Trends in the Leading Causes of Death in the United States, 1970-2002

Ahmedin Jemal, DVM, PhD
Elizabeth Ward, PhD
Yongping Hao, PhD
Michael Thun, MD, MS

Context The decrease in overall death rates in the United States may mask changes in death rates from specific conditions.

Objective To examine temporal trends in the age-standardized death rates and in the number of deaths from the 6 leading causes of death in the United States.

Design and Setting Analyses of vital statistics data on mortality in the United States from 1970 to 2002.

Main Outcome Measure The age-standardized death rate and number of deaths (coded as underlying cause) from each of the 6 leading causes of death: heart disease, stroke, cancer, chronic obstructive pulmonary disease, accidents (ie, related to transportation [motor vehicle, other land vehicles, and water, air, and space] and not related to transportation [falls, fire, and accidental posioning]), and diabetes mellitus.

Results The age-standardized death rate (per 100 000 per year) from all causes combined decreased from 1242 in 1970 to 845 in 2002. The largest percentage decreases were in death rates from stroke (63%), heart disease (52%), and accidents (41%). The largest absolute decreases in death rates were from heart disease (262 deaths per 100 000), stroke (96 deaths per 100 000), and accidents (26 deaths per 100 000).The death rate from all types of cancer combined increased between 1970 and 1990 and then decreased through 2002, yielding a net decline of 2.7%. In contrast, death rates doubled from chronic obstructive pulmonary disease over the entire time interval and increased by 45% for diabetes since 1987. Despite decreases in age-standardized death rates from 4 of the 6 leading causes of death, the absolute number of deaths from these conditions continues to increase, although these deaths occur at older ages.

Conclusions The absolute number of deaths and age at death continue to increase in the United States. These temporal trends have major implications for health care and health care costs in an aging population.

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AGE-STANDARDIZED DEATH rates from all causes have decreased in the United States since the 1960s[1]; however, the overall trend masks substantial variations in cause-specific rates and in the number of deaths occurring in different age groups from specific conditions. Understanding these trends and the relationship between the age-standardized death rates and the actual number of deaths that occur can provide valuable insight into the forces that shape the nation's health. We examined trends in death rates and number of deaths from the 6 leading causes in the United States and considered the relationship of these trends to disease prevention and health care in an aging population.

METHODS

Cause of death statistics in the United States are based on underlying cause of death.[1] The underlying cause is defined as the disease or injury that initiated the sequence of events leading directly to death. It is selected from the conditions entered in the cause of death section on the death certificate by the certifying physician, coroner, or medical examiner based on the sequence of morbid events and coding rules specified by the *International Classification of Diseases (ICD)*.[2]

Effective with data year 1968, computer software has been used by the National Center for Health Statistics to determine the underlying cause of death from information on all causes (multiple causes) listed on the death certificate.[1]

For mortality statistics in the interval 1970 through 2002, underlying causes of death were classified according to the *ICD-8*, *ICD-9*, and *ICD-10* coding and selection rules,[3-5] with major causes of death grouped consistently across the *ICD* codes to facilitate evaluation of long-term trends.[6] The *ICD-10* codes used for the 6 leading causes of death were I00-I09, I11, I13, and I20-I51 for heart disease; C00-C97 for cancer; I60-I69 for stroke (cerebrovascular disease); E10-E14 for diabetes mellitus; J40-J47 for chronic obstructive pulmonary disease (COPD); and V01-X59 and Y85-Y86 for accidents (ie, related to transportation [motor vehicle, other land vehicles, and water, air, and space] and not related to transportation [falls, fire, and accidental posioning]). The *ICD-8* and the *ICD-9* codes were 390-398, 402, 404, and 410-429 for heart disease; 430-438 for stroke; 250 for diabetes mellitus; and 800-949 for accidents. For cancer, the *ICD-8* codes were 140-207 and the *ICD-9* codes were

