: excessive drinking, reckless driving, physical inactivity, and nonuse of seat belts (Gunnarsson and Judge 1997; Paffenbarger et al. 1993; Schoenborn 1986). Further, individuals who experience high stress levels may be more likely to smoke and die early. Given the overlap in these risks, those who stop smoking may not gain much longevity benefit. Indeed, Peto and colleagues (1994) cut their estimated relative risks of smoking by half to adjust for possible spuriousness. Other efforts to more precisely partial out the influence of confounding factors have produced mixed results: some evidence suggests that the specification bias is substantial (Sterling et al. 1993), but other evidence finds only small differences in the relative risks of smoking with and without controls (La Croix et al. 1991; Thun, Apicella, and Henley 2000; Malarcher et al. 2000). In any case, the potential for bias suggests the need to determine the harm of smoking net of related social and lifestyle factors.

Consider in more detail some of the factors that may bias the effect of smoking on mortality. Measures of socioeconomic status (SES) – such as income, education level, and employment status – are negatively associated with smoking and with mortality risk. Lower SES is not only associated with smoking, but it also increases the risk of death through reduced exercise, increased stress, poorer diets, and less access to health information and medical care (Adler et al. 1994). Education is commonly used as an SES control in smoking research because it is one of the best sociodemographic predictors of cigarette smoking, and because in adulthood it is relatively stable and unlikely to be affected by poor health (Zhu et al. 1996). More highly educated individuals are more likely to invest in their health and to make more informed and therefore better decisions (Sickles and Taubman 1997). For example, compared to individuals aged 25 or over with 16 or more years of education, those with 13 to 15 years of schooling are 2.1 times as likely to smoke, those with 12 years of schooling are 2.8 times as likely to smoke, and those with 9 to 11 years of schooling are 4.2 times as likely to smoke (Zhu et al. 1996). And compared to those with lower educational levels, those with higher levels experience lower mortality (Rogers et al. 2000).

Individuals who consume alcohol are also more likely to smoke. For example, 37% of men and women who consume four or more drinks per day are also current smokers, but just 22% of current smokers consume less than one drink per day (Thun et al. 1997). Compared to abstainers, moderate alcohol consumption confers slight survival advantages, but heavy drinking can lead to heightened risks of death, especially due to cirrhosis of the liver, alcoholism, some cancers, and violent causes of death (Thun et al. 1997). Compared to nondrinkers, moderate alcohol consumption slightly reduces the risk of death among smokers and nonsmokers, but compared to nonsmokers, smoking doubles the risk of death for both drinkers and nondrinkers (Thun et al. 1997). Thus, moderate alcohol consumption can slightly reduce the risk of death, but smoking doubles the mortality risk.

Body mass also associates with smoking and with mortality risk (Garrison et al. 1983). Generally, former smokers have higher body mass than never smokers, who in turn have

higher body mass than current smokers. Smoking reduces body fat by reducing caloric intake, increasing metabolic rate, and increasing the level of energy expended (Himes 2000). Additionally, smokers often have poor diets (Levy and Marimont 1998). Because smoking can reduce body mass, quitting smoking may lead to weight gain and higher mortality risk due to greater body mass. Furthermore, smokers who are underweight may experience increased risk of death because the underweightness indicates an underlying chronic condition, often associated with wasting, such as cancer, emphysema, or other chronic respiratory diseases (Himes 2000).

The association between smoking and mortality may also be due to the beneficial impacts of social ties among nonsmokers. People who do not smoke are more likely to be married. Marital stability over time, in fact, has been linked to higher rates of nonsmoking. In turn, a number of studies have shown that social ties, including marriage, are associated with better health and lower mortality (Rogers 1992; Rogers et al. 2000). Marriage acts to select healthy individuals, to enhance social integration, and to encourage healthful behavior (Lillard and Waite 1995).

Objectives

Given the limitations of previous literature, this study aims to offer alternative estimates of the harm of cigarette smoking on U.S. adult mortality, and translate the estimates into their influence on life expectancy. To build on existing efforts, we (1) use a representative national sample, (2) measure risks of mortality for detailed categories of smoking and age, and consider all causes of mortality rather than specific causes of death, (3) attend to age differences in smoking-related deaths and their consequences for life expectancy, and (4) control for numerous confounding factors. Such enhancements are possible through the application of life tables with covariates, a relatively new and powerful demographic technique. These efforts inform debates and controversies over whether the harm of smoking is overstated by government agencies and common estimation procedures, and in so doing provide a more nuanced picture of the multiple and overlapping factors that influence mortality.

DATA AND METHODS

To examine the relationship between smoking and adult mortality in the United States, we employ the 1990 National Health Interview Survey Health Promotion and Disease Prevention (NHIS-HPDP) supplement. The NHIS includes annual information on a core set of questions that remain virtually unchanged from one year to the next, and records such variables as age, sex, marital status, family size, income, education, and employment status. It also adds supplemental questions that vary from year to year. The NHIS-HPDP includes information on cigarette smoking, along with detailed data on other important health behaviors, for 41,104 sample respondents aged 18 and older (NCHS 1993).

One of the most comprehensive mortality data sources available for the United States comes from matching the NHIS to the Multiple Cause of Death files (NHIS-MCD) via the National Death Index. The record linkage was accomplished through a probabilistic matching scheme

that assigns weights to each of twelve factors: social security number; first and last name; middle initial; race; sex; marital status; day, month, and year of birth; and state of birth and residence (Horn 1993, 1996; NCHS 2000). Eliminating records with missing data on key variables and records ineligible to be linked to death certificates results in 36,592 individual records.¹ Matches to the MCD file through December of 1997 yield 3,097 deaths over the seven-year follow-up period (NCHS 1993, 2000). The important strengths of the data set include its nationally representative character, recent release, large size, breadth and depth of health behavior factors including cigarette smoking, relatively small amount of missing data, and high quality of matches between the NHIS and MCD files (Patterson and Bilgrade 1986).

Variables and Measurement

Cigarette smoking status, our key predictor variable, is coded into never smoker, current smokers who consume less than a package of cigarettes (fewer than 19) per day, current smokers who consume a package to less than two packages of cigarettes (20 to fewer than 40) per day, current smokers who consume two or more packages of cigarettes (40 or more) per day, former smokers who on average consumed less than a package (fewer than 19) a day, former smokers who consumed a package to less than two packages (20 to fewer than 40) per day, and former smokers who consumed two or more packages (40 or more) per day.² Following convention, never smokers are defined as those who have consumed 100 or fewer cigarettes in their lifetimes. This coding scheme is more comprehensive than earlier efforts that estimated smoking-related mortality risks and life expectancies (e.g., Rogers and Powell-Griner 1991; Sterling et al. 1993; Thun et al. 2000).

The demographic control variables include age, sex, race, and marital status. Marital status is coded as currently (referent), previously, and never married. We control for race by comparing blacks to others (referent). We code sex categorically, with females as the referent. We code age in 5-year groups, from 20-24 through 85 and above, with ages 20-24 as the referent. This coding scheme allows us to calculate five-year smoking-specific mortality rates to input into life tables.

Socioeconomic variables include family income, education, and employment status. Educational categories include 11 or fewer years of education, high school completion, and some college or more (referent). Employment status is coded as employed (referent), unemployed, or not in the labor force. Except for family income, there is relatively little missing data for the variables. We imputed income because detailed values are missing for about 17% of the records.³ Further, NHIS income categories are not equal intervals. For values under \$50,000, we take the midpoint of the interval and divide it by 10,000, to

¹About 1.9% of the NHIS-HPDP records, termed "ineligible," contain insufficient information to be matched to death records. NCHS identifies these records so that they may be dropped from the analysis (NCHS 2000). We dropped about 7.9% of the remaining individuals because of missing values for education, marital status, body mass index, smoking status, exercise, stress, physical activity, seat belt use, drinking status, or income.

