

Secular Trends in Mortality From Common Cancers in the United States by Educational Attainment, 1993–2001

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- Background** Death rates for the four major cancer sites (lung, breast, prostate, and colon and rectum) have declined steadily in the United States among persons aged 25–64 years since the early 1990s. We used national data to examine these trends in relation to educational attainment.
- Methods** We calculated age-standardized death rates for each of the four cancers by level of education among 25- to 64-year-old non-Hispanic white and non-Hispanic black men and women for 1993 through 2001 using data on approximately 86% of US deaths from the National Center for Health Statistics, education level as recorded on the death certificate, and population data from the US Bureau of Census Current Population Survey. Annual percent changes in age-adjusted death rates were estimated using weighted log-linear regression models. All statistical tests were two-sided.
- Results** Death rates for each cancer decreased statistically significantly from 1993 to 2001 in people with at least 16 years of education in every sex and race stratum except lung cancer in black women, for whom death rates were stable. For example, colorectal cancer death rates among white men, black men, white women, and black women with at least 16 years of education decreased by 2.4% ($P < .001$), 4.8% ($P = .011$), 3.0% ($P < .001$), and 2.6% ($P = .030$) annually, respectively. By contrast, among people with less than 12 years of education, a statistically significant decrease in death rates from 1993 through 2001 was seen only for breast cancer in white women (1.4% per year; $P = .029$). Death rates among persons with less than 12 years of education over the same time interval increased for lung cancer in white women (2.4% per year; $P < .001$) and for colon cancer in black men (2.7% per year; $P < .001$) and were stable for the remaining race/sex/site strata. Temporal trends generally followed an educational gradient in which the slopes of the decreases in death rate became steeper with higher educational attainment.
- Conclusion** The recent declines in death rates from major cancers in the United States mainly reflect declines in more highly educated individuals.

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Death rates have decreased for the four major cancer sites (lung, colon and rectum, female breast, and prostate) among US men and women aged 25–64 years since at least the early 1990s (1,2). Factors that have contributed to these trends include reduction in risk factors, such as tobacco use for lung cancer (3–5), and improvements in early detection and treatment for the other major cancers (6,7). However, the extent to which these favorable mortality trends vary by socioeconomic status (SES) has not, to our knowledge, been examined using national data with individual measures of SES. Published studies have used area-level measures of SES (8–10), studied cohorts with higher SES than the general population (11), or were restricted to employed persons (12).

We examined the variation in cancer mortality trends from 1993 through 2001 for the four major cancers by educational attainment among non-Hispanic white and non-Hispanic black men and women aged 25–64 years, using individual-level educational attainment data from death certificates that cover approxi-

mately 86% of the US population. This analysis expands on a previous report that documented higher death rates among less-educated than among more highly educated individuals for each of the four major cancer sites in 2001 (13).

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CONTEXT AND CAVEATS

Prior knowledge

Rates of death from the four major cancers (lung, colorectal, female breast, and prostate) in the United States have declined since the early 1990s. Previous studies have indicated that the fall in death rates may be distributed unequally among groups of different socioeconomic status, but the association had not been studied in a national sample with individual-level data.

Study design

Population study in which death certificates covering 86% of US deaths in 1993–2001 were analyzed for cause of death and level of education of the decedent. Annual percent changes from 1993 through 2001 in age-standardized death rates for 25- to 64-year-olds who had died from one of the four major cancers were computed by educational level, race (non-Hispanic white and non-Hispanic black), and sex.

Contributions

Death rates for each cancer decreased from 1993 to 2001 in people with at least 16 years of education in every sex/race group except lung cancer in black women, for whom death rates were stable. Among people with less than 12 years of education, by contrast, a decrease in death rates was seen only for breast cancer in white women; death rates increased for lung cancer in white women and for colon cancer in black men and were stable for the remaining race/sex/cancer site groups.

Implications

The decreases in rates of death from the four major cancers have been limited mainly to those with higher educational attainment.

Limitations

Educational attainment is an imperfect measure of socioeconomic status. Whether the findings would generalize to the elderly, in whom most cancer deaths occur, is not known. Misclassification of educational level on death certificates could have affected the results.