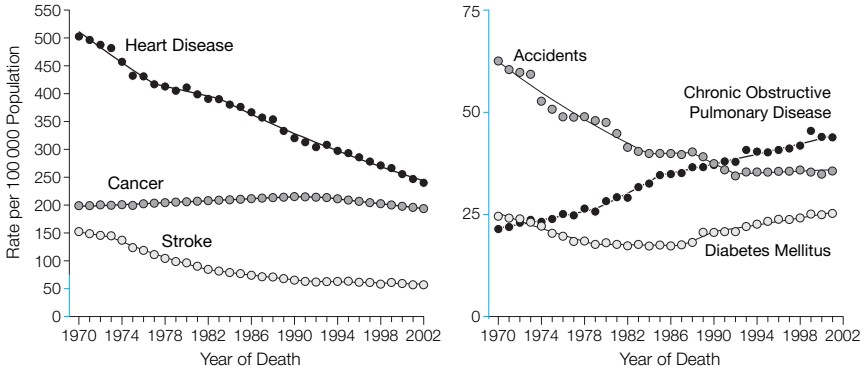
Author Affiliations: Epidemiology and Surveillance Research, American Cancer Society, Atlanta, Ga.
Corresponding Author: Ahmedin Jemal, DVM, PhD, Epidemiology and Surveillance Research, American Cancer Society, 1599 Clifton Rd, Atlanta, GA 30329 (ajemal@cancer.org).

Table. Trends in Age-Standardized Death Rates for the 6 Leading Causes of Death in the United States According to Joinpoint Analyses*

	Death Rate†			Joinpoint Analyses: 1970-2002†							
				Trend 1		Trend 2		Trend 3		Trend 4	
	1970	2002	% Change‡	Years	Annual % Change	Years	Annual % Change	Years	Annual % Change	Years	Annual % Change
All causes	1242.2	844.6	–32.0	1970-1978	–2.3§	1978-2002	–0.85§				
Heart disease	502.6	240.5	–52.1	1970-1977	–2.86§	1977-1983	–1.07§	1983-2002	–2.47§		
Cancer	198.8	193.5	–2.7	1970-1990	0.43§	1990-1993	–0.24	1993-2002	–1.09§		
Stroke	151.9	56.1	–63.1	1970-1973	–2.15	1973-1982	–5.68§	1982-1991	–3.01§	1991-2002	–0.86§
COPD	21.4	43.4	102.8	1970-1979	2.25§	1979-1985	4.60§	1985-2002	1.57§		
Accidents	62.5	36.9	–41.0	1970-1984	–3.15§	1984-1988	0.18	1988-1992	–3.40	1992-2002	0.31
Diabetes mellitus	24.6	25.4	3.2	1970-1979	–3.92§	1979-1987	–0.17	1987-1990	6.17	1990-2002	1.85§

Abbreviation: COPD, chronic obstructive pulmonary disease.
*Joinpoint Regression Program version 3.0 (National Cancer Institute/US National Institutes of Health, Bethesda, Md). The annual % change is based on rates that were age-adjusted to the 2000 US standard population using joinpoint regression analysis. Specific causes of death are ordered according to the 2002 age-standardized rates.
†Rates per 100 000 age-adjusted to the 2000 US standard population, joinpoint analyses include up to 3 joinpoints.
‡The difference between the 2002 and 1970 rate expressed as percentage of the 1970 rate.
§The annual % change is statistically significantly different from zero (2-sided $P<.05$).

Figure 1. Trends in Age-Standardized Death Rates for the 6 Leading Causes of Death in the United States, 1970-2002



Rates are age-adjusted to the 2000 US standard population.

140-208, 238.6. For COPD, the *ICD-8* codes were 490-493 and 519.3 and the *ICD-9* codes were 490-496.

We calculated the age-standardized death rates (directly adjusted to the 2000 US standard population) for all causes and the 6 leading causes of death using SEER*Stat software, developed by the Surveillance, Epidemiology, and End Results program of the National Cancer Institute.[7,8] When the 2002 death rate for a particular condition was lower than the 1970 rate, the contribution of this decrease to the overall decrease in all-cause death rates over the same time interval was expressed as a percentage. Trends in age-standardized death rates from 1970 through 2002 for each of these conditions were described using joinpoint regression analysis.[9] The joinpoint regression model fits a series of joined straight lines on a log scale to the trends in age-adjusted rates. The terms *increase* or *decrease* were used when the slope (coefficient) of the trend was statistically different from zero (2-sided $P<.05$); otherwise, the terms *stable* or *level* were used.

