Cancer Mortality in the United States by Education Level and Race

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Background Although both race and socioeconomic status are well known to influence mortality patterns in the United States, few studies have examined the simultaneous influence of these factors on cancer incidence and mortality. We examined relationships among race, education level, and mortality from cancers of the lung, breast, prostate, colon and rectum, and all sites combined in contemporary US vital statistics.

Methods Age-adjusted cancer death rates (with 95% confidence intervals [CIs]) were calculated for 137 708 deaths among 119 376 196 individuals aged 25–64 years, using race and education information from death certificates and population denominator data from the US Bureau of the Census, for 47 states and Washington, DC, in 2001. Relative risk (RR) estimates were used to compare cancer death rates in persons with 12 or fewer years of education with those in persons with more than 12 years of education.

Results Educational attainment was strongly and inversely associated with mortality from all cancers combined in black and white men and in white women. The all-cancer death rates were nearly identical for black men and white men with 0–8 years of education (224.2 and 223.6 per 100 000, respectively). The estimated relative risk for all-cancer mortality comparing the three lowest (≤12 years) with the three highest (>12 years) education categories was 2.38 (95% CI = 2.33 to 2.43) for black men, 2.24 (95% CI = 2.23 to 2.26) for white men, 1.43 (95% CI = 1.41 to 1.46) for black women, and 1.76 (95% CI = 1.75 to 1.78) for white women. For both men and women, the magnitude of the relative risks comparing the three lowest educational levels with the three highest within each race for all cancers combined and for lung and colorectal cancers was higher than the magnitude of the relative risks associated with race within each level of education, whereas for breast and prostate cancer the magnitude of the relative risks associated with race was higher than the magnitude of the relative risks associated with level of education within each racial group. Among the most important and novel findings were that black men who completed 12 or fewer years of education had a prostate cancer death rate that was more than double that of black men with more schooling (10.5 versus 4.8 per 100 000 men; RR = 2.17, 95% CI = 1.82 to 2.58) and that, in contrast with studies of mortality rates in earlier time periods, breast cancer mortality rates were higher among women with less education than among women with more education (37.0 and 31.1 per 100 000, respectively, for black women and 25.2 versus 18.6 per 100 000, respectively, for white women).

Conclusion Cancer death rates vary considerably by level of education. Identifying groups at high risk of death from cancer by level of education as well as by race may be useful in targeting interventions and tracking cancer disparities.

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Socioeconomic factors are strong predictors of all-cause mortality and shortened life expectancy in the United States and many other Western countries (1–16). However, information on the relationship between socioeconomic factors and cancer incidence and mortality is more limited. Much of the data on the relationship between cancer incidence and mortality and individual-level socioeconomic indicators (such as education level, income, and occupation) has

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come from countries other than the United States, where standardized information on socioeconomic status (SES) is more widely collected (1,2). Although it is widely recognized that both race and SES influence mortality patterns and life expectancy in the United States, few studies have examined the simultaneous influence of these factors on cancer incidence and mortality in the United States. Those that did have analyzed area-level, rather than individual-level, socioeconomic characteristics across all races (3–5) or have included information on individual-level characteristics but did not report race-specific results (6–8). The studies that did analyze race-specific associations between cancer incidence and mortality and socioeconomic indicators used mortality data from earlier time periods (9,10), reported differences between blacks and whites in cancer mortality after accounting for differences in SES (11,12), or examined cancer incidence in localized geographic areas (13,14). Two US studies that examined associations between race, education level, and cancer mortality for a more recent time period focused on breast cancer (15,16).

Historically, information on individual-level SES and mortality has been available only from studies that linked information on level of education and other SES indicators obtained in interview studies with national death records (6,7,9,11). However, since 1989, the US standard death certificate has included information about the decedent's education level (specified as number of years of education completed). As of 2001, more than 80% of death certificates in 47 US states and Washington, DC, had complete information about the decedent's education level. We used death certificate data from 2001 and population data for 2001 from the Current Population Survey (CPS) conducted by the US Bureau of the Census to examine associations between educational level and age-standardized mortality rates for lung, breast, prostate, and colorectal cancers, individually and combined, by sex and by race.

CONTEXT AND CAVEATS

Prior knowledge

Both race and socioeconomic factors influence mortality patterns and life expectancy in the United States, but few studies have examined the simultaneous influence of these factors on cancer incidence and mortality in the United States.

Study design

Death certificate data from 2001 and population data from the 2001 Current Population Survey of the US Bureau of the Census were used to examine associations between educational level and age-standardized mortality rates for lung, breast, prostate, and colorectal cancers, individually and combined, by sex and by race.

Contribution

Education level was inversely associated with the rate of death from all cancers combined for black men, white men, and white women. The difference in cancer mortality was most pronounced between those with 12 or fewer years of education and those with more than 12 years of education.

Implications

Identifying groups at high risk of death from cancer by level of education as well as by race may be useful in targeting interventions and tracking cancer disparities.

Limitations

Educational attainment was the only indicator of individual socioeconomic status used. This study was restricted to individuals who were 25–64 years old at death and to blacks and whites, which limits the generalizability of the results to older individuals and to individuals of other races and ethnicities.

Methods

We used US mortality data for 2001 from the National Center for Health Statistics (NCHS) (17). Deaths from cancer as the underlying cause were identified using the coding and selection rules of the International Classification of Diseases, 10th Revision (ICD-10) (18). There were 553 768 deaths with cancer as the underlying cause in 2001. We restricted our analyses to cancer deaths that occurred in individuals who were 25–64 years old at death (n = 160 348) because individuals who were younger than 25 years when they died may not have completed their education and because the information on educational status on death certificates for individuals who were younger than 65 years at death is more accurate and better predicts SES than that for individuals who were 65 years or older at death (19,20). Our analyses were further restricted to blacks and non-Hispanic whites (n = 146 616) because death certificate information on race and ethnicity is less accurate among other populations (21,22). We excluded 5691 deaths that occurred in Georgia, Rhode Island, and South Dakota because fewer than 80% of the death certificates in these states had complete education information. We excluded another 3217 deaths that occurred in other states because of missing data on education; the excluded deaths comprised 854 (3.8%) of the 22 670 deaths among blacks and 2363 (2.0%) of the 118 255 deaths among whites. The 137 708 deaths included in the analysis represent 97.7% of all cancer deaths that occurred among black and non-Hispanic white men and women aged 25–64 years in 47 states and Washington, DC, in 2001.