From the Editors

Methods

Data Sources

Mortality data for this study were obtained from the National Center for Health Statistics (NCHS), which compiles comprehensive US mortality data abstracted from death certificates of all deaths that occur in the United States and its territories. Underlying causes of death were classified according to the *International Classification of Disease, Ninth Revision (ICD-9)*, coding rules for the years 1993–1998 (14) and *International Classification of Diseases, Tenth Revision (ICD-10)*, coding rules for the years 1999–2001 (15). The ICD-9 codes used for the underlying causes of death were 153–154.1 and 159.0 for colon or rectal cancer, 174–175 for breast cancer, 185 for prostate cancer, and 162.2–162.5, 162.8, and 162.9 for cancer of the lung or bronchus. The ICD-10 codes used were C18–C20 and C26.0 for colon or rectal cancer, C61 for prostate cancer, C50 for breast cancer, and C34 for cancer of the lung or bronchus.

Level of education is recorded on death certificates as the number of years of formal schooling completed. This information is

typically provided by a surviving family member and entered on the death certificate by the funeral director. We categorized educational attainment by four levels: less than 12 years (did not finish high school), 12 years (high school graduate), 13–15 years (some college), and 16 or more years (college graduate or higher). The analysis was restricted to deaths that occurred at age 25–64 years because 1) individuals who died before age 25 years may not have completed their education and 2) educational attainment information is recorded more accurately on death certificates (16) and better predicts SES (17,18) for individuals younger than 65 years than for older individuals. We further restricted the study to non-Hispanic white and non-Hispanic black subgroups because the accuracy of race classification on death certificates has been shown to be lower for other populations (19,20) and because both cancer risk and demographic characteristics differ by Hispanic ethnicity (21,22). Specifically, Hispanics are disproportionately represented in the lowest socioeconomic category and have a much lower cancer risk than whites or blacks (21,22). We excluded seven states (Georgia, Rhode Island, Oklahoma, South Dakota, New York, Kentucky, and West Virginia) because recording of educational level on the death certificates was not at least 80% complete for all years from 1993 through 2001. A total of 561 482 deaths of 25- to 64-year-olds from the included cancer sites were recorded from 1993 through 2001 in the remaining 43 states and the District of Columbia. Due to missing data on educational attainment, 2.6% (14 779) of these deaths were excluded from analyses that stratified on this variable. The final analysis of trends by educational attainment therefore included 546 703 deaths, accounting for approximately 86% of the total deaths recorded among whites and blacks of the same age and time intervals in the entire United States and 97.4% of those recorded in the 43 states and the District of Columbia.

Yearly US population estimates by state, race/ethnicity, sex, 5-year age category, and educational attainment were obtained in a custom-designed tabulation from the US Bureau of Census (C. S. Carbaugh, BA, Housing and Household Economic Statistics Division, US Bureau of Census, personal communication, 2006). These data were based on the Annual Social and Economic Supplement to the Current Population Survey (CPS), a monthly survey of approximately 50 000 households. The population data were restricted to the same 43 states and District of Columbia as represented by the numerator counts for these analyses. Mortality and population data were categorized to create corresponding numerator and denominator data for strata based on individual years 1993–2001, 5-year age category, race/ethnicity (non-Hispanic white and non-Hispanic black), sex, educational attainment category, and cancer site (lung, prostate, breast, or colorectal). For brevity, we use the terms “white” and “black” instead of “non-Hispanic white” and “non-Hispanic black” in the rest of the article.

Statistical Analysis

Annual age-standardized death rates (expressed per 100 000 population and standardized to the 2000 US population) were computed among 25- to 64-year-olds by race/ethnicity, sex, and education category for each cancer site (23). All discussion of death “rates” in this paper refers to these age-adjusted rates. Standard errors and 95% confidence intervals for the rates were computed using

methods that are designed to account for both random variability of death counts (24,25) and sampling variability of the CPS-based population estimates by educational attainment (24). Computations of rates and standard errors were performed using SAS Version 9.1 software (SAS Institute, Cary, NC).

Temporal trends in death rates from 1993 through 2001 were characterized by fitting weighted least squares linear regression models to the log-transformed annual age-standardized death rates for each of the 9 years with the use of Joinpoint Regression Program, Version 3.0 software (26). Separate models were fit for each sex/race/education stratum for each cancer site, using year as the independent variable. Weights for least squares estimation were based on the standard errors of each observed yearly rate, computed as described above. Annualized change in death rates are reported as annual percent changes (APCs), which were obtained from the estimated coefficients (slopes) of the fitted regression models (27,28). Linear trends in the APCs (ie, changes in slope) over increasing levels of education within each race/sex/site stratum were tested using weighted linear regression by treating the lowest to the highest educational category, valued at 1–4, as a predictor of the estimated slope; the inverse variance of the estimated slope was used as the weight. Rate ratios comparing the lowest with the highest educational categories and 95% confidence intervals were calculated for the years 1993 and 2001 to summarize the net changes from 1993 through 2001 in the disparities in cancer mortality with educational level.