We also examined the leading causes of death in 2002 by age and temporal trends in age-specific death rates and number of deaths from heart disease and cancer for individuals aged 40 years or older by 10-year age intervals from 1970 to 2002.

RESULTS

Between 1970 and 2002, the age-standardized death rate (per 100 000 population) from all causes combined decreased 32% from 1242.2 to 844.6 based on the year 2000 age standard (TABLE). Among the 6 leading causes of death (Table and FIGURE 1), the largest percentage decreases during this interval were in the death rates from heart disease (52%), cerebrovascular disease or stroke (63%), and accidents (41%). The absolute decrease was largest for heart disease (262 deaths per 100 000) followed by stroke (96 deaths per 100 000), accidents (26 deaths per 100 000), and cancer (5 deaths per 100 000). The age-standardized death rate from all types of cancers combined first increased from 1970 to 1990, and then decreased through 2002, yielding a net decline of 2.7%. In contrast, death rates doubled since 1970 for COPD and increased by 45% since 1987 for diabetes mellitus (3% net increase from 1970 to 2002).

When examined by joinpoint regression analysis, the decrease in heart disease and cancer death rates continues, whereas the decrease in the mortality rates from stroke and accidents has slowed or stopped since the early 1990s. In 2002, the leading causes of death were heart disease among persons aged 75 years or older, cancer among persons aged 40 to 74 years, and accidents among persons younger than age 40 years (FIGURE 2).

Analysis of temporal trends in age-specific death rates from heart disease

and cancer shows that the decrease in the mortality rate from heart disease (FIGURE 3, top panel) affects all age groups containing individuals aged 40 years or older throughout the entire time interval, whereas the decrease in age-specific death rates from all types of cancer begins later and becomes smaller in proportionate terms with increasing age (Figure 3, bottom panel).

A different perspective on the temporal trends in mortality from heart disease and cancer is provided by data on the number of deaths that occur from these conditions (FIGURE 4). Because of the aging and growth of the population, the number of deaths attributed to heart disease among persons aged 80 years or older (Figure 4, top panel) increased 60% from 1970 to 2002, even though the age-standardized death rate decreased by 40%

Figure 2. Age-Specific US Death Rates for the 4 Leading Causes of Death by 5-Year Intervals, 2002