The following ICD-10 codes were used to determine the underlying cause of death: C00–C97 for all cancers, C34 for lung/bronchus cancer, C18–C20 and C26.0 for colorectal cancer, C61 for prostate cancer, and C50 for female breast cancer (18). The number of cancer deaths, the percentage of the population at risk, and age-standardized death rates for all cancer sites combined by sex, race, and educational attainment are provided in Table 1; numbers of deaths and age-standardized death rates for lung, colorectal, prostate, and breast cancer are provided in Supplementary Tables 1 and 2 (available online).

The denominators used to calculate mortality rates (i.e., populations of men and women aged 25–64 years within strata of education level, attained age, and race) were estimated using CPS data from the US Bureau of the Census for the year 2001. The CPS covers a nationally representative sample of US households weighted to resident population totals (23). The CPS data, which were obtained by NCHS through an interagency agreement with the US Bureau of the Census, are used by NCHS to produce its official national death rates by educational attainment (24,25). We excluded populations from Georgia, Rhode Island, and South Dakota from the denominators. There were 119 376 196 individuals in the population studied.

Table 1. Number of deaths and death rates by sex, race, and educational attainment for all cancers combined in 47 states and Washington, DC, United States, 2001*

Educational attainment, y	Population denominator		No. of cancer deaths	Cancer death rate (95% CI)
	No. of people	% of total		
Men				
Black				
0–8	334309	4	1168	224.2 (179.1 to 269.3)
9–11	901498	12	2384	228.7 (201.9 to 255.5)
12	3115745	40	5222	217.4 (196.4 to 238.4)
13–15	2155494	28	1515	95.4 (82.6 to 108.2)
16	949495	12	584	85.2 (69.6 to 100.8)
≥17	340598	4	325	82.8 (62.6 to 103.0)
P_{trend}†				.04
Non-Hispanic white				
0–8	1015464	2	4155	223.6 (203.3 to 243.9)
9–11	3024396	6	6822	196.5 (183.2 to 209.8)
12	16139559	32	26063	152.5 (147.6 to 157.4)
13–15	13971596	27	11205	81.2 (77.9 to 84.5)
16	10907465	21	7193	70.7 (67.3 to 74.1)
≥17	5953728	12	4938	63.4 (60.1 to 66.7)
P_{trend}†				.03
Women				
Black				
0–8	296381	3	495	107.2 (85.8 to 128.6)
9–11	1185734	13	1617	122.2 (109.1 to 135.3)
12	3092002	34	4799	170.6 (157.1 to 184.1)
13–15	2825224	32	2183	96.3 (87.0 to 105.6)
16	1099524	12	958	116.1 (97.3 to 134.9)
≥17	469518	5	566	116.0 (92.9 to 139.1)
P_{trend}†				.69
Non-Hispanic white				
0–8	873602	2	2376	167.4 (149.8 to 184.9)
9–11	2727272	5	5232	151.2 (141.4 to 161.0)
12	16748626	32	25925	123.7 (120.4 to 127.0)
13–15	15317386	30	11375	73.5 (70.9 to 76.0)
16	10867260	21	6326	71.0 (67.4 to 74.6)
≥17	5064320	10	4282	76.6 (72.2 to 81.0)
P_{trend}†				.07

* Numbers of deaths are from the 2001 National Vital Statistics public files. Cancer death rates are per 100000 and are age adjusted to the US 2000 standard population of blacks and whites aged 25–64 years using denominator data from the 2001 Current Population Survey of the US Bureau of the Census. Three states (Georgia, Rhode Island, and North Dakota) for which more than 20% of the education data were missing were excluded. CI = confidence interval.

† P_{trend} estimated by inverse variance weighted linear regression of the relationship between years of education (based on an estimated median for each category of 6, 10, 12, 14, 16, and 18 years) and death rates.

Information on years of education was recorded on the death certificate as the number of years of formal schooling completed by the decedent (range = 0–17 or more years). This information was typically provided by a relative of the decedent. We categorized educational attainment into six groups: 0–8 years, 9–11 years, 12 years (high school graduate or equivalent), 13–15 years, 16 years (college graduate or equivalent), and 17 or more years.

We used data from the 2000 National Health Interview Survey (NHIS) (26), a national survey of the non-institutionalized civilian population conducted by the NCHS, to assess patterns in selected cancer risk factors and screening utilization by educational attainment. A total of 32374 adults participated in the 2000 NHIS, and the final response rate was 82.6%. Our analysis included the 13326 non-Hispanic white and 2953 black men and women aged 25–64 years who provided data on the 2000 NHIS on educational attainment, smoking practices, obesity, health insurance, and utilization of mammography and colorectal screening.

Statistical Analysis

We calculated age-specific and age-standardized death rates (per 100000 persons) for all cancers combined and for the four main cancer sites (lung, prostate, colon/rectum, and breast) by sex, race, 5-year age groups, and educational attainment. Rates were age standardized to the 2000 US standard population, aged 25–64 years. The 95% confidence intervals (CIs) were calculated using methods that take into account both the random variability of the numerator and the sampling variability of the denominator (25). Because errors in classification of level of education on death certificates most often involve specification of 12 years of education on the death certificate for those with fewer than 12 years of education (19), we also report the rate ratios and 95% confidence intervals comparing the average

death rates in the three lowest with the three highest educational attainment categories, thereby comparing death rates among those who completed 12 or fewer years of education (high school graduate or less), referred to as "lower levels of education," with those who completed more than 12 years of education, referred to as "higher levels of education."