All statistical tests were two-sided. Annual percent change values that were statistically significantly different from 0 were interpreted as evidence of a temporal change in death rate in the observed direction. Non-statistically significant APC values were interpreted as evidence of a stable death rate over the time period.

Results

Table 1 and Figures 1–3 present the mortality rates for the four most common cancers for white and black men and women by educational attainment. In general, the death rates decreased statistically significantly from 1993 through 2001 for those with 13–15 years of education (some college) or 16 or more years of education (college graduate) but increased or remained constant (no statistically significant change in APC, Table 1) in those with less than 12 years of education (did not finish high school) or 12 years of education (high school graduate).

Among both white and black men, death rates from lung cancer decreased from 1993 through 2001 in those with 12 or more years of education but were stable in those with less than 12 years of education (Table 1, Figure 1). Specifically, lung cancer death rates decreased by 1.5% ($P = .001$), 3.5% ($P < .001$), and 4.9% ($P < .001$) per year in white men with 12, 13–15, and 16 or more years of education, respectively. The corresponding annual percentage decreases in lung cancer death rates among black men were 3.2% ($P = .009$), 4.7% ($P < .001$), and 6.8% ($P < .001$), respectively. Among white women, death rates from lung cancer decreased for those with 13–15 and 16 or more years of education (1.7% per year; $P = .003$, and 2.9% per year; $P < .001$, respectively), were stable for those with 12 years of education, and increased for those with less than 12 years of education (2.4% per year; $P < .001$). Among black women, death rates from lung cancer were stable within every level of education.

For black and white men and white women, the rate of decrease in the lung cancer death rates followed an educational gradient, such that each group of increasing educational level experienced a progressively steeper decrease (Table 1, Figure 1). Among white men, the lung cancer death rate ratio comparing the rates for the least educated (<12 years) to the most highly educated (≥ 16 years) was already 4.2 in 1993; by 2001, that ratio had increased to 6.4. Similarly, between 1993 and 2001, the lung cancer death rate ratio increased from 2.6 to 4.3 among black men and from 3.3 to 4.8 among white women (Table 1). All three rate ratio differences between 1993 and 2001 were statistically significant ($P < .001$). By contrast, the rate ratio among black women underwent a non-statistically significant decrease, from 2.2 to 1.8 ($P = .09$).

Death rates from colorectal cancer among whites decreased from 1993 through 2001 for men with 13 or more years of education and for women with 12 or more years of education, whereas rates remained stable for men with 12 or fewer years of education and for women with less than 12 years of education (Table 1, Figure 2). For example, colorectal cancer death rates among white women decreased statistically significantly by 1.0% ($P = .010$), 1.6% ($P = .006$), and 3.0% ($P < .001$) annually for those with 12, 13–15, and 16 or more years of education, respectively, but were stable for those with less than 12 years of education. Among black men and women, colorectal cancer death rates decreased statistically significantly by 4.8% per year ($P = .011$) in men and 2.6% per year ($P = .030$) in women for those with 16 or more years of education, increased by 2.7% per year ($P < .001$) among men with less than 12 years of education, and were stable in the remaining sex/education groups. Between 1993 and 2001, the mortality rate ratio of colorectal cancer for the least educated to the most highly educated persons increased statistically significantly (all $P < .001$) from 1.5 to 2.0 among white men, from 1.1 to 1.8 among black men, and from 1.4 to 1.9 among white women but remained statistically unchanged in black women ($P = .232$) (Table 1).

Breast cancer death rates decreased from 1993 to 2001 among white women in every educational group, with the slope of the decrease becoming steeper with higher educational attainment (Table 1, Figure 3): the decrease ranged from 1.4% per year ($P = .029$) in women with less than 12 years of education to 4.3% per year ($P < .001$) in those with 16 or more years of education. Among black women, a decrease in breast cancer death rates during the same time interval was restricted to those with 16 or more years of education (decrease of 3.8% per year; $P < .001$) (Table 1, Figure 3). The death rate ratio in the least educated compared with the most highly educated increased statistically significantly between 1993 and 2001 for both white and black women ($P < .001$ and $P = .004$, respectively) (Table 1).