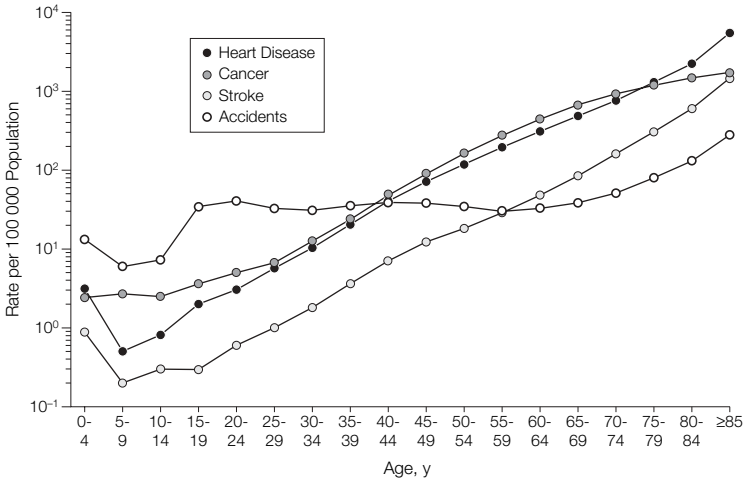
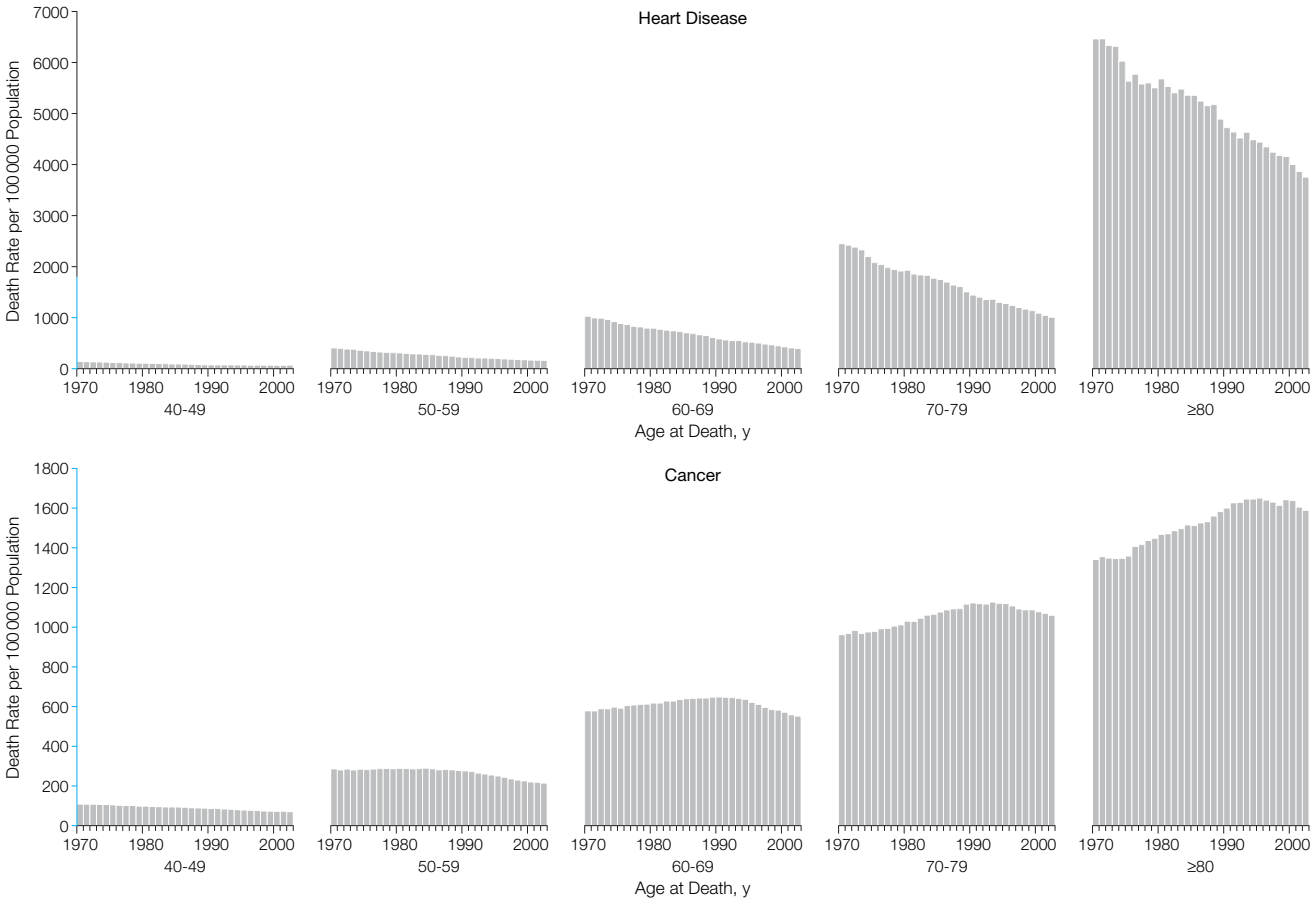


Figure 3. Age-Specific Death Rates for Heart Disease and Cancer for Individuals Aged 40 Years or Older by 10-Year Intervals, 1970-2002