We used cross-sectional prevalence data from the 2000 NHIS to examine the distribution of important cancer risk and preventive factors by level of education among 25- to 64-year-olds in the US population. Factors considered were lack of heath insurance (by both private and public health insurance), current cigarette smoking, obesity (body mass index of 30 kg/m^2 or more based on self-reported height and weight), and utilization of mammography and colorectal cancer screening. The age range used to calculate the prevalence of mammography screening (defined as having had a mammogram in the previous 2 years) was restricted to 40–64 years because guidelines for screening in average-risk women generally recommend screening at age 40; the age range used to calculate the prevalence of colorectal cancer screening (defined as having had a fecal occult blood test in the previous year and/or flexible sigmoidoscopy or colonoscopy in the previous 5 years) was restricted to 50–64 years old because guidelines for screening in average-risk men and women recommend screening at age 50. All estimates were age adjusted to the standard US population in 2000 and were calculated using SUDAAN software (27), which takes into account the complex sampling design of the NHIS.

Results

Mortality for All Cancer Sites Combined

Educational attainment was inversely associated with mortality from all cancers combined in both black and white men aged 25–64 years (Fig. 1; Tables 1 and 2). The all-cancer death rate was nearly identical for black and white men with 0–8 years of education (224.2 per 100 000 persons [95% CI = 179.1 to 269.3 per 100 000 persons] and 223.6 per 100 000 persons [95% CI = 203.3 to 243.9 per 100 000 persons], respectively) (Fig. 1). The all-cancer death rate was 3.5 times higher among white men with 0–8 years of education than among white men with 17 or more years of education (223.6 per 100 000 persons [95% CI = 203.3 to 243.9 per 100 000 persons] versus 63.4 per 100 000 persons [95% CI = 60.1 to 66.7 per 100 000 persons]); the all-cancer death rate was 2.7 times higher among black men with 0–8 years of education than among black men with 17 or more years of education (224.2 per 100 000 persons [95% CI = 179.1 to 269.3 per 100 000 persons] versus 82.8 per 100 000 persons [95% CI = 62.6 to 103.0 per 100 000 persons]) (Fig. 1; Table 1). Most of the variation in all-cancer mortality among black and white men occurred between those with lower educational attainment (i.e., ≤12 years) and those with higher educational attainment (i.e., >12 years) (Fig. 1). The relative risk of all-cancer mortality estimated for lower compared with higher levels of education in black men was 2.38 (95% CI = 2.33 to 2.43); for white men, it was 2.24 (95% CI = 2.23 to 2.26) (Table 2).

Among white women, the all-cancer death rate for individuals with 0–8 years of education was 2.2 times higher than that for individuals with 17 or more years of education (167.4 per 100 000 persons [95% CI = 149.8 to 184.9 per 100 000 persons] versus 76.6 per 100 000 persons [95% CI = 72.2 to 81.0 per 100 000 persons]). As was observed in men, most of the variation in all-cancer mortality among white women occurred between those with lower (≤12 years) and higher (>12 years) educational attainment (Fig. 1). In white women, the relative risk of all-cancer mortality estimated for lower compared with higher levels of education was 1.76 (95% CI = 1.75 to 1.78) (Table 2). Among black women, by contrast, there was no consistent trend in all-cancer death rates by level of education; the highest death rate was observed among women who completed 12 years of education (Fig. 1; Table 1). However, despite the lack of a consistent trend, the relative risk of all-cancer mortality among black women in the three highest compared with the three lowest levels of education was 1.43 (95% CI = 1.41 to 1.46) (Table 2).

All-cancer mortality rates for black men were higher than those for white men in all six educational categories (Fig. 1; Table 1). Among men in the lowest three levels of education, the relative risk of all-cancer mortality in black compared with white men was 1.31 (95% CI = 1.30 to 1.32), and among men in the highest three levels of education, the relative risk of all-cancer mortality in black men compared with white men was 1.23 (95% CI = 1.21 to 1.26) (Table 2). Among women, all-cancer death rates were statistically significantly higher in black compared with white women in four of six categories of education (Fig. 1; Table 1). Among women in the lowest three levels of education, the relative risk of all-cancer mortality in black women compared with white women was 1.15 (95% CI = 1.14 to 1.16); among women in the highest three levels of education, the relative risk of all-cancer mortality in black women compared with white women was 1.42 (95% CI = 1.39 to 1.44) (Table 2). Thus, for both men and women, the magnitude of the relative risks for all-cancer mortality between the three lowest and the three highest educational levels within each race was higher than the relative risks associated with race at each level of education (Table 2).

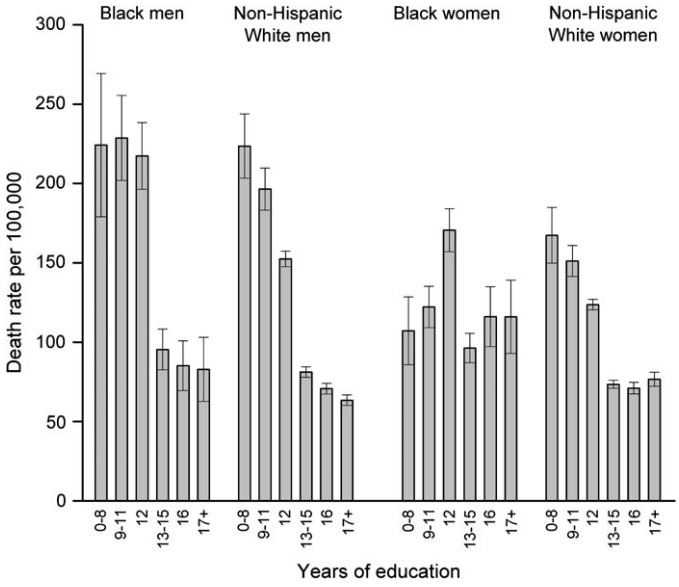

Fig. 1. All-site cancer mortality rates, by education level, sex, and race, for persons aged 25–64 years in the United States, 2001. **Error bars** correspond to 95% confidence intervals.