²Our analysis assumes smoking statuses persist throughout the follow-up period or until death. Although some individuals change their smoking status over time, and thereby modify their risk of death, many individuals experience return transitions, for example, quitting but later resuming smoking (Mamun et al. 2002). Additional data collection efforts and research is warranted to fully capture smoking status transitions and subsequent mortality risk.

approximate a continuous income value. Because the top category of \$50,000 and above is open-ended and lacks a midpoint, we estimate a median value for this category.⁴

We also control for health behaviors and conditions that are associated with cigarette smoking and amenable to change: exercise, body mass, drinking, seat belt use, and stress. The respondent is asked whether he or she is more active than, less active than, or about as active as others of the same age (referent). We operationalize body mass through the body mass index (BMI), which is calculated by dividing weight in kilograms by height in meters squared and is classified according to the World Health Organization (1997) as normal weight (BMI 18.5-24.9; the referent), underweight (BMI <18.5), overweight (BMI 25.0-29.9), or obese class I (BMI 30.0-34.9), II (BMI 35.0-39.9), or III (BMI 40 or greater). Drinking status includes current drinker (referent), former drinker, infrequent drinker, and abstainer. Although studies have demonstrated higher mortality risk among excessive drinkers, small cell sizes precluded detailed examination of drinkers at extremely high levels of alcohol consumption. Seat belt use compares individuals who wear seat belts at least some of the time to those who never wear seat belts when driving (referent). The stress variable captures self-reports of whether respondents experience stress a lot or not a lot (referent).

Discrete Time Hazard Models

We employ discrete-time hazard models to determine the risk of death due to cigarette smoking, net of other covariates. With prospective data that follow the records of individuals who were interviewed in 1990 to find out if they died between the time of the interview and the end of 1997 (the most recent period of follow-up [NCHS, 2000]), we have a dichotomous dependent variable, and cases based on the combination of persons and years survived. Assuming that the deaths are distributed evenly within each year, the pooling of persons and years in the discrete time hazard models means, for example, that individuals who survive a year contribute one person-year of survival, and individuals who die within

³We use Ordinary Least Squares regression to estimate income separately for those with family incomes below \$20,000, and for those with incomes equal to or above that amount – a question in the survey with a much higher response rate. We use age, age-squared, marital status, employment status, education, and race to predict income, and use the coefficients to impute values for those missing family income on the more detailed income variable.

⁴We find that an estimated median value is more accurate than an estimated mean, and use the Pareto Curve to estimate the median. Parker and Fenwick (1983) note that the double log form of the Pareto Curve is linear at the upper tail of the income distribution, so that as the level of income in a category increases, the number of people in that category decreases. This allows them estimate this slope, ν , as:

$$\nu = \frac{\log(n_t + n_{t-1}) - \log(n_t)}{\log(x_t) - \log(x_{t-1})}$$

where n_t is the number of people in the open-ended category, n_{t-1} is the number of people in the income category immediate preceding the open-ended category, x_t is the lower limit of the open-ended category, and x_{t-1} is the lower limit of the penultimate category. They then use this value to estimate a median value (MD) for the category, as specified in Wright (1976:163):

$$MD = 10^{(.301/\nu)(x_t)}$$

Thus, for our analyses, we use the estimated median value of \$68,645 for those individuals with a family income of \$50,000 or more.

the second year contribute one person-year of exposure and one death. Because individuals were interviewed throughout 1990, some were exposed to death for nearly the entire year (from January through December 31), while others were exposed for as little as a few days (for example, if they were interviewed in December); therefore, we counted 1990 as one-half a person-year of exposure. Thus, individuals interviewed in 1990 contributed as many as 7.5 person-years of survival over the full range of the follow-up period.

In the discrete time hazard models, estimates take the form of logistic regression coefficients (Allison 1984; Powers and Xie 2000), but the exponentiated values of the coefficients can be interpreted as odds ratios. To determine which particular sets of variables contribute most to the confounding of the relationship between smoking and mortality risk, we build our models progressively (see Mirowsky 1999). The first model examines the effects of cigarette smoking on mortality, controlling for only basic demographic variables. More complex models sequentially include SES, health behaviors, and health conditions. Progressive adjustment is a valuable way to first show that an association exists, and then to show how holding sets of confounding variables constant will reduce, accentuate, or eliminate the association. All coefficients and standard errors in the models are corrected for stratification and clustering in the sample design with Stata 7.0 software (StataCorp 2001).⁵

Life Tables with Covariates

Whereas conventional life tables mathematically express the expected years of additional life to be lived at specific ages given a set of age-specific mortality rates, life tables with covariates also adjust for factors such as alcohol consumption, exercise, and SES that are needed to identify the independent mortality risks associated with smoking status. With the intercept and coefficients from the discrete-time hazard models, we construct smoking status specific life tables with covariates by converting the coefficients to age-specific central death rates, or m_x values (Moore and Hayward 1990). In conventional life table analysis, the central death rate is calculated by dividing the deaths for individuals at a specific age during the year by the age-specific midyear population. Based on the multivariate model, we calculate m_x values with the following equation:

$$m_x = \frac{1}{1 + e^{-z}}$$

where x is a specific age group, say, ages 20 to 24, and z is the estimated logit coefficient for the age group and a given set of values for the other variables.

Excess Deaths Due to Smoking

To determine how many deaths are attributable to smoking, we calculate the number of excess deaths (ED) on the basis of age-specific population size, age-specific smoking prevalence, and mortality risk. With 2,349,005 deaths among individuals aged 20 and above

⁵The discrete time hazard models using logistic regression produce results quite similar to those obtained from continuous time hazard models. In addition, extending the discrete time hazard model to include dummy variables for each follow-up year does little to change the results. Although the model with the duration effects fit our data slightly better, the estimated effects of the substantive factors on mortality were identical to those in Model 6 in terms of direction, magnitude, and levels of significance.

in the United States in 2000 (Miniño et al. 2002), the excess number of deaths measures how many of these deaths could have been averted if all current and former smokers were to experience the mortality risk associated with never smokers or with less risky smoking statuses. Building on the general formulas for attributable fractions, or the proportion of deaths that were caused by cigarette smoking (see Lilienfeld and Stolley 1994), we calculate age-specific deaths for five-year age groups and smoking-specific deaths for six smoking statuses.

First, we determine how many individuals would be in each smoking status by multiplying the age-specific smoking status prevalence rates (derived from NCHS 2002) by the age-specific population, based on the age-specific distribution of the U.S. adult population in the year 2000 (U.S. Census Bureau 2000). Appendix A lists these numbers. Second, we compute the excess risks of each smoking status relative to never smokers by subtracting the age-specific central death rates for never smokers from the age-specific central death rates for each of the smoking statuses. These death rates come from our analysis of the NHIS-MCD data. Third, we multiply the excess age-specific death rates for each smoking status by the number of persons in each age group and smoking status. This product translates the age-specific excess rates into age-specific excess deaths. Fourth, we sum the excess number of deaths for each age group within each smoking status, and then sum the excess number of deaths for all smoking statuses to obtain a total.

For example, excess deaths (ED) for current heavy smokers (C) compared to never smokers (N) comes from the following formula:

$$ED_c = \sum_{x=20-24}^{85+} [(Prev_{x,c} * Pop_x) * (m_{x,c} - m_{x,n})],$$

where $m_{x,c}$ is the central death rate for heavy smokers at age x , $m_{x,n}$ is the central death rate for never smokers at age x , $Prev_{x,c}$ is the prevalence of current heavy smokers at age x , and Pop_x is the age specific population (for similar calculations, see Doll and Peto 1981a, 1981b). After using the formula to calculate excess deaths for light, moderate, and heavy former and current smokers, the sum gives total excess deaths.⁶ This approach also allows us to estimate the excess deaths that would be saved through other, more logically consistent transitions – for example, if all current smokers became former smokers.

