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Inequalities in Premature Death From Colorectal Cancer by State

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ABSTRACT

Purpose
Although disparities in colorectal cancer (CRC) with regard to race, socioeconomic status, and geography are well documented, the extent to which these factors contribute to premature death resulting from CRC nationwide and by state is unknown.

Patients and Methods
We calculated age-standardized CRC death rates for three broad educational categories as a marker of socioeconomic status by race/ethnicity and state among individuals age 25 to 64 years from 2008 through 2010. We also calculated the proportion of premature death resulting from CRC that could potentially be averted in each state by applying the average death rate for the five states with the lowest rates among the most educated whites (Connecticut, North Dakota, Utah, Vermont, and Wisconsin) to all populations.

Results
Compared with those with the most education, those with the least education had significantly higher CRC death rates in virtually all states for each racial/ethnic group. For example, rate ratios ranged from 1.15 (95% CI, 0.66 to 2.01) in Delaware to 3.18 (95% CI, 2.01 to 5.05) in New Mexico among whites. Overall, half the premature deaths resulting from CRC that occurred nationwide from 2008 through 2010, or 7,690 deaths annually, would have been avoided if everyone had experienced the lowest death rates of the most educated whites. More premature deaths could be averted in southern states (60% to 70%) than in northern and western states (30% to 40%). Restricting the analyses to persons age 50 to 64 years, for whom CRC screening is recommended, resulted in similar findings.

Conclusion
The majority of premature deaths from CRC in southern states and half these deaths nationwide are due to racial/ethnic, socioeconomic, and geographic inequalities.

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INTRODUCTION

Colorectal cancer (CRC) is the third leading cause of cancer death in both men and women in the United States.[1] Historically, CRC death rates were higher in individuals with higher rather than lower socioeconomic status (SES), in whites than in blacks, and in northern than in southern states.[2-5] However, over the past few decades, there has been a cross-over such that rates are now highest in persons with the lowest SES, in blacks, and in southern states.[2,6-8] This shift is likely the result of differential dissemination of advances in prevention, early detection, and treatment.[9-11] The extent to which these racial/ethnic and socioeconomic disparities vary within each state and contribute to premature death resulting from CRC is unknown.

Herein, we examine CRC death rates from 2008 through 2010 among adults age 25 to 64 years by state, race/ethnicity, and educational attainment (as a marker of SES). We also estimate the proportion of annual CRC deaths in this age group (ie, premature deaths) that could have been avoided if racial, socioeconomic, and geographic inequalities had been eliminated. We performed a similar, supplementary analysis for the 50- to 64-year-old age group for whom CRC screening is recommended. For this study, we focused our analyses on the 25- to 64-year-old age group because deaths occurring in this age interval result in a greater number of life-years lost and because cancer disparities are larger in this age group than in the age 65 or older group,[12] in

part because of differences in the availability of universal health care coverage.

PATIENTS AND METHODS

Mortality data for CRC from 2008 through 2010 by age, sex, race/ethnicity, educational attainment (as an indicator of individual-level SES), and state of residence were obtained from the National Vital Statistics System of the National Center for Health Statistics within the Centers for Disease Control and Prevention. The International Classification of Diseases (10th Revision) was used to identify the underlying cause of death on the death certificates as CRC (codes C18 to C21).[13] Population denominators for the corresponding age, sex, race/ethnicity, educational attainment, and state of residence categories were obtained in a custom tabulation from the U.S. Bureau of Census (Hung Xuan Pham, U.S. Census Bureau, Survey Processing Branch, personal communication, November 2013). These estimates were derived from the Annual Social and Economic Supplement to the Current Population Survey.

Age-standardized CRC death rates were calculated by educational attainment (≤ 12 years, 13 to 15 years, and ≥ 16 years of education) and race/ethnicity (non-Hispanic white, non-Hispanic black, and Hispanic, hereafter referred to as white, black, and Hispanic) for adults age 25 to 64 years in each state (except Georgia and Rhode Island because educational attainment information on death certificates was incomplete for these states) using the 2000 U.S. standard population. We restricted our analyses to ages 25 to 64 years because deaths occurring in this age interval result in a greater number of life-years lost and because disparities are larger in this age group than in the 65 years or older age group.[12] Socioeconomic disparities in CRC death rates were expressed as rate ratios comparing rates among the least educated with those among the most educated with corresponding 95% CIs.[14] Point estimates for two categories were considered to be statistically different if their 95% CIs did not overlap. Only states with rates based on 16 or more deaths for all three educational categories were considered in this analysis: 47 states for whites, 18 states for blacks, and four states for Hispanics (California, Florida, New York, and Texas).