Table 2. Death rates per 100 000 persons from selected cancers and relative risks of death by educational attainment, race, and sex in the United States, 2001*

	Men			Women		
Cancer site	**Black**	**Non-Hispanic white**	**RR (95% CI)**	**Black**	**Non-Hispanic white**	**RR (95% CI)**
All cancers						
≤12 years of education	214.4	163.8	1.31 (1.30 to 1.32)	148.1	128.8	1.15 (1.14 to 1.16)
>12 years of education	90.1	73.0	1.23 (1.21 to 1.26)	103.3	73.0	1.42 (1.39 to 1.44)
RR (95% CI)	2.38 (2.33 to 2.43)	2.24 (2.23 to 2.26)		1.43 (1.41 to 1.46)	1.76 (1.75 to 1.78)	
Lung cancer						
≤12 years of education	73.2	61.0	1.20 (1.18 to 1.22)	30.8	37.1	0.83 (0.80 to 0.86)
>12 years of education	25.8	18.1	1.42 (1.35 to 1.50)	17.9	14.2	1.26 (1.18 to 1.34)
RR (95% CI)	2.84 (2.69 to 3.00)	3.36 (3.30 to 3.43)		1.72 (1.61 to 1.84)	2.60 (2.53 to 2.67)	
Colorectal cancer						
≤12 years of education	20.6	14.2	1.45 (1.37 to 1.53)	14.1	9.4	1.51 (1.41 to 1.62)
>12 years of education	11.3	7.9	1.44 (1.30 to 1.59)	10.8	5.4	1.99 (1.81 to 2.19)
RR (95% CI)	1.81 (1.63 to 2.02)	1.81 (1.73 to 1.89)		1.31 (1.18 to 1.45)	1.72 (1.63 to 1.82)	
Prostate cancer						
≤12 years of education	10.5	3.3	3.22 (2.94 to 3.53)			
>12 years of education	4.8	2.2	2.19 (1.84 to 2.60)		NA	
RR (95% CI)	2.17 (1.82 to 2.58)	1.47 (1.34 to 1.62)				
Breast cancer						
≤12 years of education				36.1	25.2	1.43 (1.37 to 1.48)
>12 years of education		NA		31.1	18.5	1.68 (1.60 to 1.76)
RR (95% CI)				1.16 (1.10 to 1.22)	1.36 (1.32 to 1.40)	

* Number of deaths is from the 2001 National Vital Statistics public files. Cancer death rates are per 100 000 and are age adjusted to the US 2000 standard population of blacks and whites aged 25–64 years using denominator data from the 2001 Current Population Survey of the US Bureau of the Census. Three states (Georgia, Rhode Island, and North Dakota) for which more than 20% of the education data were missing were excluded. RR = relative risk; CI = confidence interval; NA = not applicable.

Lung Cancer Mortality

The variation in lung cancer mortality with years of education (Fig. 2; Table 2; Supplementary Table 1, available online) was larger than that seen for other cancer sites. The largest variability in death rates by level of education was observed among white men, in whom the death rate was nearly ninefold higher among those with 0–8 compared with 17 or more years of education (94.5 per 100 000 [95% CI = 84.9 to 104.1 per 100 000] for those with 0–8 years of education versus 10.7 per 100 000 [95% CI = 9.8 to 11.6 per 100 000] for those with 17 or more years of education). The relative risks of lung cancer mortality in the three lowest compared with the three highest educational categories, from lowest to highest relative risk, were 1.72 (95% CI = 1.61 to 1.84) for black women, 2.60 (95% CI = 2.53 to 2.67) for white women, 2.84 (95% CI =2.69 to 3.00) for black men, and 3.36 (95% CI = 3.30 to 3.43) for white men (Table 2).

Lung cancer mortality rates were substantially higher in black men than in white men in five of the six educational categories (Fig. 2; Supplementary Table 1, available online). Among men in the lowest three levels of education, the relative risk of lung cancer mortality in black compared with white men was 1.20 (95% CI = 1.18 to 1.22), whereas among men in the three highest levels of education, the relative risk of lung cancer mortality in black men compared with white men was 1.42 (95% CI = 1.35 to 1.50) (Table 2). Among women, lung cancer death rates were substantially higher in black women compared with white women in four of six categories of education (Fig. 2; Supplementary Table 1, available online). Among women in the lowest three levels of education, the relative risk of lung cancer mortality in black women compared with white women was 0.83 (95% CI = 0.80 to 0.86); among women in the highest three levels of education, the relative risk of lung cancer mortality for black women compared with white women was 1.26 (95% CI = 1.18 to 1.34) (Table 2). Thus, in both men and women, the magnitudes of the relative risks for lung cancer mortality comparing the three lowest with the three highest educational levels within each race were higher than the relative risks associated with race within each level of education (Table 2).

Colorectal Cancer Mortality

Associations between educational attainment and colorectal cancer mortality were weaker than the associations between educational

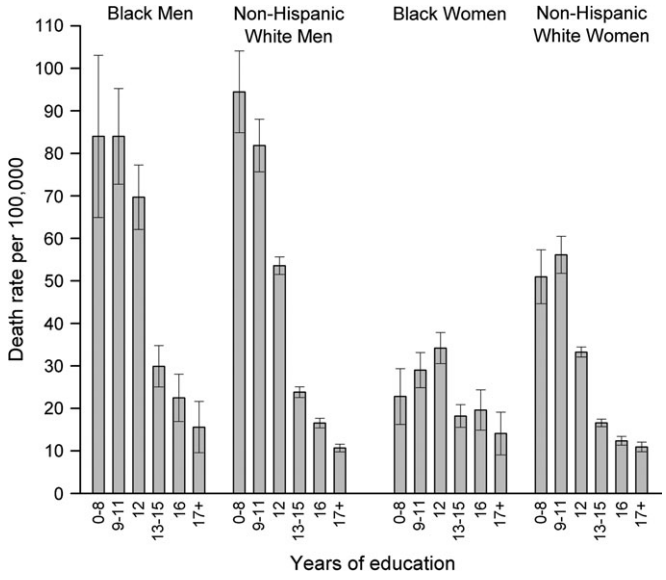

Fig. 2. Lung cancer mortality rates, by education level, sex, and race, for persons aged 25–64 years in the United States, 2001. **Error bars** correspond to 95% confidence intervals.