From 1993 to 2001, prostate cancer death rates among white men decreased for each educational category except for those with less than 12 years of education (Table 1, Figure 3). Among black men, rates decreased for those with 13–15 years of education (7.4% per year; $P = .003$); a large decrease (5.9% per year) was also seen among those with 16 or more years of education, but it was not statistically significant ($P = .071$) (Table 1, Figure 3). The death rate ratio in the least educated compared with the most highly educated increased statistically significantly between 1993 and 2001 for white men ($P = .001$), from 1.1 to 1.5, and increased

Table 1. Trends in age-adjusted rates* of death from four major cancers by educational attainment, ages 25–64 years, 43 states and the District of Columbia, 1993–2001

	White non-Hispanic				Black non-Hispanic			
	1993 Rate	2001 Rate	APC‡	P value§	1993 Rate	2001 Rate	APC‡	P value§
Lung and bronchus								
Male								
All education†	46.9 (48.8)	35.7 (36.4)	−3.3 (−3.5)	<.001 (<.001)	81.4 (88.5)	57.9 (60.2)	−4.0 (−4.4)	<.001 (<.001)
<12 y	88.1	87.3	−0.1	.905	98.3	90.4	−0.2	.705
12 y	59.5	53.2	−1.5	.001	98.6	73.7	−3.2	.009
13–15 y	32.7	24.2	−3.5	<.001	45.6	32.2	−4.7	<.001
≥16 y	20.7	13.7	−4.9	<.001	38.3	21.0	−6.8	<.001
Rate difference	67.3	73.6			60.0	69.4		
Rate ratio¶	4.2 (4.1 to 4.4)	6.4 (6.2 to 6.6)		<.001	2.6 (2.5 to 2.8)	4.3 (3.9 to 4.8)		<.001
P _{trend} #			.001				.004	
Female								
All education†	27.6 (28.4)	24.7 (25.1)	−1.4 (−1.6)	<.001 (<.001)	28.7 (30.5)	26.3 (26.9)	−1.0 (−1.5)	.068 (.011)
<12 y	45.5	55.4	2.4	<.001	32.7	30.4	0.8	.476
12 y	32.1	33.1	0.1	.657	37.3	35.7	−0.7	.191
13–15 y	19.8	16.6	−1.7	.003	20.1	19.3	−1.3	.282
≥16 y	13.9	11.6	−2.9	<.001	14.8	16.7	−2.2	.246
Rate difference	31.6	43.8			17.9	13.7		
Rate ratio¶	3.3 (3.1 to 3.5)	4.8 (4.5 to 5.0)		<.001	2.2 (1.8 to 2.7)	1.8 (1.6 to 2.1)		.090
P _{trend} #			.009				.059	
Colon and rectum								
Male								
All education†	11.7 (12.0)	10.6 (10.7)	−1.5 (−1.6)	<.001 (<.001)	18.0 (19.7)	17.9 (18.3)	0.0 (−0.7)	.981 (.080)
<12 y	14.1	16.0	0.9	.237	17.4	20.9	2.7	<.001
12 y	14.6	13.9	−0.9	.130	21.9	23.9	1.0	.341
13–15 y	9.2	8.1	−1.1	.006	15.4	11.7	−2.7	.161
≥16 y	9.3	7.9	−2.4	<.001	16.3	11.5	−4.8	.011
Rate difference	4.8	8.2			1.1	9.4		
Rate ratio¶	1.5 (1.4 to 1.6)	2.0 (1.9 to 2.2)		<.001	1.1 (0.9 to 1.3)	1.8 (1.5 to 2.2)		<.001
P _{trend} #			.039				.010	
Female								
All education†	8.3 (8.5)	7.2 (7.3)	−1.7 (−1.8)	<.001 (<.001)	13.0 (13.7)	13.0 (13.3)	−0.3 (−0.7)	.518 (.103)
<12 y	9.5	10.4	1.4	.073	11.0	10.3	−0.3	.745
12 y	9.7	9.2	−1.0	.010	16.1	17.8	−0.3	.730
13–15 y	6.4	5.5	−1.6	.006	9.4	10.0	0.7	.659
≥16 y	6.8	5.4	−3.0	<.001	15.6	12.2	−2.6	.030
Rate difference	2.8	4.9			−4.5	−1.9		
Rate ratio¶	1.4 (1.3 to 1.6)	1.9 (1.7 to 2.1)		<.001	0.7 (0.6 to 0.9)	0.8 (0.7 to 1.0)		.232
P _{trend} #			.063				.288	
Breast								
Female								
All education†	27.4 (28.2)	21.4 (21.7)	−3.4 (−3.5)	<.001 (<.001)	38.0 (40.1)	34.9 (35.5)	−1.1 (1.5)	.027 (.003)
<12 y	27.4	24.1	−1.4	.029	30.0	28.7	0.1	.855
12 y	30.6	25.4	−2.9	<.001	45.3	43.4	−1.5	.078
13–15 y	23.2	17.3	−3.6	<.001	35.3	30.0	−0.9	.447
≥16 y	27.4	20.1	−4.3	<.001	45.7	35.8	−3.8	<.001
Rate difference	0.0	4.0			−15.7	−7.0		
Rate ratio¶	1.0 (1.0 to 1.1)	1.2 (1.1 to 1.3)		<.001	0.7 (0.6 to 0.7)	0.8 (0.7 to 0.9)		.004
P _{trend} #			.025				.046	
Prostate								
Male								
All education†	3.9 (4.0)	2.7 (2.8)	−4.6 (−4.7)	<.001 (<.001)	11.8 (12.7)	8.8 (9.1)	−3.3 (−3.6)	<.001 (<.001)
<12 y	4.0	3.4	−1.6	.054	10.4	9.6	−1.6	.133
12 y	4.3	3.3	−3.5	.003	16.2	12.7	−1.6	.171
13–15 y	3.4	2.3	−5.5	<.001	10.3	5.3	−7.4	.003
≥16 y	3.8	2.3	−6.3	<.001	7.6	4.8	−5.9	.071
Rate difference	0.2	1.1			2.7	4.8		
Rate ratio¶	1.1 (0.9 to 1.2)	1.5 (1.3 to 1.7)		.001	1.4 (1.0 to 1.8)	2.0 (1.5 to 2.7)		.054
P _{trend} #			.022				.211	