RESULTS

Table 1 presents descriptive statistics for each variable by smoking status. Females are more likely than males to be never smokers, as are blacks than non-blacks, never married individuals than married ones, people not in the labor force than those unemployed, and more highly educated people than less highly educated ones. Similarly nondrinkers are more likely than drinkers to be never smokers, as are regular seat belt users than nonusers, people experiencing less stress than those under stress, and physically active people than inactive

⁶Although it would be possible to calculate potential deaths averted separately for males and females, such calculations would, given the combined models for men and women, rely on covariate values averaged across sex rather than sex-specific average values.

ones. Individuals who engage in unhealthy behaviors or exhibit less healthy characteristics – e.g., those who never wear their seat belts, who are under a lot of stress, and who are less physically active – are more likely to smoke, and among smokers, to be moderate or heavy smokers. For example, 23% of those who never wear their seat belt are current moderate smokers; in contrast just 11% of those who wear their seat belt at least some of the time are moderate smokers. Thus, there are correlations between smoking and other covariates of mortality risk. For the multivariate models that simultaneously control for these risk factors in predicting mortality, we turn to Table 2.

Table 2 reveals the effects of smoking status on mortality risk net of other covariates. We begin with the basic model and then build greater complexity by introducing additional covariates. The basic model, Model 1, examines the effects of smoking and age on mortality risk. Among all smoking statuses, never smokers (the referent) experience the lowest risk of death over the follow-up period, and former smokers experience lower mortality than current smokers. Former and current smokers display a clear mortality gradient associated with cigarette consumption. Indeed, over the follow-up period, compared to never smokers, current light smokers (less than a package of cigarettes per day) experience a 2.4-fold greater mortality risk (or $e^{0.879}$), current moderate smokers (one to less than two packs per day) experience a 2.6-fold greater mortality risk, and current heavy smokers (two or more packs) experience a 3.7-fold greater mortality risk.

Model 2 additionally controls for sex. Because compared to females, males experience higher mortality, are more likely to smoke, and have higher levels of consumption, controlling for sex reduces the mortality differentials by smoking status. In fact, the differential between former light smokers and never smokers is no longer statistically significant. Model 3, which controls for both demographic and socioeconomic factors, further reduces the smoking status differentials – by 10% for current light smokers, by 7% for current moderate smokers, and by 9% for current heavy smokers, compared to Model 2.

Controlling for the beneficial effects of light to moderate drinking in Model 4 actually increases the mortality gap between never smokers and people with other smoking statuses (for similar results, see Thun et al. 2000). There is a J-shaped relation between drinking and mortality: compared to moderate and infrequent drinkers, non-drinkers and former drinkers experience higher mortality risk. Compared to individuals who have never smoked, individuals who have ever smoked are also more likely to drink (see Table 1; see also Thun et al. 1997). Model 5 adjusts for other health behaviors and health conditions. In combination, other health behaviors further attenuate the relation between smoking status and mortality.

Finally, Model 6 adjusts for all covariates simultaneously. Controlling for demographic, socioeconomic, and most health behavioral factors dampens the excess mortality that is attributable to smoking, but controlling for drinking slightly increases the differential.⁷ All told, the most inclusive model reveals that current smokers exhibit over twice the risk of

⁷We tested but did not uncover interactions between smoking and sex, income, education, employment status, and seatbelt use. Because we employ age as a control to include in life table analysis, we did not examine the potential for interactions between age and smoking.

mortality in the seven-year follow-up period compared to never smokers, with the greatest risk for current heavy smokers. In addition, former moderate and former heavy smokers also each continue to show considerably higher mortality risk in the most complete model, albeit not as high as any of the current smoking categories. Among the current smoking statuses, controlling for covariates has a greater impact among heavier smoking consumption levels. For example, between Models 1 and 6, the odds ratios of current light smokers declines by 13%, the odds ratios for current moderate smokers declines by 17%, and the odds ratios for current heavy smokers declines by 29%. Thus, while controlling for confounders is clearly important and has a greater impact among individuals with higher levels of cigarette consumption, the smoking-mortality relationship remains extremely strong and graded.

Although the relations in Table 2 impart important information, they cannot be interpreted as intuitively as life expectancies. Fortunately, we can convert the regression coefficients into central death rates and, ultimately, into life expectancy estimates. Table 3 displays unisex life expectancies at age 20 by smoking status, controlling for various risk factors. For the first column, “Average,” we calculate smoking-specific life expectancies by providing sample averages for the other covariates, including sex, race, marital status, and the socioeconomic and behavioral factors. (Appendix Table B provides abridged unisex smoking status life tables for the Average column in Table 3.⁸)

In the Average case, compared to never smokers at age 20, current light smokers can expect to live 11.4 fewer years, current moderate smokers can expect to live 11.7 fewer years, and current heavy smokers can expect to live 14.5 fewer years. There is also a graded relationship between never and former smokers depending on quantities smoked. Compared to never smokers at age 20, former light smokers can expect to live 2.4 fewer years, former moderate smokers can expect 6.9 fewer years, and former heavy smokers can expect 8.1 fewer years of life.⁹

The best-case scenario, in the second column, assumes that all individuals are married, have high SES, and engage in healthy behaviors. This is not a realistic scenario; few people fit it with perfect consistency throughout their lives, and at older ages, individuals are likely to become widowed, retire, earn less income, and become less active. Nevertheless, the best case is instructive: compared to current heavy smokers, never smokers can expect to live 21.3 additional years, showing the powerful influence of heavy smoking within a population that has statistically been freed of other risk factors.

⁸For example, the m_x value for never smokers aged 20-24 is calculated by $m_{20-24} = 1 / (1 + e^{-z})$. To calculate z for never smokers for this age group, we multiply the proportions of individuals in each category of sex, race, marital status, employment status, education, drinking status, seatbelt use, stress, physical activity, and body mass index, as well as the mean income, by the coefficient for each category, using the proportions in Appendix Table C and the coefficients from Table 2, Model 6. We add this value to the intercept and to the value of the age coefficient for the group of interest and the smoking status of interest, which is 0.0 for never smokers aged 20 to 24 as they are the referent categories, for a value of -7.4644. Thus, calculating the m_x for never smokers aged 20

to 24 as follows: $m_{20-24} = \frac{1}{1 + e^{-(-7.4644)}} = 0.000573$, produces the first entry in Appendix Table B.

⁹Recall, though, that the difference between former light smokers and never smokers was not statistically significant in the most complete regression model. Thus, the 2.4 year difference in life expectancy between these two groups may reflect randomness and should be cautiously interpreted.

Although both dimensions are clearly important, individuals can expect to live longer with good health but low SES than with the reverse. An Average never smoker can expect to live longer than any current or former smoker who has either poor health or low SES. Indeed, only former smokers in the best-case scenario – who have high SES and good health, an unlikely set of circumstances – have higher life expectancies than Average never smokers. When looking at the “worst case” scenario, never smokers at age 20 still exhibit 9 to 11 years higher life expectancy than current smokers, even with the strong risk factors specified here. Thus, within an extremely high risk mortality group, smoking remains a very important predictor of premature adult mortality.

Figure 2 presents survival curves by smoking status based on the Average Model. The y-axis sets all smoking status groups to 100,000 persons at age 20 and follows their survival through old age, based on the smoking status mortality rates calculated within 5-year age groups. Never smokers have the highest survival. For instance, over one-half of all never smokers at age 20 can expect to live past age 85. Survival curves in this figure are quite similar for current light and current moderate smokers. Survival declines among current and former smokers and with increasing cigarette consumption. Indeed, only one quarter of current heavy smokers can expect to live to age 85. The survival curves begin with the same number of never smokers and current heavy smokers. But one-third more never smokers survive to age 70, 51% more never smokers survive to age 80, and 2.4 times as many never smokers survive to age 85. Thus, the smaller numbers of heavy smokers, coupled with the low survival of heavy smokers, translates into very few heavy smokers at the oldest ages.