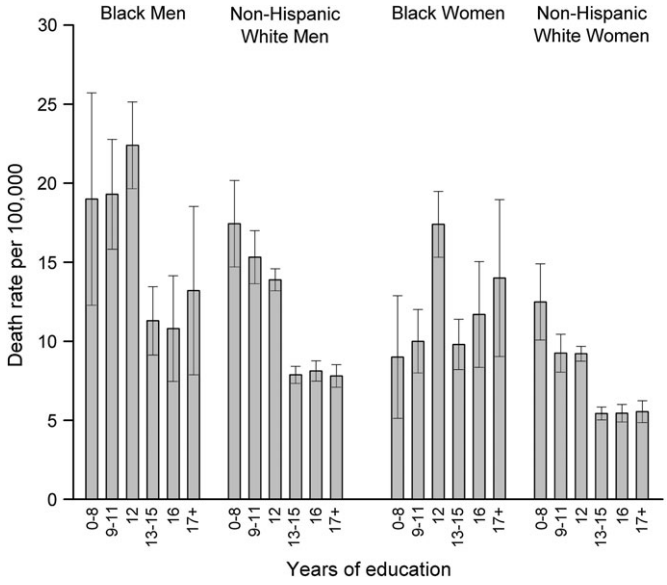

Fig. 3. Colorectal cancer mortality rates, by education level, sex, and race, for persons aged 25–64 years in the United States, 2001. **Error bars** correspond to 95% confidence intervals.

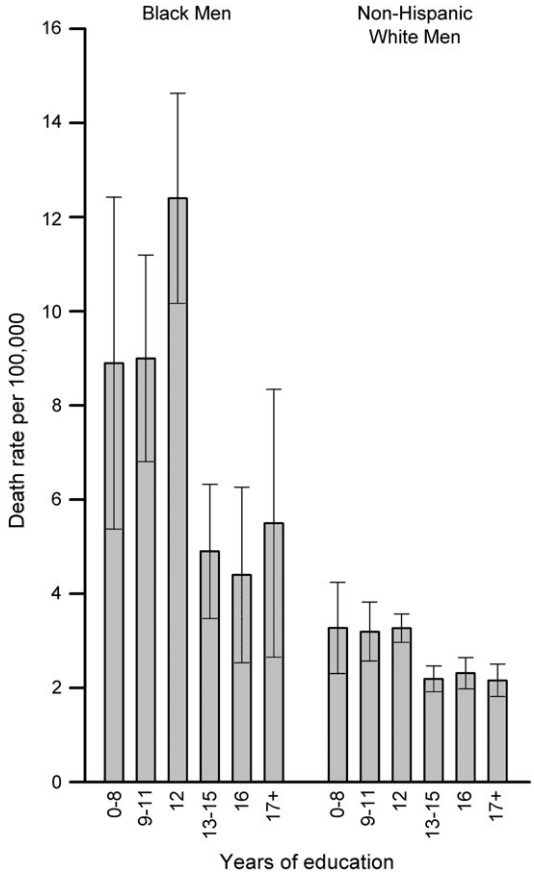

Fig. 4. Prostate cancer mortality rates, by education level and race, for men aged 25–64 years in the United States, 2001. **Error bars** correspond to 95% confidence intervals.

attainment and lung cancer mortality and varied more by race and sex (Fig. 3). Among both white men and white women, colorectal cancer death rates were approximately 2.2 times higher for individuals with 0–8 years of education than for individuals with 17 or more years of education; for white men, the death rates were 17.4 per 100 000 (95% CI = 14.7 to 20.1 per 100 000) for those with 0–8 years of education and 7.8 per 100 000 (95% CI = 7.1 to 8.5 per 100 000) for those with 17 or more years of education, and for white women, the death rates were 12.5 per 100 000 (95% CI = 10.1 to 14.9 per 100 000) for those with 0–8 years of education and 5.5 per 100 000 (95% CI = 4.8 to 6.2 per 100 000) for those with 17 or more years of education. In both white men and white women, rates generally declined across the six education levels, with almost no variation in rates in the top three levels of education. Among black men, colorectal cancer death rates were approximately 1.4 times higher for individuals with 0–8 years of education (19.0 per 100 000; 95% CI = 12.3 to 28.0 per 100 000) than for those with 17 or more years of education (13.2 per 100 000; 95% CI = 7.9 to 20.9 per 100 000), but no consistent trend in death rates by level of education was observed (Fig. 3; Supplementary Table 1, available online). Among black women, the colorectal cancer death rates were highest among those with 12 years of education and 17 or more years of education, and again there was no consistent trend in death rates by level of education (Fig. 3; Supplementary Table 1, available online). Nonetheless, relative risk estimates comparing the death rates in the three lowest with the three highest educational levels were statistically significantly different from 1.0 for all race and sex groups, including black women (Table 2).

Colorectal cancer mortality rates were substantially higher in black men than in white men in all educational categories presented (Fig. 3; Supplementary Table 1, available online). Among men in the lowest three levels of education, the relative risk of colorectal cancer mortality for black men compared with white men was 1.45 (95% CI = 1.37 to 1.53); among men in the highest three levels of education, the relative risk of colorectal cancer mortality was 1.44 (95% CI = 1.30 to 1.59). Colorectal cancer death rates were higher among black women than among white women in four of six categories of education (Fig. 3; Supplementary Table 1, available online). Among women in the lowest three levels of education, the relative risk of colorectal cancer mortality for black women compared with white women was 1.51 (95% CI = 1.41 to 1.62), whereas among women in the highest three levels of education categories, the relative risk of colorectal cancer mortality for black women compared with white women was 1.99 (95% CI = 1.81 to 2.19). Thus, in both men and women, the magnitude of the relative risks for colorectal cancer mortality comparing the three lowest with the three highest educational levels within each race was higher than the relative risks associated with race within each level of education (Table 2).