* Single-year rates per 100,000 people were age adjusted to the 2000 US standard population for ages 25–64 years.

† Excludes persons with missing data for educational attainment (data in parentheses includes persons with missing educational attainment).

‡ Annual percent change (APC) estimated from weighted least squares linear regression models fit to the log-transformed age-adjusted death rates for years 1993–2001.

§ Value adjacent to APC indicates test for APC statistical difference from 0, two-sided. Value adjacent to rate ratios indicates test for statistical difference between rate ratios for single years 1993 and 2001.

|| The difference between the age-adjusted rates for less than 12 years and 16 or more years education for the indicated year.

¶ Rate ratio (95% confidence interval) comparing age-adjusted rate for less than 12 years education to 16 or more years education for the indicated year.

Test for trend in APC over levels of education using inverse variance weighted linear regression.

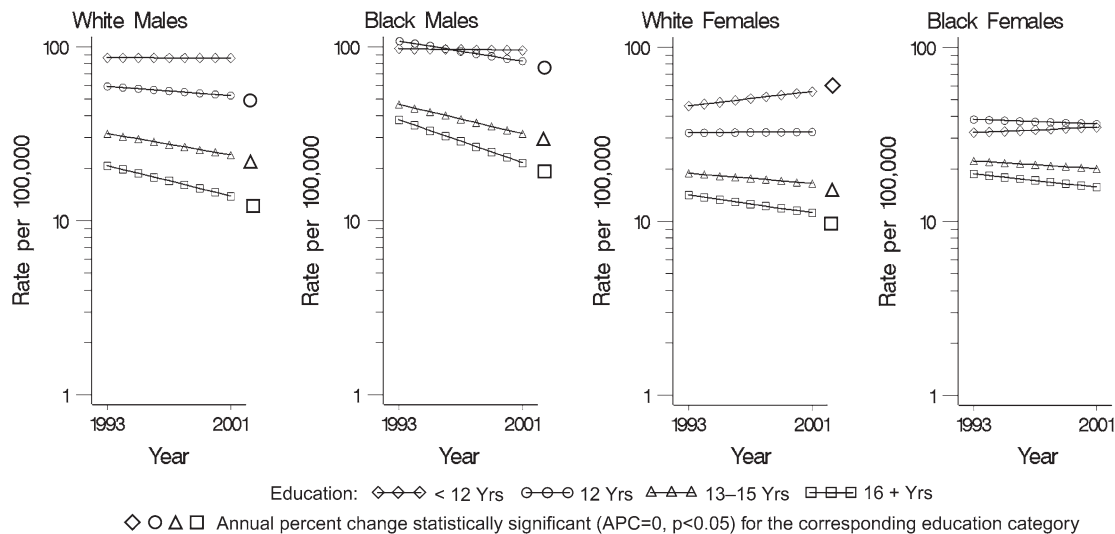


Figure 1. Temporal trends in age-adjusted US death rates from lung cancer by educational attainment for individuals aged 25–64 years in 43 states and the District of Columbia, 1993–2001. Annual percent change (APC) was estimated and tested for statistical significance using weighted log-linear regression models. The **symbols** at the right of the **lines** indicate APCs that are statistically significantly different from 0 at $P < .05$ (exact P values for all APCs are given in Table 1).

non-statistically significantly for black men ($P = .054$), from 1.4 to 2.0 (Table 1).

Discussion

This analysis of recent trends in mortality rates from the four most common cancer sites among 25- to 64-year-old white and black men and women in the United States by educational attainment illustrates that the remarkable reduction in mortality from these common cancers during this 9-year interval was confined largely to more highly educated men and women. Among the least educated persons (<12 years of education), by contrast, death rates increased for lung cancer in white women and for colorectal cancer