From the unisex age-specific mortality rates, smoking status prevalence rates, and U.S. population distributions, we can determine the number of smoking-attributable deaths for different scenarios (see Table 4). For example, if current *and* former smokers had the same mortality rates as never smokers, we would expect to see 343,414 fewer deaths in the U.S. in 2000. This is the upper bound of our estimates – the largest number of deaths that can be attributed to smoking within that particular year. But current smokers cannot become never smokers; the best mortality rates they can achieve are those for former smokers. If all current light, moderate, and heavy smokers quit and they were assigned their appropriate former smoker categories, 129,457 deaths would be averted. Or if each current smoker moved down one smoking status – e.g., if heavy smokers became moderate smokers, moderate smokers became light smokers, and current light smokers became former light smokers – 77,197 deaths would be averted. Because of the large number of current light smokers, much of this change – 66,046 deaths – would be owing to their quitting alone. Even if the only change were for all moderate and heavy smokers to cut back to light smoking, 11,747 deaths would be averted in a single year.

The estimated number of deaths averted varies by age. Figure 3 shows the number of deaths that would be averted by age group if everyone could assume the mortality risks of never smokers. Three-quarters of these averted deaths fall between ages 40 and 79; only 6% fall between 20 and 39. As age increases, the number of deaths averted increases disproportionately with increasing cigarette consumption, first among current smokers, and later among former smokers. For instance, at ages 20-24, over 50% of all deaths averted would be among current light smokers. At ages 30-54, almost 40% of all deaths averted

would be among current moderate smokers. Among individuals aged 40-49, 16% of all deaths averted would be among current heavy smokers. At ages 60 and above, nearly 30% of all deaths averted would be among former moderate smokers. And at ages 75 and above, almost 60% of all deaths averted would be among former moderate and heavy smokers.

CONCLUSION

Using data from a nationally representative sample, detailed measures of smoking status and age, and mortality information from all causes of death, we have estimated how much the smoking gap in mortality stems from confounding. Because cigarette smoking is associated with other risky behaviors and conditions – including heavy drinking, lack of exercise, and lower SES – we cannot summarily attribute all of smokers' excess mortality directly to smoking. However, we find that the influence of other factors on the smoking/mortality relationship is modest (see also CDC 2002a; Thun et al. 2000), and differentially affects individuals at the higher levels of cigarette consumption. Controls for confounding factors reduce the odds ratios between never and current light smokers by 13%, between never and current moderate smokers by 17%, and between never and current heavy smokers by 29%. Thus, whereas adjusting for confounders is clearly important, particularly among individuals with higher levels of cigarette consumption, the net smoking-mortality relationship remains extremely strong and graded. Indeed, in our most complete multivariate models, compared to never smokers, current smokers exhibit up to 2.7 times the risk of mortality, whereas former smokers who used to smoke at least one package of cigarettes per day exhibit 1.5 times the risk of death over the follow-up period.

Based on the multivariate models, we also show how age-specific smoking status differences in mortality risks translate into life expectancies. The life table figures have the benefits of adjusting for confounding factors, converting coefficients into meaningful and easy to interpret statistics, summarizing large amounts of information, depicting results visually in the form of survival curves, and presenting various life expectancy scenarios. Indeed, we were able to present life expectancy estimates for the “average” person as well as for individuals in good or poor health, and high or low SES. We found that smoking status “trumps” other factors for high life expectancies: an average never smoker can expect to live longer than even the “best case scenario” for current smokers, that is, individuals with high SES and with good health behaviors.

Our estimate of smoking-attributable adult mortality – 343,414 deaths in the U.S. in the year 2000 – is 15% smaller than the estimate of 405,000 provided by CDC (2002a). It also differs from the estimates of Peto et al. (1994) and Thun et al. (2000), which closely match those of the CDC. Our lower figure results from differences in methodologies, time periods, subpopulations, and assumptions. In contrast to previous studies, we categorize smokers into seven smoking status groups rather than three, base the excess deaths on the year 2000 population rather than on earlier years, and estimate the risk of death due to smoking with controls for confounding factors, including SES and health behaviors.

The upper-bound estimate of excess deaths due to smoking assumes that all smoking statuses could experience the low mortality risk of never smokers. Although this provides a

sense of the numbers of deaths that are lost to smoking, not all such deaths could reasonably be averted through smoking reductions. For example, if all current smokers quit and assumed the mortality of former smokers rather than never smokers, we could avert 129,457 deaths in a year. Or, if current light smokers became former light smokers – a reasonable assumption and goal – we could avert 66,046 deaths in a year.

Of course, a lag exists between smoking behavior and mortality from lung and other cancers, chronic obstructive pulmonary disease, and coronary heart disease. The benefits of reduced smoking for mortality may conversely take some time to emerge: once a person stops smoking, the body may take several months or even as many as 15 years to fully recover (DHHS 1990). Indeed, some current and former smokers will die from smoking-related chronic illnesses that they have already contracted (Nam et al. 1994). Still, the estimates illustrate the potential to avert deaths and extend life expectancy through reduced smoking.

Deaths averted vary not only by smoking status, but also by age: at older ages, the number of deaths averted increases disproportionately with increasing cigarette consumption, first among current smokers, and later among former smokers. But the added years of life would be small given the risks older persons face from nonsmoking diseases. A larger proportion of deaths are averted among middle aged adults. Unlike many health conditions – such as some cancers, functional limitations, and Alzheimer's disease – which have high prevalence rates and high associated mortality at the older ages – cigarette smoking has its highest prevalence and – because the addiction tends to be cumulative – its highest intensity in the middle years. At younger ages, a substantial majority of all deaths averted would be among current light smokers. Relatively fewer deaths would be averted at the youngest ages both because of the lag effect and because relatively few young people smoke heavily, but the consequences for life expectancy would be large. This fact emphasizes the importance of preventing the adoption of cigarettes at young ages.

Overall, we have revealed the factors that contribute to smoking-related mortality in the United States. Better knowledge of the prevalence and mortality risk from cigarette smoking can illuminate the current relations and future health and longevity prospects of the entire population.

Appendix

Table A

Numbers of Adults by Smoking Status, by 5-Year Age Groups, U.S., 2000.

Age Group	Never Smoked	Former Smoker	Current Smoker
Male			
20-24	5,446,442	775,845	2,868,917
25-29	5,090,359	961,233	2,542,370
30-34	5,504,563	1,257,522	2,668,305
35-39	6,085,336	1,560,359	2,972,469
40-44	5,515,371	2,020,089	3,548,516

Age Group	Never Smoked	Former Smoker	Current Smoker
45-49	4,252,691	2,570,867	2,770,872
50-54	3,275,480	2,572,810	2,305,834
55-59	2,098,995	2,577,261	1,445,863
60-64	1,522,088	2,452,819	999,632
65-69	1,353,131	1,988,245	633,335
70-74	1,249,426	2,339,315	424,359
75-79	1,033,982	1,804,087	199,838
80-84	702,329	1,057,225	72,425
85+	333,216	511,278	33,167
Total	43,463,409	24,448,955	23,485,902

Female			
20-24	6,068,339	870,170	2,302,382
25-29	6,166,232	918,657	1,980,658
30-34	6,432,296	1,141,185	2,236,505
35-39	6,763,162	1,562,154	3,027,185
40-44	6,002,186	2,272,723	2,818,381
45-49	5,661,436	2,144,431	2,281,746
50-54	4,599,306	2,177,713	1,822,612
55-59	3,388,559	1,927,704	1,400,915
60-64	2,858,578	1,551,803	1,102,563
65-69	2,912,347	1,504,108	588,103
70-74	2,812,481	1,285,772	557,821
75-79	2,692,432	1,151,274	348,128
80-84	2,047,607	599,362	127,239
85+	1,525,201	383,223	69,275
Total	59,930,162	19,490,279	20,663,513

Source: Derived from NCHS 2002.