Prostate Cancer Mortality

Prostate cancer mortality varied with education level to a greater extent among black men than among white men (Fig. 4). Among black men, the highest prostate cancer death rate was among those in the 12 years of education group (12.4 per 100 000; 95% CI = 10.2 to 14.6 per 100 000) and the lowest was among those in the 16 years of education group (4.4 per 100 000; 95% CI = 2.5 to 7.2 per 100 000) (Fig. 4; Supplementary Table 2, available online). The relative risk of prostate cancer mortality for the three lowest

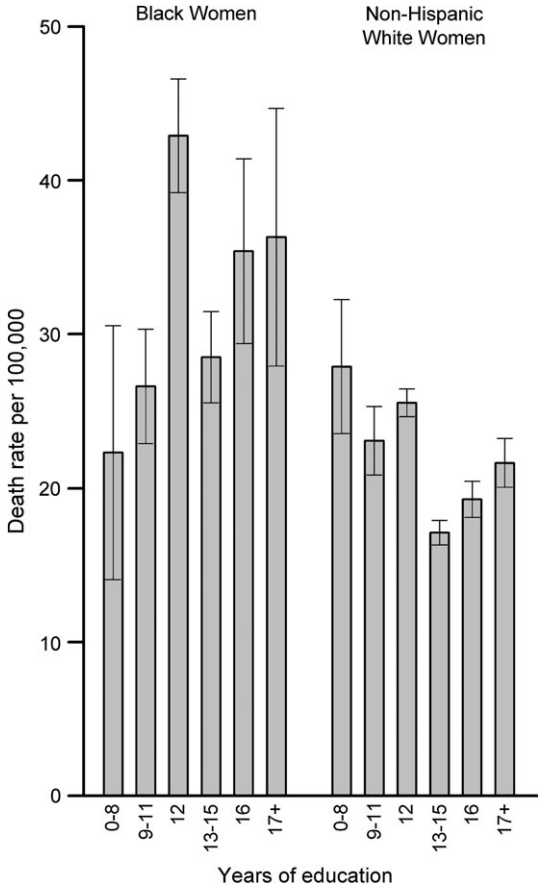

Fig. 5. Breast cancer mortality rates, by education level and race, for women aged 25–64 years in the United States, 2001. **Error bars** correspond to 95% confidence intervals.

compared with the three highest levels of educational attainment among black men was 2.17 (95% CI = 1.82 to 2.58) (Table 2). Among white men, prostate cancer death rates varied from 2.2 to 3.3 per 100 000 (Fig. 4; Supplementary Table 2, available online); the relative risk in the three lowest compared with the three highest level-of-education categories among white men was 1.47 (95% CI = 1.34 to 1.62) (Table 2).

Prostate cancer mortality rates in black men were higher than those among white men in all six educational categories (Fig. 4; Supplementary Table 2, available online). Among men in the lowest three levels of education, the relative risk of prostate cancer mortality for black men compared with white men was 3.22 (95% CI = 2.94 to 3.53); among men in the highest three levels of education categories, the relative risk for black men compared with white men was 2.19 (95% CI = 1.84 to 2.60) (Table 2). Thus, despite the substantial variability in prostate cancer mortality by level of education, especially among black men, the magnitude of the relative risks associated with race within the three lowest compared with the three highest education levels was substantially higher than the magnitude of the relative risks for level of education within race (Table 2).

Breast Cancer Mortality in Women

Breast cancer mortality varied with level of education among both black and white women (Fig. 5). Among black women, the highest breast cancer death rates were observed in the 12 years of education group (42.9 per 100 000; 95% CI = 39.2 to 46.6 per 100 000) and the 17 or more years of education group (36.3 per 100 000; 95% CI = 27.9 to 44.7 per 100 000) and the lowest rates were among those with 0–8 years of education (22.3 per 100 000; 95% CI = 14.1 to 33.4 per 100 000) (Fig. 5; Supplementary Table 2, available online). Among black women, the relative risk of death from breast cancer for women in the three lowest levels of education compared with those in the three highest levels of education was 1.16 (95% CI = 1.10 to 1.22) (Table 2). Among white women, breast cancer death rates varied from 17.1 per 100 000 (95% CI = 16.3 to 17.9 per 100 000) for those with 13–15 years of education to 27.9 per 100 000 (95% CI = 23.5 to 32.3 per 100 000) for those with 0–8 years of education (Fig. 5; Supplementary Table 2, available online). The relative risk of death from breast cancer for white women in the three lowest levels of education compared with the three highest levels of education was 1.36 (95% CI = 1.32 to 1.40) (Table 2).

Breast cancer death rates were substantially higher among black women than among white women in five of the six education level categories (Fig. 5; Supplementary Table 2, available online). Among women in the three lowest levels of education, the relative risk of breast cancer mortality in black women compared with white women was 1.43 (95% CI = 1.37 to 1.48); among women in the three highest levels of education, the relative risk of breast cancer mortality in black women compared with white women was 1.68 (95% CI = 1.60 to 1.76) (Table 2). Thus, the magnitude of the relative risks of breast cancer mortality associated with race within the population of women in the three lowest education levels compared with those in the three highest education levels was substantially higher than the magnitude of the relative risks for level of education within race (Table 2).

Association Between Education Level and Selected Cancer Risk Factors

A number of factors could influence the association between education level and cancer death rate, including access to medical care associated with lack of health insurance; the prevalence of exposure to important cancer risk factors, such as cigarette smoking and obesity; and the likelihood of cancer screening utilization. The contribution of these factors to the variations in cancer mortality observed in this study could not be assessed because information about these factors is not available on death certificates. Instead, we examined the relationship between educational attainment and various factors that may increase or decrease risk of cancer death using data from the NHIS, a national population-based survey that was conducted in 2000 (26). Within each race and sex group, the percentage of individuals without health insurance generally declined as education level increased (Table 3). The percentage of individuals reporting that they currently smoked cigarettes also declined with increasing level of education (Table 3). We observed no consistent trend for the relationship between level of educational attainment and the percentage of individuals who were considered obese (defined as having a body mass index $\geq$30 kg/m^2), even though in most race–sex groups the percentage of obese individuals was lower among individuals in the two highest level-of-education categories than among all others (Table 3). The percentage of black women who reported having had a mammogram during the previous 2 years was lowest among those with 0–11 years of education

Table 3. Relationship between years of education completed and selected risk factors for cancer mortality by sex and race, National Health Interview Survey (NHIS), 2000*