in black men; rates were stable for the remaining race-, sex-, and cancer site-specific groups except for breast cancer in white women, in whom rates declined. Differences among educational groups in temporal changes in risk factor patterns and access to prevention, early detection, and treatment services may plausibly explain these educational disparities in mortality trends.

Temporal trends in lung cancer mortality in the United States predominantly reflect historical patterns of smoking (29,30) because tobacco exposure accounts for approximately 90% and 70% of lung cancer deaths in US males and females, respectively (31). The proportion of Americans who never start to smoke has increased steadily since 1974 among those with at least some college education but has changed little among those with 12 or fewer

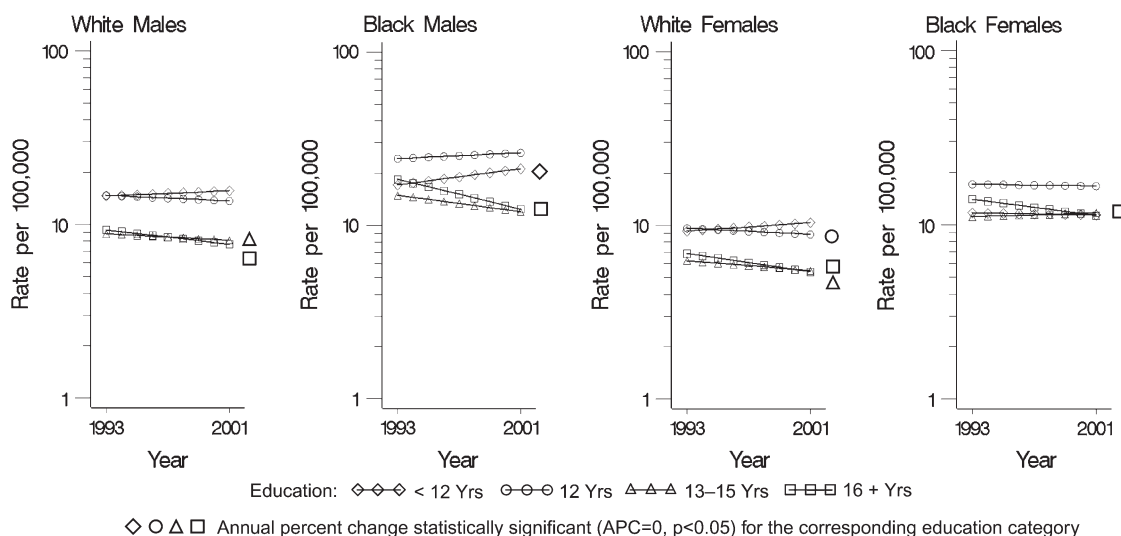


Figure 2. Temporal trends in age-adjusted US death rates from colon and rectal cancer by educational attainment for individuals aged 25–64 years in 43 states and the District of Columbia, 1993–2001. Annual percent change (APC) was estimated and tested for statistical significance using weighted log-linear regression models. The **symbols** at the right of the **lines** indicate APCs that are statistically significantly different from 0 at $P < .05$ (exact P values for all APCs are given in Table 1).

obesity and overweight, one of the most well-established behavioral risk factors for colorectal cancer (52). Prevalence of obesity has increased rapidly in every educational group among black and white men and women in the United States since the 1970s (53). This increase would be expected to contribute to the increase in colorectal cancer mortality rates among the least educated black men, help stall the decrease among lesser educated men and women, and attenuate the decrease among the most highly educated men and women.