We estimated the proportion of premature deaths from CRC that would have been averted annually in each state from 2008 through 2010 in the absence of racial/ethnic, socioeconomic, and geographic disparities by first calculating aggregated crude death rates by age (25 to 44 and 45 to 64 years) for the five states with the lowest rates for the most educated whites (Connecticut, North Dakota, Utah, Vermont, and Wisconsin). Five states were combined and broad age groups were used to improve the stability of the age-specific rates; whites were selected as the referent group, despite reports of slightly lower rates in the most educated Hispanics, because whites are the most representative of the general population, particularly in terms of duration of residence. These rates were then applied to the corresponding age-specific populations in each state to obtain the expected number of CRC deaths in the absence of disparities. Finally, the number of potentially avertable CRC deaths in each state was estimated by subtracting the expected deaths from the total number of observed deaths.

We performed a similar, supplementary analysis for potentially avertable CRC deaths by state among individuals age 50 to 64 years for whom screening is recommended. We also examined receipt of CRC screening (either a fecal occult blood test within the past year or sigmoidoscopy or colonoscopy within the past 10 years) for all races combined in this age interval by educational attainment across states based on data from the 2010 Behavioral Risk Factor Surveillance System.[15] SAS-callable SUDAAN release 11.0.1 was used to generate weighted prevalence estimates for CRC screening by state.

RESULTS

Figure 1 shows CRC death rates by educational attainment and race/ethnicity nationwide from 2008 through 2010. Rates decreased with increasing educational attainment within each racial/ethnic group,

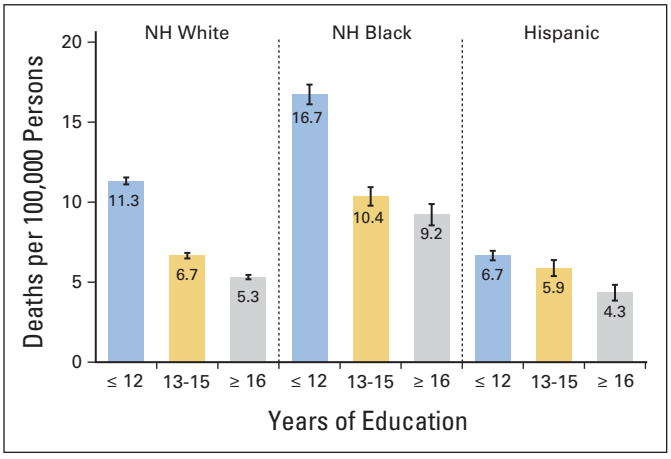

Fig 1. Annual colorectal cancer death rates by educational attainment and race/ethnicity, United States, 2008 to 2010. NH, non-Hispanic. Vertical bars indicate 95% CIs.

although some of the differences were not statistically significant among blacks and Hispanics. Mortality rate ratios comparing the least with the most educated group were 2.13 (95% CI, 2.06 to 2.20) in whites, 1.82 (95% CI, 1.68 to 1.97) in blacks, and 1.54 (95% CI, 1.36 to 1.74) in Hispanics. There were also notable differences in the magnitude of death rates between racial/ethnic groups. For example, among the least educated, the CRC death rate was 6.7 per 100,000 for Hispanics, 11.3 for whites, and 16.7 for blacks.

Rate ratios comparing the least with the most educated group by state ranged from 1.15 (95% CI, 0.66 to 2.01) in Delaware to 3.18 (95% CI, 2.01 to 5.05) in New Mexico among whites and from 0.84 (95% CI, 0.54 to 1.30) in Mississippi to 2.41 (95% CI, 1.62 to 3.59) in Virginia among blacks (Tables 1 and 2). Forty-three of 47 states for whites and 14 of 18 states for blacks showed statistically significantly higher rates in the least educated group. Among Hispanics, only California, Florida, New York, and Texas had sufficient data to estimate rates for all education levels; the rate ratio in the least compared with the most educated group ranged from 1.44 (95% CI, 1.07 to 1.94) in Texas to 1.91 (95% CI, 1.24 to 2.94) in New York (Table 3). Within educational strata, there were striking differences between states. For example, among the most educated whites, the CRC death rate per 100,000 persons was more than twice as high in Mississippi (8.9) as in Connecticut (3.8).

Figure 2A shows the average annual percentage of premature deaths from CRC among those age 25 to 64 years that could be averted if all populations were to experience the average death rate in the five states with the lowest rates among the most educated whites (Connecticut, North Dakota, Utah, Vermont, and Wisconsin). This percentage ranged from 29% of the premature deaths resulting from CRC in Utah to 69% in Mississippi. The largest proportion of avoidable deaths occurred in Southern states. In total, approximately 50% (23,072 of 46,538) of the premature deaths resulting from CRC that occurred nationwide from 2008 through 2010—the equivalent of 7,690 deaths annually—could have been avoided by eliminating racial, socioeconomic, and geographic inequalities in CRC mortality rates. As expected, the proportion of deaths avertable in the 50- to 64-year-old age group by state was remarkably similar to that in the 25- to 64-year-old age group (Fig 2B) because deaths in the 50- to