	Education level					
Risk factor	**0–8 y**	**9–11 y**	**12 y**	**13–15 y**	**16 y**	**≥17 y**
No health insurance, %						
Black men	35.5	30.0	24.9	14.1	13.1	13.9
Non-Hispanic white men	33.2	32.4	16.1	12.8	4.9	4.5
Black women	26.2	27.3	24.4	16.9	10.6	3.8
Non-Hispanic white women	32.8	27.0	13.9	10.5	5.7	2.1
Current cigarette smokers, %						
Black men	40.7	43.8	33.6	23.3	16.3	15.0
Non-Hispanic white men	57.6	52.3	37.9	26.8	14.6	10.1
Black women	27.9	37.7	28.6	21.3	11.7	11.4
Non-Hispanic white women	37.5	44.1	33.6	25.0	13.4	7.6
Body mass index ≥ 30 kg/m^2, %						
Black men	22.4	29.3	25.6	28.5	26.1	18.2
Non-Hispanic white men	25.5	30.4	25.0	24.8	18.1	16.8
Black women	39.7	49.7	38.0	35.4	27.6	23.2
Non-Hispanic white women	38.6	27.2	22.8	23.2	13.4	11.8
Had a mammogram during the previous 2 years†, %						
Black women		58.2	70.6	67.9	83.1	
Non-Hispanic white women		58.5	69.4	74.1	81.7	
Had colorectal cancer screening‡,%						
Black men		39.5	36.7	42.8	35.8	
Non-Hispanic white men		30.1	41.3	42.2	53.7	
Black women		29.1	30.4	34.8	47.5	
Non-Hispanic white women		31.2	36.7	42.9	49.8	

* Restricted to NHIS survey respondents, aged 25–64 years in the NHIS, except where noted; all percentages are age standardized to US 2000 standard population.

† Restricted to women 40–64 years old. The 0–8 and 9–12 years-of-education categories were combined because of small numbers; the 16 and 17 or more years-of-education categories were also combined because of small numbers.

‡ Restricted to adults 50–64 years old. Includes fecal occult blood testing during the previous year and endoscopy during the previous 5 years. The 0–8 and 9–12 years-of-education categories were combined because of small numbers; the 16 and 17 or more years-of-education categories were also combined because of small numbers.

(i.e., 58.2%) and highest among those with 16 or more years of education (i.e., 83.1%). Among white women, 58.5% of those with 0–11 years of education and 81.7% of those with 16 or more years of education reported having had a mammogram during the previous 2 years (Table 3). The prevalence of colorectal cancer screening did not vary in a consistent fashion by level of education (Table 3).

Discussion

We found an inverse relationship between education level and the rate of death from all cancers combined for black men, white men, and white women. The difference in cancer mortality was most pronounced between those with 12 or fewer years of education and those with more than 12 years of education. For all cancers combined and for lung and colorectal cancers, the relative risks of death among individuals in the lowest three compared with the highest three levels of education within each race and sex group were larger than the relative risks of death among black men compared to white men and black women compared to white women within the three lowest versus the three highest education categories. This pattern was not observed for prostate cancer or breast cancer, for which the relative risks of death associated with race within the three lowest versus the three highest levels of education were larger than the relative risks of death associated with the level of education within race.

Death rates for all cancers combined and the four cancer sites studied were generally higher among blacks than among whites with similar levels of education. Higher cancer mortality among blacks compared with whites at similar levels of education likely reflects socioeconomic disparities in work, wealth, income, housing, overall standard of living, and access to medical care that are not fully captured by the single measure of SES available for our analysis (i.e., years of education). It is also noteworthy that a higher proportion of the black population than the white population aged 25–64 years (53% versus 40%) was represented in the three lowest level-of-education categories (Table 1); thus, any variations in cancer mortality by level of education will have a disproportionate impact in the black population.

A novel finding of our study was the large difference in prostate cancer mortality in relation to education in both black and white men. Black men who completed 12 or fewer years of education had a prostate cancer death rate that was more than double that of black men with further schooling. Although the relationship between education level and prostate cancer mortality was weaker in white men than in black men and was not linear in men of either race, the observed associations between prostate cancer mortality

and level of education suggests that modifiable factors associated with lower levels of education may play an important role in the uniquely high mortality from prostate cancer among black men. No prior study, to our knowledge, has examined the relationship between educational attainment and prostate cancer mortality in blacks and whites separately using a nationally representative sample, although several studies have examined the association between SES and prostate cancer incidence or mortality (5,7,8,28–34) with inconsistent results. Some studies (28,34) have shown a positive association between prostate cancer incidence and SES, but others (35) have not. Studies of this association have varied with respect to the time period studied, geographic locations, and SES measures used in the studies. The reasons for the inverse relationship that we observed between education level and prostate cancer mortality are not known.

A second novel finding of our study was an apparent change in the direction of the relationship between educational attainment and breast cancer mortality compared with previous studies. Historically, studies in the United States and Europe have found that women with higher levels of education (or other characteristics related to higher SES) have higher risks of developing breast cancer (36,37) and of dying from breast cancer (9,37) than women with lower levels of education. Our study found that among women who died in 2001, the most recent time period to be analyzed in any study, the risk of dying of breast cancer is lower among more highly educated women than in less highly educated women. The positive association between SES and breast cancer incidence and mortality in earlier studies has been attributed to a higher prevalence of reproductive risk factors, including later age at first birth among women of higher compared with lower SES (9,36,37). Changing patterns of breast cancer mortality by SES may be related to a number of factors. Differences in reproductive patterns by SES that resulted in increased breast cancer risk among higher SES women have diminished over time, while differences in survival related to earlier detection and timely, high-quality treatment among higher SES women have increased (38). The positive association between education and breast cancer mortality has been previously reported to be diminishing or disappearing in the United States (16,39), France (40), and Finland (41). However, to our knowledge, this is the first study to document an actual reversal in the association, such that in the United States in a recent time period, higher education is associated with lower breast cancer death rates among both black and white women.