A few previous studies have examined trends in colorectal cancer death rates by SES, but none have done so by educational attainment. Steenland et al. (12) reported that colorectal cancer death rates in 35- to 64-year-olds decreased from 1984 through 1997 in all SES groups among women but in only the highest SES group among men. Singh et al. (9) reported that colorectal cancer death rates during 1950–1998 decreased in all area-level socioeconomic groups, although the rate of decline was substantially greater in the higher than the lower SES areas. By contrast, among men aged 25–64 years, colorectal cancer mortality rates decreased in the higher SES areas and increased in the lower SES areas during the same time interval (9). Our data are generally consistent with the findings of these studies.

The remarkable decrease in US breast cancer death rates since 1990 has been attributed to earlier detection and improved treatment (54). Therefore, the smaller decrease in breast cancer death rates in less educated white women and the lack of decrease in less educated black women, compared with highly educated women, most likely reflect differences in early detection and treatment services. Between 1987 and 2000, the proportion of women aged 40 years or older who reported having had a mammogram within the past 2 years increased from 17% to 57% in those without a high school diploma and from 38% to 80% in those with a college degree (44). The disparities in mammography prevalence during 1987–2000 by health insurance status were even larger than the disparities by the educational attainment. (44). The National Breast and Cervical Cancer Early Detection Program of the CDC, whose mission is to increase the rate of cancer screening among low income and uninsured women, has covered only about 13% of all eligible women aged 40–64 years during 2002–2003 (55).

Poverty, lack of health insurance, and lack of a usual source of care (eg, a regular healthcare provider) have all been associated with receiving substandard breast cancer treatment (56–60). Bradley et al. (57) reported that breast cancer patients residing in census tracts with higher poverty rates are less likely to receive breast conserving surgery, radiation therapy following breast conserving surgery, and any forms of surgery than those residing in census tracts with lower poverty rates. They also found similar disparities in breast cancer treatment between Medicaid insured patients and those not insured by Medicaid (57).

At least three previous studies examined breast cancer mortality trends by SES. Wagener and Schatzkin (61) showed that, among women aged 45–64 years, breast cancer mortality among US women decreased from 1969 to 1989 only for white women in the two highest quintiles of county-level income but increased substantially for black women of every income level. Chu et al. (8) reported a decrease in breast cancer mortality rates for both white and black women in the United States from the early 1990s to the late 1990s in all poverty-area groups, with the rates of decrease

being larger among the higher SES women in both racial groups. Steenland et al. (12) also reported a decrease in breast cancer rates from 1984 through 1997 in all occupationally defined SES groups in 27 selected states. These findings are consistent with our results. However, our results are based on individual-level SES rather than area-level SES and are race specific.

The factors that have contributed to the reduction in prostate cancer death rates in the United States are less well understood than those that have contributed to the reduction in death rates for the other three major cancers because of the lack of known modifiable risk factors (62,63) and because the benefit of early detection using prostate-specific antigen (PSA) screening has not yet been proven. One study has suggested that part of the initial decrease (ie, >30% during the 1990s) in prostate cancer mortality in the United States was due to decreases in late-stage disease following widespread adoption of PSA testing (64); however, prostate cancer death rates have also decreased in countries where PSA testing is rare (65). The decrease in mortality rates in these countries and, to some extent, in the United States may reflect recent advances in treatment (7,66).

The more rapid decreases in prostate cancer mortality that we observed among white and black men with higher than lower levels of education are more likely to reflect differences by educational level in temporal changes in early detection and treatment than differences by education in changes in the underlying risk factors. A number of studies conducted on data from the 1990s have shown an association between low educational attainment, as measured on both area (67) and individual (44,68–71) levels, and lower use of PSA screening (44,68,71), more advanced disease severity at diagnosis (67,69,70), and decreased stage-specific survival (69). Furthermore, several studies (72–74) have found that socioeconomically disadvantaged persons are less likely than better-off individuals to receive aggressive treatment for prostate cancer.