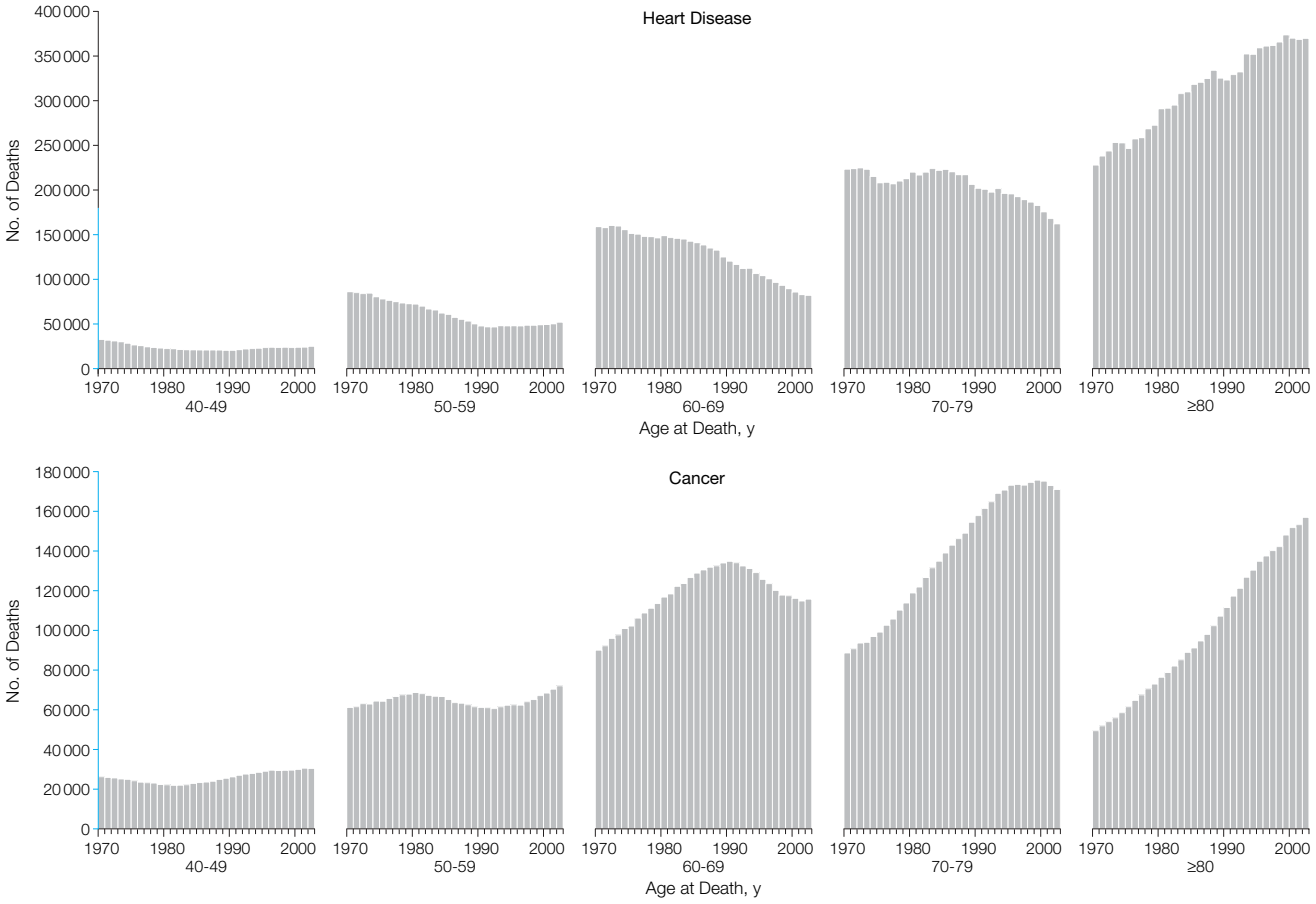
in this age group over the same period (Figure 3, top panel). Figure 4 also illustrates the influence of the baby boomer generation (born after World War II) as reflected in the pattern of deaths due to heart disease and cancer in individuals aged 50 to 59 years. A large increase in the number of individuals in this age group began in approximately 1990, resulting in an increase in the number of cancer deaths and flattening rather than decreasing the number of deaths from heart disease.

COMMENT

This article provides a concise overview of trends in both age-standardized death rates and numbers of deaths for the 6 leading causes of mortality in the United States from 1970 to 2002, updating a similar analysis from 1950 to 1986.[10] These findings illustrate the substantial and continuing progress in reducing the age-standardized death rate from heart disease, the lack of continuing progress for stroke and accidents, and the increase in the age-standardized rates for COPD and diabetes. The study also illustrates that the reduction in age-standardized death rates, the best measure of progress against diseases, is not synonomous with reducing the number of deaths from these conditions. In fact, the number of deaths continues to increase because of population growth and aging. It is the number of individuals affected by various conditions rather than the age-standardized rate that influence the planning and allocation of preventive and medical services.