An important strength of this study is its use of contemporary national vital statistics data, which provided nearly complete ascertainment of deaths in the US population. The 137 708 deaths included in this study represent 97.7% of all cancer deaths among individuals who were 25–64 years old and lived in most states in the United States and include a sufficiently large number of blacks to allow us to conduct race-specific analyses. The associations between educational attainment and all-cancer mortality for black and white men and for white women observed in this study are, in general, stronger than those observed in previous US studies (7,9,10,32) and in studies of level of education and cancer incidence or mortality in other countries (1,42). These differences may reflect the broader representation of all socioeconomic strata in the general population in our study, as well as the increasing differences in morbidity and mortality by race and SES for many chronic conditions observed in the past several decades in the United States and Europe (1,2,43–46). Several studies (43,46) have documented that declines in mortality rates for many causes of death that are associated with improvements in disease prevention and treatment have had a much greater impact on whites than on blacks and in higher SES areas than in lower SES areas.

The collection of level-of-education information on death certificates provides a potentially important opportunity to identify and monitor disparities in population health, which could potentially lead to effective public health interventions. However, the usefulness of vital statistics data to analyze the relationship between individual educational attainment and mortality depends on the validity of individual-level information on death certificates. Sorlie and Johnson (19) assessed the validity of the education information on death certificates by comparing it with data previously self-reported by participants in the National Longitudinal Mortality Study (NLMS). They found a high level of agreement (ranging from 70% to 85%) between the NLMS and death certificates for three broad categories of educational attainment (≤11, 12–15, and >16 years). However, they also found that the level of education as reported on death certificates was systematically rounded up, such that 38% of persons who were listed as high school graduates on death certificates had less than a high school education by previous self-report. This discrepancy was greater among death certificates of blacks (50%) than among those of whites (36%) (19). Although such misclassification of individuals with less than a high school education may produce an underestimate of death rates for individuals with fewer than 12 years of education and a corresponding overestimate of death rates for individuals with 12 years of education, it does not bias the comparison of death rates between those who are educated beyond high school and those who are not (19).

Associations between lower educational attainment and higher risks of developing or dying from many cancers are likely to be influenced by a number of risk factors that are associated with SES. For example, historical patterns in the prevalence and intensity of cigarette smoking by SES (47) clearly account for much of the associations we observed between education level and lung cancer mortality among black and white men and the smaller associations we observed in women. The difference in the prevalence of smoking by education level and other measures of SES has widened in the United States since 1975 because individuals with higher levels of education and SES have been more likely to refrain from smoking and/or to quit in response to health warnings than have been those with a high school education or less (47). The variation in lung cancer mortality with education accounts for a substantial portion of the variation in all-cancer death rates with education in men, as reported from other studies in the United States (3–5) and Europe (1). Lung cancer mortality rates are also influenced by stage at diagnosis and survival from lung cancer, which have also been found to vary by SES and race (48,49).

The relationships between education level and the mortality rates for colorectal, prostate, and breast cancers are more complex than that for lung cancer. For those cancers, no single risk factor accounts for as much of the variation in cancer mortality as does smoking in

lung cancer mortality. The inverse association that we observed between colorectal cancer mortality and educational attainment is stronger than that observed in two earlier US studies (7,9) that did not report data separately for blacks and whites. SES-associated factors that influence the risk of developing or dying from colorectal cancer include obesity (29), physical inactivity, diet, and use of hormone replacement therapy, anti-inflammatory drugs, and colorectal cancer screening (50). Greater use of colorectal cancer screening among individuals with higher levels of education (51,52) is likely to have contributed to the lower colorectal cancer mortality rates observed in this and in previous studies (7,9), although this trend was not apparent for black men in our analysis of the 2000 NHIS survey, when screening rates were low in all groups (Table 3). Our study considered only mortality, and we did not attempt to differentiate variations attributable to colorectal cancer incidence from those affecting survival. However, more advanced stage at diagnosis and lower rates of receipt of appropriate treatment have been found for black compared with white colorectal cancer patients (48).

Our study has several limitations. First, we relied on only one indicator of individual SES, namely, educational attainment. Level of education has been used as an indicator of individual SES in many studies because it is a stable indicator of lifetime SES, it is associated with other indicators of SES such as income, and the data are relatively easy to collect (53). However, spousal SES can have as strong an influence on income and other characteristics as personal SES, especially for women; thus, our inability to account for a spouse's SES may have contributed, in part, to the weaker association between educational attainment and overall cancer mortality we observed in women than in men. It is widely recognized that SES is a complex concept that reflects a combination of individual- and geographic area–level influences and that, when possible, it is desirable to consider multiple indices of SES in analyzing relationships between SES and health outcomes (54,55). We were unable to do so in this study because the data available for analysis of mortality by individual level of education could not be linked to geographic area–level SES indicators and because level of education is the only indicator of SES available in vital statistics records.

Second, this study was restricted to individuals who were 25–64 years old at death, which limits the generalizability of the results to older individuals. However, cancer deaths in the age group studied are of particular societal importance because they impact individuals and families during a period of life when they are most likely to be in the workforce and raising children and/or supporting other family members. It is possible that differences in mortality by level of education may be attenuated in individuals older than 65 years because such individuals may have better access to health care through Medicare. Restriction of the current analysis to black and non-Hispanic whites also limits the generalizability of the results to other racial and ethnic population groups.

It is widely recognized that cancer death rates provide a meaningful composite index of the success of cancer control measures throughout the cancer continuum, which ranges from prevention and early diagnosis to treatment and survival. Studies of trends in cancer mortality by race and geographic region have historically been an important resource for identifying high-risk populations. This study demonstrates the utility of examining mortality rates by level of education using national vital statistics data to identify and monitor health disparities in the United States. This information would be even more valuable if it could be augmented by routine collection of data on level of education in a broad array of administrative health record systems. Information on education is routinely collected in surveys of behavioral risk factors and is used to examine socioeconomic gradients in relation to those risk factors and to selected measures of self-reported health care utilization and outcomes but is not available in medical records that are used as the basis for cancer registries and health services research studies. Collecting data on individual level of education would allow researchers to examine the contribution of variations in cancer incidence, stage at diagnosis, and survival to differences in cancer mortality by level of education.

In conclusion, we have found that cancer death rates vary substantially by race, level of education, and sex in a recent time period in the United States. Our findings provide a baseline against which efforts to reduce cancer disparities can be measured.

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