The strengths of our study include the use of contemporary death rates that are based on 86% of the non-Hispanic white and non-Hispanic black US population from 1993 through 2001 and access to an individual-level measure of SES, that is, educational attainment. The large sample size allowed for precise statistical estimates of death rates by race, sex, and education for specific cancer sites. Education has desirable qualities as an individual-level indicator of SES, including its stability and close association with other indicators of SES that are not routinely obtained (75) and its ability to minimize the ecologic fallacy by avoiding use of area-level socioeconomic measure, although it has recognized limitations as an SES predictor among individuals older than 65 years (16–18). Because SES is a multifactorial construct that reflects a combination of individual- and geographic area-level influences, it is ideal to consider multiple indices of SES in examining relationships with health outcomes (76,77); however, that was not possible in our study because information on address of the deceased is not publicly available.

Our study has several additional limitations. First, the generalizability of our findings to all ages is limited because cancer deaths that occur at ages 25–64 years represent a small proportion of total cancer deaths. Disparities in mortality trends by education may differ among older individuals because those aged 65 years and above have universal access to health care through

Medicare. Indeed, preliminary analyses that were restricted to 65- to 74-year-olds showed weaker educational gradients in mortality trends (data not shown). For example, death rates for colorectal and prostate cancers decreased from 1993 through 2001 for every educational category among 65- to 74-year-old whites (data not shown), whereas rates remained stable in some educational categories among 25- to 64-year-old whites (Table 1). However, deaths in persons aged 25–64 years are of particular societal importance because they affect individuals who are most likely to be in the workforce, raising children, and/or supporting other family members (13).

Changes in coding and selection rules of underlying causes of death are additional potential limitations in interpretation of mortality trends. Beginning with the 1999 mortality data, underlying causes of death were classified by NCHS using *ICD-10*, replacing *ICD-9*, which had been used for mortality data since 1979. The *ICD-10* coding and selection rules, compared with the *ICD-9* rules, resulted in a 0.6% and 1.3% net increase in allocation of deaths to breast and prostate cancers, respectively, and in a 1.6% net decrease in allocation of deaths to lung cancer but essentially did not change the allocation of deaths to colorectal cancer (78). The *ICD* coding change could have attenuated the decrease in female breast and prostate cancer death rates and accelerated the decrease in breast cancer death rates. However, these changes are unlikely to have differentially affected mortality trends by education.

Another limitation of the study relates to known biases in how years of education are reported on death certificates. Sorlie and Johnson (16) showed that in 1989 a high proportion of US decedents who did not complete high school were misclassified as being high school graduates. This bias would have resulted in underestimation of death rates for those with less than complete high school educations and overestimation of rates for high school graduates. The more highly educated groups had little misclassification in the study of Sorlie and Johnson (16), and this bias was more pronounced for blacks than whites but appeared nondifferential between males and females. Whether the degree of misclassification changed over the period of our study (1993–2001) is unknown, but the findings of Sorlie and Johnson (16) suggest that such bias would likely affect the results in the conservative direction, reducing the magnitude of rate ratios comparing lowest to highest educational categories and possibly attenuating the temporal APC trends over educational levels.

A further limitation of the study is that, due to missing education data on some death certificates, a total of 2.6% of decedents from the study population (43 states and the District of Columbia) were excluded from the numerator but not from the denominator. The proportion of deaths with missing education decreased between 1993 and 2001 (Supplementary Tables 1 and 2, available online). Therefore, death rates by education were underestimated more in 1993 than in 2001, and the APCs may, therefore, have been overestimated for the increasing trends and underestimated for the decreasing trends shown in Table 1. Trend analyses among the same 43 states and the District of Columbia for all education levels combined inclusive of missing values resulted in slightly different APCs than those obtained with missing values excluded, especially for black men and women (Table 1). Similarly, the APCs

differed slightly when we examined data for the entire United States inclusive of missing values (data not shown). However, the statistical significance of the APCs and the interpretation of mortality trends from the four major cancers by race and sex in the study population were similar to those based on the entire US population and were not affected by the exclusion of deaths with missing education data, except that the decreasing trend in lung cancer death rates among black women became non-statistically significant (Table 1).

In conclusion, the recent reductions in death rates from major cancers in the United States have bypassed less educated working-age people, suggesting that persons in lower socioeconomic groups have not yet benefited equivalently from recent advances in prevention, early detection, and treatment of the major fatal cancers.

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