Table B

Unisex Abridged Life Table, by Smoking Status, for the "Average" U.S. Adult, or Those with Average Values on Socioeconomic and Health Status, 1990-1997.

Age group	m_x	q_x	l_x	d_x	L_x	T_x	x
A. Never Smokers							
20-24	0.000573	0.00286	100000	286	499285	6783743	67.8
25-29	0.000558	0.00279	99714	278	497875	6284458	63.0
30-34	0.000695	0.00347	99436	345	496318	5786583	58.2
35-39	0.000955	0.00476	99091	472	494275	5290264	53.4
40-44	0.001679	0.00836	98619	825	491033	4795989	48.6
45-49	0.002011	0.01000	97794	978	486526	4304956	44.0
50-54	0.003416	0.01694	96816	1640	479981	3818431	39.4
55-59	0.005256	0.02594	95176	2469	469710	3338450	35.1

Age group	m_x	q_x	l_x	d_x	L_x	T_x	x
60-64	0.008605	0.04212	92708	3905	453777	2868740	30.9
65-69	0.010990	0.05348	88803	4749	432143	2414963	27.2
70-74	0.016302	0.07832	84054	6583	403812	1982821	23.6
75-79	0.024249	0.11432	77471	8856	365215	1579008	20.4
80-84	0.034921	0.16059	68615	11019	315528	1213794	17.7
85+	0.064119	1.00000	57596	57596	898266	898266	15.6
B. Current Smokers Who Smoke Two or More Packs Per Day							
20-24	0.00152	0.00756	100000	756	498110	5331611	53.3
25-29	0.00148	0.00737	99244	731	494393	4833501	48.7
30-34	0.00184	0.00916	98513	903	490309	4339107	44.0
35-39	0.00253	0.01257	97610	1226	484986	3848798	39.4
40-44	0.00444	0.02196	96384	2117	476628	3363812	34.9
45-49	0.00531	0.02622	94267	2472	465156	2887184	30.6
50-54	0.00901	0.04404	91795	4043	448869	2422028	26.4
55-59	0.01382	0.06677	87752	5859	424113	1973159	22.5
60-64	0.02250	0.10649	81893	8721	387662	1549047	18.9
65-69	0.02862	0.13355	73172	9772	341430	1161385	15.9
70-74	0.04209	0.19042	63400	12073	286817	819955	12.9
75-79	0.06182	0.26773	51327	13742	222280	533138	10.4
80-84	0.08755	0.35913	37585	13498	154180	310857	8.3
85+	0.15374	1.00000	24087	24087	156677	156677	6.5
C. Current Smokers Who Smoke One to Two Packs Per Day							
20-24	0.00122	0.00609	100000	609	498477	5613633	56.1
25-29	0.00119	0.00594	99391	590	495478	5115156	51.5
30-34	0.00148	0.00739	98801	730	492178	4619678	46.8
35-39	0.00204	0.01014	98071	994	487868	4127500	42.1
40-44	0.00358	0.01774	97077	1722	481078	3639632	37.5
45-49	0.00428	0.02119	95355	2021	471720	3158555	33.1
50-54	0.00727	0.03568	93334	3330	458342	2686834	28.8
55-59	0.01116	0.05427	90003	4884	437806	2228492	24.8
60-64	0.01820	0.08702	85119	7407	407078	1790686	21.0
65-69	0.02318	0.10954	77712	8513	367278	1383609	17.8
70-74	0.03418	0.15743	69199	10894	318761	1016330	14.7
75-79	0.05039	0.22377	58305	13047	258907	697570	12.0
80-84	0.07172	0.30409	45258	13763	191883	438662	9.7
85+	0.12763	1.00000	31495	31495	246779	246779	7.8
D. Current Smokers Who Smoke Less Than One Pack Per Day							
20-24	0.00120	0.00599	100000	599	498503	5636800	56.4
25-29	0.00117	0.00584	99401	580	495555	5138297	51.7
30-34	0.00146	0.00726	98821	718	492311	4642741	47.0

Age group	m_x	q_x	l_x	d_x	L_x	T_x	x
35-39	0.00200	0.00996	98103	977	488073	4150430	42.3
40-44	0.00352	0.01744	97126	1694	481396	3662357	37.7
45-49	0.00421	0.02083	95432	1988	472191	3180961	33.3
50-54	0.00714	0.03508	93444	3278	459024	2708770	29.0
55-59	0.01097	0.05337	90166	4812	438798	2249746	25.0
60-64	0.01789	0.08561	85354	7307	408499	1810948	21.2
65-69	0.02279	0.10780	78046	8413	369197	1402449	18.0
70-74	0.03361	0.15502	69633	10795	321177	1033252	14.8
75-79	0.04957	0.22052	58838	12975	261753	712075	12.1
80-84	0.07058	0.29997	45863	13757	194922	450322	9.8
85+	0.12571	1.00000	32106	32106	255400	255400	8.0
E. Former Smokers Who Smoked Two or More Packs Per Day							
20-24	0.00095	0.00472	100000	472	498821	5969816	59.7
25-29	0.00092	0.00459	99528	457	496499	5470995	55.0
30-34	0.00115	0.00572	99071	567	493940	4974496	50.2
35-39	0.00158	0.00785	98505	773	490590	4480556	45.5
40-44	0.00277	0.01375	97731	1344	485297	3989966	40.8
45-49	0.00332	0.01644	96387	1585	477975	3504669	36.4
50-54	0.00563	0.02774	94803	2630	467438	3026694	31.9
55-59	0.00865	0.04232	92173	3901	451111	2559255	27.8
60-64	0.01413	0.06822	88272	6022	426305	2108144	23.9
65-69	0.01801	0.08619	82250	7089	393528	1681839	20.4
70-74	0.02663	0.12483	75161	9383	352349	1288311	17.1
75-79	0.03941	0.17938	65778	11799	299395	935962	14.2
80-84	0.05637	0.24703	53979	13334	236561	636567	11.8
85+	0.10161	1.00000	40645	40645	400006	400006	9.8
F. Former Smokers Who Smoked One to Two Packs Per Day							
20-24	0.00087	0.00435	100000	435	498913	6088871	60.9
25-29	0.00085	0.00424	99565	422	496771	5589958	56.1
30-34	0.00106	0.00527	99143	523	494409	5093187	51.4
35-39	0.00145	0.00724	98620	714	491316	4598778	46.6
40-44	0.00255	0.01269	97906	1242	486425	4107462	42.0
45-49	0.00306	0.01517	96664	1467	479653	3621037	37.5
50-54	0.00519	0.02562	95197	2439	469889	3141384	33.0
55-59	0.00798	0.03911	92758	3628	454723	2671494	28.8
60-64	0.01304	0.06313	89131	5627	431586	2216771	24.9
65-69	0.01663	0.07984	83504	6667	400850	1785186	21.4
70-74	0.02460	0.11589	76836	8905	361920	1384336	18.0
75-79	0.03645	0.16702	67932	11346	311293	1022415	15.1
80-84	0.05220	0.23088	56586	13064	250267	711122	12.6
85+	0.09444	1.00000	43521	43521	460855	460855	10.6

Age group	m_x	q_x	l_x	d_x	L_x	T_x	x
G. Former Smokers Who Smoked Less Than One Pack Per Day							
20-24	0.00066	0.00328	100000	328	499180	6540019	65.4
25-29	0.00064	0.00319	99672	318	497565	6040839	60.6
30-34	0.00080	0.00398	99354	395	495781	5543274	55.8
35-39	0.00110	0.00546	98959	540	493442	5047493	51.0
40-44	0.00193	0.00958	98418	943	489734	4554051	46.3
45-49	0.00231	0.01146	97475	1117	484584	4064317	41.7
50-54	0.00392	0.01939	96358	1868	477122	3579733	37.2
55-59	0.00602	0.02966	94490	2803	465445	3102611	32.8
60-64	0.00985	0.04808	91688	4409	447416	2637165	28.8
65-69	0.01258	0.06099	87279	5323	423087	2189749	25.1
70-74	0.01865	0.08908	81956	7301	391527	1766662	21.6
75-79	0.02771	0.12956	74655	9672	349094	1375135	18.4
80-84	0.03984	0.18115	64983	11771	295485	1026040	15.8
85+	0.07284	1.00000	53211	53211	730555	730555	13.7