Inaccuracies in death certificates and changes in classification of causes of death are potential limitations in the interpretation of mortality trends. However, our analyses are restricted to broad disease categories for which death certificate data are more accurate than for specific diseases.[11] Although 2 revisions of the *ICD* have been implemented in the United States during the study period (*ICD-9* in 1979 and *ICD-10* in 1999), there was only 1 significant discontinuity in these broad disease categories. The *ICD-8* codes developed by the World Health Organization did not have a code for COPD without mention of asthma, bronchitis, or emphysema. However, in 1970 the National Center for Health Statistics introduced a code (519.3), used in the United States, for this category of diseases, allowing comparability in classification of deaths due to COPD un-

Figure 4. Number of Deaths From Heart Disease and Cancer for Individuals Aged 40 Years or Older by 10-Year Intervals, 1970-2002



der *ICD-8*, *ICD-9*, and *ICD-10*.[12] The effect of the changes in *ICD* rules on the 6 leading causes of death described herein have been studied by calculating the comparability ratio based on the classification of 1 year's mortality data by both the new *ICD* codes and the previous *ICD* codes. All comparability ratios (the total number of deaths due to a specific cause under the new revision divided by the total number of deaths under the previous revision) for the cause of death categories described were between 0.99 and 1.06.[12,13]

Several important insights are suggested by these temporal trends in the death rates and number of deaths at various ages. First, the decrease in the age-standardized death rate for 4 of the 6 leading causes of death in the United States represents progress toward one of the fundamental goals of disease prevention by extending the number of years of potentially healthy life. This progress has been greater for heart disease and for accidental deaths than for cancer, yet even for cancer the age-standardized death rate has been decreasing by 1.1% per year since 1993. Less favorable developments are the slowing of the decline in age-standardized mortality rates from stroke and accidents since the early 1990s, and the increase in death rates from COPD and diabetes.

Several other countries have reported similar slowdowns in the decrease in stroke mortality[14]; this is striking in the face of a continuing decrease in age-standardized mortality from heart disease. Analyses that differentiate subgroups of stroke mortality[15] suggest that an increase in hemorrhagic (nonthrombotic, nonembolic) stroke may be partly offsetting a continuing decrease in thrombotic stroke. A likely explanation for this is increased use of aspirin and other antithrombotic agents. The reduction in the death rate from accidents from 1970 through the early 1990s coincided with implementation of a 55-mph speed limit during the first energy crisis in the 1970s and mandated use of seat belts in most states[16] beginning in 1984.[17] The recent flattening of the accident mortality rate coincides with the relaxation of the maximum interstate speed limits since 1987.[18,19] The biphasic trend in cancer mortality rates reflects both the impact of the tobacco epidemic on tobacco-related cancers through 1990, followed by reduction in cancer mortality through tobacco control and advances in early detection, in treatment, or in both.[20] The increase in COPD death rates results largely from the long-term effects of tobacco smoking in an aging population,[21] whereas the increase in diabetes mortality since the late 1980s reflects dramatic increases in obesity.[22]

A consequence of the large decrease in cardiovascular death rates, combined with the high birth rates that immediately followed World War II, is the growing importance of health and health care needs in an aging population. While improved detection and treatment for chronic diseases has resulted in declining mortality rates, it has also increased the prevalence of "treated disease" and an associated increase in health care expenditures.[23]

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Study concept and design: Jemal.
Acquisition of data: Jemal.
Analysis and interpretation of data: Jemal, Ward, Hao, Thun.
Drafting of the manuscript: Jemal.
Critical revision of the manuscript for important intellectual content: Ward, Hao, Thun.
Statistical analysis: Jemal, Hao.
Study supervision: Ward, Thun.
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REFERENCES

1. Kochanek KD, Murphy SL, Anderson RN, Scott C. Deaths: final data for 2002. *Natl Vital Stat Rep*. 2004; 53:1-115.
2. National Center for Health Statistics. Vital statistics, instructions for classifying the underlying causes of death: NCHS instruction manual; part 2a. Available at: http://www.cdc.gov/nchs/data/dvs/2a2005a.pdf. Accessibility verified July 29, 2005.
3. US Department of Health Education and Welfare and National Center for Health Statistics. *Manual of the International Statistical Classification of Diseases, Injuries, and Causes of Death: Adapted for Use in the United States, Eighth Revision.* Washington, DC: Public Health Service; 1967.
4. World Health Organization. *Manual of the International Statistical Classification of Diseases, Injuries, and Causes of Death, Ninth Revision.* Geneva, Switzerland: World Health Organization; 1977.
5. World Health Organization. *International Statistical Classification of Diseases and Related Health Problems, Tenth Revision.* Geneva, Switzerland: World Health Organization; 1992.
6. Surveillance, Epidemiology, and End Results (SEER) Program: SEER cause of death recode. Available at: http://seer.cancer.gov/codrecode/. Accessibility verified July 29, 2005.
7. Surveillance, Epidemiology, and End Results (SEER) Stat Database. Mortality: all COD, public use with state, total US (1969-2002). Available at: http://www.seer.cancer.gov. Accessibility verified July 29, 2005.
8. National Cancer Institute. Underlying mortality data provided by National Center for Health Statistics. Available at: http://www.cdc.gov/nchs. Accessibility verified July 29, 2005.
9. Kim HJ, Fay MP, Feuer EJ, Midthune DN. Permutation tests for joinpoint regression with applications to cancer rates. *Stat Med*. 2000;19:335-351.
10. Sutherland JE, Persky VW, Brody JA. Proportionate mortality trends: 1950 through 1986. *JAMA*. 1990; 264:3178-3184.
11. Gittelsohn A, Royston PN. Annotated bibliography of cause-of-death validation studies, 1958-80. *Vital Health Stat 2*. 1982:1-42.
12. Estimates of selected comparability ratios based on dual coding of 1976 death certificates by the eighth and ninth revisions of the *International Classification of Diseases*. Available at: http://www.cdc.gov/nchs/data/mvsp/supp/mv28_11.pdf. Accessed on July 5, 2005.
13. Anderson RN, Minino AM, Hoyert DL, Rosenberg HM. Comparability of cause of death between ICD-9 and ICD-10: preliminary estimates. *Nat Vital Stat Rep*. 2001;49:1-32.
14. Sarti C, Rastenyte D, Cepaitis Z, Tuomilehto J. International trends in mortality from stroke, 1968 to 1994. *Stroke*. 2000;31:1588-1601.
15. *Mortality: Age-Adjusted Death Rates for 72 Selected Causes by Race and Sex Using Year 2000 Standard Population: United States, 1979-98.* Atlanta, Ga: Centers for Disease Control and Prevention; 2000.
16. Impact of primary laws on adult use of safety belts—United States, 2002. *MMWR Morb Mortal Wkly Rep*. 2004;53:257-260.
17. Wagenaar AC, Wiviott MB. Effects of mandating seatbelt use: a series of surveys on compliance in Michigan. *Public Health Rep*. 1986;101:505-513.
18. Farmer CM, Retting RA, Lund AK. Changes in motor vehicle occupant fatalities after repeal of the national maximum speed limit. *Accid Anal Prev*. 1999;31: 537-543.
19. Garber S, Grahman JD. The effects of the new 65 mile-per-hour speed limit on rural highway fatalities: a state-by-state analysis. *Accid Anal Prev*. 1990;22: 137-149.
20. Jemal A, Clegg LX, Ward E, et al. Annual report to the nation on the status of cancer, 1975-2001, with a special feature regarding survival. *Cancer*. 2004;101:3-27.
21. Mannino DM, Homa DM, Akinbami LJ, Ford ES, Redd SC. Chronic obstructive pulmonary disease surveillance—United States, 1971-2000. *Respir Care*. 2002; 47:1184-1199.
22. Mokdad AH, Ford ES, Bowman BA, et al. The continuing increase of diabetes in the US. *Diabetes Care*. 2001;24:412.
23. Thrope KE, Florence CS, Howard DH, Joski P. The rising prevalence of treated disease: effects on private health insurance spending. *Health Aff (Millwood)*. doi 10.1377/hlthaff.w5.317. Published online June 27, 2005. Available at: http://content.healthaffairs.org/cgi/content/abstract/hlthaff.w5.317. Accessibility verified August 23, 2005.