Source: Based on coefficients in Table 2, Model 6, and proportions from Appendix Table C

Table C

Proportions of Individuals in Categories of the Covariates, U.S. Adults, 1990-1997

Covariate	Proportion
Smoking Status	
Current 2+	0.026
Current 1-<2	0.120
Current < 1	0.113
Former 2+	0.046
Former 1-<2	0.092
Former <1	0.097
Never	0.506
Sex	
Female	0.526
Male	0.474
Race	
Non-black	0.891
Black	0.109
Marital Status	
Currently married	0.655
Previously married	0.163
Never married	0.183
Family Income*	3.490
Employment Status	
Employed	0.668

Covariate	Proportion
Unemployed	0.031
Not in the labor force	0.301
Education	
11 years or less	0.201
High school degree	0.387
Any college	0.412
Drinking Status	
Abstain from drinking	0.164
Infrequent drinker	0.127
Former drinker	0.093
Current drinker	0.615
Seatbelt Use	
Never	0.088
At least some of the time	0.912
Stress	
A lot	0.281
Not a lot	0.719
Physical Activity	
More active	0.327
About as active	0.473
Less active	0.200
Body Mass Index	
Obese class III	0.010
Obese class II	0.024
Obese class I	0.095
Over weight	0.321
Normal weight	0.517
Under weight	0.032

Source: NCHS 1990, 2000

* Note: family income represents mean value

References

- Adler, Nancy E.; Boyce, Thomas; Chesney, Margaret A.; Cohen, Sheldon; Folman, Susan; Kahn, Robert; Syme, S Leonard. Socioeconomic status and health: The challenge of the gradient. *American Psychologist*. 1994; 49:15–24. [PubMed: 8122813]
- Allison, Paul D. *Event history analysis*. Beverly Hills: Sage Publications; 1984.
- Centers for Disease Control (CDC). Adult SAMMEC: Smoking-attributable mortality, morbidity, and economic costs. 2002a. Available at <http://www.cdc.gov/tobacco/sammec>
- Centers for Disease Control (CDC). Annual smoking-attributable mortality, years of potential life lost, and economic costs – United States, 1995-1999. *Morbidity and Mortality Weekly Report*. 2002b; 1:300–303.
- Centers for Disease Control (CDC). Number (in millions) of adults 18 years and older who were current, former, or never smokers, overall and by sex, race, Hispanic origin, age, and education,

National Health Interview Surveys, selected years – United States, 1965-1995. 2002c.
www.cdc.gov/tobacco/research_data/adults_prev/tab_3.htm

- Doll, Richard; Peto, Richard. The causes of cancer: Quantitative estimates of avoidable risks of cancer in the United States today. *Journal of the National Cancer Institute*. 1981a; 66:1191–1308. [PubMed: 7017215]
- Doll, Richard; Peto, Richard. The causes of cancer. Oxford, England: Oxford University Press; 1981b.
- Garfinkel, Lawrence. Cancer mortality among non-smokers: Prospective study by the American Cancer Society. *National Cancer Institute Monograph*. 1980; 65:1169–1173.
- Garrison, Robert J.; Feibleib, M.; Castelli, William P.; McNamara, PM. Cigarette smoking as a confounder of the relationship between relative weight and long term mortality: The Framingham Heart Study. *Journal of the American Medical Association*. 1983; 249:2199–2223. [PubMed: 6834617]
- Gunnarsson, Olfur T.; Judge, James O. Exercise at midlife: How and why to prescribe it for sedentary patients. *Geriatrics*. 1997; 52:71–80. [PubMed: 9152219]
- Himes, Christine L. Obesity, disease, and functional limitation in later life. *Demography*. 2000; 37:73–82. [PubMed: 10748990]
- Horm, John. The National Health Interview Survey and the National Death Index. presented to the National Center for Health Statistics; May 19; Hyattsville, MD. 1993.
- Horm, John. Linkage of the National Health Interview Survey with the National Death Index: Methodologic and analytic issues. presented at the Population Association of America Meetings; New Orleans. 1996.
- LaCroix, Andrea Z.; Lang, Janet; Scherr, Paul; Wallace, Robert B.; Cornoni-Huntley, Joan; Berkman, Lisa; Curb, David; Evans, Denis; Hennekens, Charles H. Smoking and mortality among older men and women in three communities. *New England Journal of Medicine*. 1991; 324(23):1619–1625. [PubMed: 2030718]
- Levy, Robert A.; Marimont, Rosalind B. Lies, damned lies, & 400,000 smoking-related deaths. *Regulation*. 1998; 21(4):24–29.
- Lilienfeld, David E.; Stolley, Paul D. *Foundations of Epidemiology*. Third Edition. NY: Oxford University Press; 1994.
- Lillard, Lee A.; Waite, Linda. Til death do us part: Marital disruption and mortality. *American Journal of Sociology*. 1995; 100:1131–1156.
- Link, Bruce G.; Phelan, Jo C. Social conditions as fundamental causes of disease. *Journal of Health and Social Behavior*. 1995:80–94. Extra Issue. [PubMed: 7560851]
- Malarcher, Ann M.; Schulman, Jane; Epstein, Leonardo A.; Thun, Michael J.; Mowery, Paul; Pierce, Ben; Escobedo, Luis; Giovino, Gary A. Methodological issues in estimating smoking-attributable mortality in the United States. *American Journal of Epidemiology*. 2000; 152(6):573–584. [PubMed: 10997548]
- Mamun, Abdullah Al; Willekens, Frans; Peeters, Anna; Bonnuex, Luc. Multistate smoking status life tables. presented at the Population Association of America Meetings; Atlanta, Georgia. 2002.
- Mendez, David; Warner, Kenneth E.; Courant, PN. Has smoking cessation ceased? Expected trends in the prevalence of smoking in the United States. *American Journal of Epidemiology*. 1998; 148:249–258. [PubMed: 9690361]
- Miniño, Arian M.; Arias, Elizabeth; Kochanek, Kenneth D.; Murphy, Sherry L.; Smith, Betty L. Deaths: Final data for 2000. *National Vital Statistics Reports*. 2002; 50(15):1–120. [PubMed: 12382630]
- Mirowsky, John. Analyzing associations between mental health and social circumstances. In: Aneshensel, Carol S.; Phelan, Jo C., editors. *Handbook of the sociology of mental health*. NY: Kluwer Academic/Plenum Publishers; 1999. p. 105-123.
- Moore, David E.; Hayward, Mark D. Occupational careers and mortality of elderly men. *Demography*. 1990; 27(1):31–53. [PubMed: 2303140]
- Nam, Charles B.; Hummer, Robert A.; Rogers, Richard G. Underlying and multiple causes of death related to smoking. *Population Research and Policy Review*. 1994; 13:305–25.

- Nam, Charles B.; Rogers, Richard G.; Hummer, Robert A. Impact of future cigarette smoking scenarios on mortality of the adult population in the United States: 2000-2050. *Social Biology*. 1996; 43:155-168. [PubMed: 9204694]
- National Center for Health Statistics (NCHS). National Health Interview Survey, 1990: Health Promotion and Disease Prevention (HPDP) Sample Person Supplement. [Computer file]. 1993. Hyattsville, Md: U.S. Dept of Health and Human Services, National Center for Health Statistics [producer]; 1990. Ann Arbor, MI: Interuniversity Consortium for Political and Social Research [distributor]; 1993.
- National Center for Health Statistics (NCHS). Diskette and documentation. National Center for Health Statistics; Hyattsville, MD: 2000. National Health Interview Survey: Multiple Cause of Death Public Use Data File: 1986-1997 Survey Years.
- National Center for Health Statistics (NCHS). Diskette and documentation. National Center for Health Statistics; Hyattsville, MD: 2002. 2002 National Health Interview Survey.
- Paffenbarger, Ralph S.; Hyde, Robert T.; Wing, Alvin L.; Lee, I-Min; Jung, Dexter L.; Kampert, James B. The association of changes in physical activity level and other lifestyle characteristics with mortality among men. *The New England Journal of Medicine*. 1993; 328:538-545. [PubMed: 8426621]
- Pampel, Fred C. Cigarette use and the narrowing sex differential in mortality. *Population and Development Review*. 2002; 28:77-104.
- Parker, Robert Nash; Fenwick, Rudy. The Pareto curve and its utility for open-ended income distributions in survey research. *Social Forces*. 1983; 61(3):873-85.
- Patterson, Blossom H.; Bilgrade, Robert. Use of the National Death Index in cancer studies. *Journal of the National Cancer Institute*. 1986; 77:877-881. [PubMed: 3463819]
- Peto, Richard; Lopez, Alan D.; Boreham, Jullian; Thun, Michael; Heath, Clark, Jr. Mortality from smoking in developed countries 1950-2000: Indirect estimates from National Vital Statistics. Oxford: Oxford University Press; 1994.
- Powers, Dan A.; Xie, Yu. Statistical methods for categorical data analysis. San Diego, CA: Academic Press; 2000.
- Rogers, Richard G. Living and dying in the USA: Sociodemographic determinants of death among blacks and whites. *Demography*. 1992; 29:287-303. [PubMed: 1607053]
- Rogers, Richard G.; Hummer, Robert A.; Nam, Charles B. Living and dying in the USA: Behavioral, health, and social differentials of adult mortality. New York: Academic Press; 2000.
- Rogers, Richard G.; Powell-Griner, Eve. Life expectancies of cigarette smokers and non-smokers in the United States. *Social Science and Medicine*. 1991; 32:1151-9. [PubMed: 2068598]
- Schoenborn, Charlotte A. Health habits of U.S. adults, 1985: The 'Alameda 7' revisited. *Public Health Reports*. 1986; 101(6):571-580. [PubMed: 3097736]
- Sickles, Robin C.; Taubman, Paul. Mortality and morbidity among adults and the elderly. In: Rosenzweig, Mark R.; Stark, Oded, editors. *Handbook of population and family economics: Volume 1A*. Amsterdam: Elsevier; 1997. p. 559-643.
- StataCorp. Stata statistical software: Release 7.0. Stata Corporation; College Station, TX: 2001.
- Sterling, Theodor D.; Rosenbaum, Wilf L.; Weinkam, James J. Risk attribution and tobacco-related deaths. *American Journal of Epidemiology*. 1993; 138:128-39. [PubMed: 8342531]
- Thun, Michael J.; Apicella, Louis F.; Henley, S Jane. Smoking vs. other risk factors as the cause of smoking-attributable deaths. *Journal of the American Medical Association*. 2000; 284(6):706-712. [PubMed: 10927778]
- Thun, Michael J.; Peto, Richard; Lopez, Alan D.; Monaco, Jane H.; Henley, Jane; Heath, Clark W., Jr; Doll, Richard. Alcohol consumption and mortality among middle-aged and elderly U.S. adults. *New England Journal of Medicine*. 1997; 337(24):1705-1714. [PubMed: 9392695]
- U.S. Census Bureau. Statistical abstract of the United States: 2000. 120. Washington, DC: USGPO; 2000.
- U.S. Department of Health and Human Services (DHHS). Reducing the health consequences of smoking: 25 years of progress A report of the Surgeon General. Atlanta, GA: HHS, Public Health Service (PHS), Centers for Disease Control (CDC), National Center for Chronic Disease

Prevention and Health Promotion (NCCDPHP), Office on Smoking and Health (OSH); 1989. HHS Pub. No (CDC) 89-8411

U.S. Department of Health and Human Services (DHHS). The health benefits of smoking cessation A report of the Surgeon General. Atlanta, GA: HHS, Public Health Service (PHS), Centers for Disease Control (CDC), National Center for Chronic Disease Prevention and Health Promotion (NCCDPHP), Office on Smoking and Health (OSH); 1990. HHS Pub. No (CDC) 90-8416

U.S. Department of Health and Human Services (DHHS). Healthy people 2010: Understanding and improving health. 2. Washington, DC: USGPO; 2000.

U.S. Department of Health and Human Services (DHHS). Women and smoking: A report of the Surgeon General. Rockville, MD: U.S. Department of Health and Human Services, Public Health Service, Office of the Surgeon General, Washington DC; 2001.

Viscusi, W Kip. Smoking: Making the risky decision. New York: Oxford University Press; 1992.

World Health Organization. Obesity: Preventing and managing the global epidemic. Geneva: World Health Organization; 1997.

Wright, Erik Olin. Unpublished Ph D dissertation. University of California; Berkeley: 1976. Class structure and income inequality.

Zhu, Bao-Ping; Giovino, Gary A.; Mowery, Paul D.; Eriksen, Michael P. The relationship between cigarette smoking and education revisited: Implications for categorizing persons' educational status. American Journal of Public Health. 1996; 86(11):1582–1589. [PubMed: 8916524]

Figure 1.
Population Pyramid of Smoking Status, U.S. Adults, 2000

Figure 2.
Survival Curves by Smoking Status, U.S. Adults Aged 20 and Over, 1990-1997

Figure 3.
Estimated Smoking Attributable Deaths by Age, U.S. Adults, 2000

Table 1

Percentage Distribution of Demographic, Social, and Behavioral Characteristics by Smoking Status, U.S. Adults, 1990.

	Smoking Status					
	Current			Former		
	2+ packs	1-2 packs	<1 pack	2+ packs	1-2 packs	<1 pack
Age *	47.1	44.9	41.8	57.5	54.2	50.2
Sex						
Female	1.5	10.2	11.6	2.3	6.5	9.8
Male	3.8	14.0	10.9	7.2	12.2	9.6
Race						
Non-black	2.8	12.6	10.4	5.0	9.7	9.7
Black	0.8	7.7	18.2	1.4	5.2	9.2
Marital Status						
Currently married	2.7	12.2	10.1	5.5	11.0	10.8
Previously married	3.6	14.7	13.0	4.5	8.4	8.5
Never married	1.2	9.2	14.1	1.4	3.5	6.7
Family Income *	33,812	32,019	30,506	38,019	37,671	37,711
Employment Status						
Employed	2.7	12.9	11.6	4.1	8.8	9.5
Unemployed	4.8	16.6	17.5	3.2	5.9	7.0
Not in the labor force	2.2	9.7	9.8	5.8	10.5	10.3
Education						
11 years or less	3.5	15.9	13.8	5.0	9.2	8.6
High school degree	3.1	14.3	12.7	4.8	9.2	8.9
Any college	1.7	8.0	8.7	4.3	9.2	11.0
Drinking Status						
Abstain from drinking	0.7	4.1	5.1	1.1	2.9	3.4
Infrequent drinker	1.6	8.8	9.5	2.5	6.4	8.3
Former drinker	3.7	12.4	8.6	9.6	17.8	13.0
Current drinker	3.1	14.8	13.7	5.2	10.2	11.1
Seatbelt Use						

	Smoking Status							
	Current				Former			
	2+ packs	1-2 packs	<1 pack	2+ packs	1-2 packs	<1 pack	Never	
Never	7.0	22.8	12.5	6.3	8.3	6.5	36.5	
At least some of the time	2.2	11.0	11.2	4.4	9.3	10.0	52.0	
Stress								
A lot	4.2	14.2	13.0	4.8	8.8	9.3	45.8	
Not a lot	2.0	11.2	10.6	4.5	9.4	9.8	52.5	
Physical Activity								
More active	2.4	10.1	10.7	5.5	10.2	10.9	50.4	
About as active	2.4	12.7	11.3	4.1	8.9	9.2	51.4	
Less active	3.4	13.6	12.1	4.4	8.3	8.9	49.3	
Body Mass Index								
Obese class III	3.5	9.6	9.0	8.1	7.9	9.0	53.0	
Obese class II	2.8	9.7	8.5	5.2	9.0	9.1	55.6	
Obese class I	2.9	9.5	10.4	8.2	9.8	9.2	49.9	
Over weight	3.0	11.2	10.0	6.3	11.2	10.0	48.3	
Normal weight	2.2	13.1	12.1	3.0	8.2	9.7	51.9	
Under weight	2.6	13.9	16.8	1.6	5.0	8.6	51.5	

Source: Derived from NCHS 1993.

* Note: age and family income represent mean values

Table 2

Logistic Regression Coefficients of Smoking Status and Other Risk Factors on Mortality, U.S. Adults, 1990-97.

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Smoking Status						
Current 2+	1.318 *	1.154 *	1.060 *	1.099 *	0.936 *	0.975 *
Current 1-<2	0.945 *	0.844 *	0.776 *	0.824 *	0.714 *	0.759 *
Current < 1	0.879 *	0.826 *	0.725 *	0.770 *	0.700 *	0.741 *
Former 2+	0.661 *	0.467 *	0.487 *	0.522 *	0.469 *	0.501 *
Former 1-<2	0.559 *	0.405 *	0.402 *	0.435 *	0.389 *	0.420 *
Former <1	0.174 *	0.079	0.090	0.125	0.103	0.137
Never	ref	ref	ref	ref	ref	ref
Age						
20-24	ref	ref	ref	ref	ref	ref
25-29	-0.127	-0.122	-0.023	-0.018	-0.032	-0.026
30-34	-0.012	0.000	0.204	0.208	0.188	0.194
35-39	0.256	0.272	0.525	0.523	0.511	0.512
40-44	0.801 *	0.821 *	1.104 *	1.096 *	1.081 *	1.077 *
45-49	0.950 *	0.978 *	1.284 *	1.268 *	1.267 *	1.257 *
50-54	1.471 *	1.511 *	1.794 *	1.775 *	1.802 *	1.789 *
55-59	1.945 *	1.987 *	2.213 *	2.193 *	2.236 *	2.221 *
60-64	2.534 *	2.572 *	2.694 *	2.671 *	2.736 *	2.718 *
65-69	2.911 *	2.953 *	2.910 *	2.886 *	2.984 *	2.965 *
70-74	3.383 *	3.432 *	3.258 *	3.238 *	3.381 *	3.364 *
75-79	3.827 *	3.879 *	3.638 *	3.619 *	3.785 *	3.770 *
80-84	4.254 *	4.313 *	4.005 *	3.981 *	4.168 *	4.145 *
85+	4.910 *	4.989 *	4.620 *	4.587 *	4.814 *	4.784 *
Sex (male=1)		0.394 *	0.531 *	0.542 *	0.598 *	0.607 *
Race (black=1)			0.237 *	0.221 *	0.205 *	0.191 *

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Marital Status						
Currently married	ref			ref	ref	ref
Previously married	0.173 *	0.172 *	0.173 *	0.172 *	0.157 *	0.156 *
Never married	0.252 *	0.250 *	0.252 *	0.250 *	0.228 *	0.227 *
Family Income	-0.061 *	-0.055 *	-0.061 *	-0.055 *	-0.052 *	-0.047 *
Employment Status						
Employed	ref		ref	ref	ref	ref
Unemployed	0.516 *	0.525 *	0.516 *	0.525 *	0.488 *	0.496 *
Not in the labor force	0.540 *	0.531 *	0.540 *	0.531 *	0.443 *	0.437 *
Education						
11 years or less	0.249 *	0.218 *	0.249 *	0.218 *	0.199 *	0.176 *
High School Degree	0.068	0.063	0.068	0.063	0.067	0.063
Any College	ref	ref	ref	ref	ref	ref
Drinking Status						
Abstain from drinking		0.229 *		0.229 *		0.206 *
Infrequent drinker		-0.060		-0.060		-0.061
Former drinker		0.195 *		0.195 *		0.156 *
Current drinker		ref		ref		ref
Seatbelt Use (never=1)				0.173 *	0.173 *	0.171 *
Stress (a lot=1)				0.193 *	0.193 *	0.193 *
Physical Activity						
More active				-0.238 *	-0.238 *	-0.231 *
About as active				ref	ref	ref
Less active				0.314 *	0.314 *	0.309 *
Body Mass Index						
Obese class III				0.440 *	0.440 *	0.431 *
Obese class II				0.211	0.211	0.207
Obese class I				0.010	0.010	0.014
Over weight				-0.045	-0.045	-0.048

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Normal weight					ref	ref
Under weight					0.426 *	0.413 *
Intercept	-7.268 *	-7.437 *	-7.816 *	-7.891 *	-7.919 *	-7.988 *
Log Likelihood	-13.350	-13.304	-13.162	-13.146	-13.073	-13.061

*
p .05.

Source: Derived from NCHS 1993, 2000.

Table 3
Life Expectancy Estimates at Age 20 by Smoking Status for Combinations of Health and Socioeconomic Status, U.S., 1990–1997.

Smoking Status	Unisex Life Expectancies at Age 20				
	Average ^a	Best Case ^b	High SES Poor Health ^c	Low SES Good Health ^d	Worst Case ^e
Never Smoked	67.8	84.1	53.9	64.9	42.4
Current Smoker					
Two or more packs per day	53.3	62.8	42.0	51.2	31.2
One to less than 2 packs per day	56.1	66.4	44.6	54.0	33.6
Less than 1 pack per day	56.4	66.7	44.8	54.2	33.8
Former Smoker					
Two or more packs per day	59.7	71.3	47.7	57.4	36.6
One to less than 2 packs per day	60.9	73.1	48.7	58.5	37.5
Less than 1 pack per day	65.4	80.1	52.2	62.7	40.8

Source: Derived from Table 2, Model 6 and from Appendix Table C.

Notes:

^aNotes: Average case indicates average values for socioeconomic and health status.

^bBest case assumes that all individuals are married, earning \$50,000 or more, employed, with some college education, who currently drink, use a seatbelt, are not under a lot of stress, are more active, and are of normal weight

^cHigh SES but Poor Health assumes that individuals earn \$50,000 or more, are employed, with some college, abstain from drinking, never use a seatbelt, are under a lot of stress, are less active, and are in obese class III.

^dLow SES but Good Health assumes that individuals earn \$15,000 or less, are not in the labor force, have 11 years or less education, currently drink, use a seatbelt, are not under a lot of stress, are more active, and are of normal weight.

^eWorst Case assumes that individuals have never married, earn \$15,000 or less, are not in the labor force, have 11 years or less education, abstain from drinking, never use a seatbelt, are under a lot of stress, are less active, and are in obese class III.

Table 4
Number of Potential Deaths Averted in a Year Due to Smoking, Based on Various Scenarios.

Various Scenarios	Estimated Number of Deaths Averted
All current and former smokers experience the mortality of never smokers	343,414
All current smokers move to their respective locations as former smokers	129,457
Current smokers reduce consumption by one package of cigarettes per day, with current light smokers becoming former light smokers	77,197
Current light smokers become former light smokers	66,046
Those currently smoking one or more packages of cigarettes per day begin to smoke less than one pack per day	11,747

Source: Derived from Table 2 and Appendix Table C.