Table 1. CRC Death Rates for Non-Hispanic Whites Age 25 to 64 Years by Educational Attainment and RR in the Least Versus the Most Educated Persons by State, 2008-2010

	Years of Education							
	≤ 12		13-15		≥ 16		RR ≤ 12 *v* ≥ 16	
State*	Rate	95% CI	Rate	95% CI	Rate	95% CI	RR	95% CI
NM	14.0	9.7 to 18.3	8.8	5.9 to 11.7	4.4	2.9 to 5.9	3.18	2.01 to 5.05
MD	14.0	12.0 to 16.0	5.2	4.0 to 6.5	4.8	3.9 to 5.7	2.91	2.30 to 3.67
LA	14.3	12.2 to 16.3	8.8	6.6 to 11.0	5.1	3.8 to 6.4	2.80	2.10 to 3.72
KS	12.3	10.0 to 14.5	7.0	5.4 to 8.6	4.7	3.5 to 5.9	2.61	1.90 to 3.59
ND	11.3	7.3 to 15.3	7.1	4.4 to 9.9	4.3	2.1 to 6.6	2.61	1.39 to 4.89
CA	12.9	11.8 to 14.0	6.9	6.3 to 7.5	5.0	4.5 to 5.4	2.60	2.31 to 2.93
OK	15.9	13.5 to 18.3	12.3	9.9 to 14.7	6.1	4.7 to 7.6	2.59	1.95 to 3.43
WA	11.8	10.1 to 13.5	5.4	4.6 to 6.2	4.6	3.9 to 5.4	2.54	2.05 to 3.16
VA	11.7	10.3 to 13.1	6.5	5.3 to 7.6	4.6	3.9 to 5.3	2.54	2.09 to 3.08
VT	10.2	7.0 to 13.4	5.4	2.6 to 8.1	4.1	2.2 to 6.1	2.47	1.40 to 4.37
SC	13.4	11.5 to 15.3	7.6	6.1 to 9.1	5.5	4.2 to 6.7	2.46	1.87 to 3.22
NH	12.6	9.8 to 15.3	4.0	2.5 to 5.5	5.1	3.6 to 6.6	2.46	1.70 to 3.57
CT	8.7	7.1 to 10.3	4.2	3.0 to 5.5	3.8	3.0 to 4.7	2.28	1.71 to 3.03
IA	11.8	10.0 to 13.6	6.0	4.7 to 7.2	5.4	4.0 to 6.7	2.20	1.65 to 2.95
KY	13.8	12.3 to 15.3	6.9	5.6 to 8.3	6.4	5.0 to 7.7	2.18	1.71 to 2.77
TX	12.7	11.6 to 13.7	8.4	7.5 to 9.2	5.9	5.2 to 6.5	2.16	1.89 to 2.47
IL	11.3	10.2 to 12.4	7.3	6.4 to 8.2	5.2	4.6 to 5.9	2.15	1.83 to 2.52
MI	10.5	9.5 to 11.5	5.4	4.6 to 6.1	4.9	4.2 to 5.6	2.14	1.79 to 2.56
WV	12.4	10.6 to 14.2	6.4	4.4 to 8.4	5.8	3.9 to 7.8	2.13	1.47 to 3.08
NV	12.2	9.8 to 14.6	7.7	5.8 to 9.7	5.8	4.1 to 7.4	2.12	1.49 to 3.01
MA	9.7	8.5 to 11.0	5.4	4.3 to 6.5	4.6	3.9 to 5.3	2.11	1.72 to 2.58
AL	13.9	12.0 to 15.8	6.5	5.1 to 8.0	6.7	5.2 to 8.1	2.09	1.62 to 2.70
AZ	10.3	8.5 to 12.2	6.2	5.1 to 7.3	4.9	4.0 to 5.9	2.09	1.61 to 2.73
FL	11.2	10.2 to 12.1	7.7	6.9 to 8.5	5.3	4.7 to 5.9	2.09	1.83 to 2.40
TN	13.2	11.8 to 14.6	7.8	6.4 to 9.2	6.4	5.2 to 7.6	2.06	1.66 to 2.55
ID	10.6	8.0 to 13.3	6.5	4.6 to 8.4	5.1	3.4 to 6.9	2.06	1.34 to 3.16
MT	10.9	7.9 to 13.9	4.9	3.0 to 6.9	5.3	3.3 to 7.4	2.05	1.28 to 3.29
WI	8.5	7.4 to 9.7	5.5	4.5 to 6.4	4.2	3.4 to 5.0	2.04	1.61 to 2.58
NC	11.6	10.3 to 12.8	6.4	5.4 to 7.4	5.7	4.8 to 6.6	2.03	1.69 to 2.44
OR	10.0	8.4 to 11.6	5.9	4.8 to 7.1	5.1	4.0 to 6.2	1.97	1.51 to 2.57
NJ	10.8	9.5 to 12.1	7.6	6.2 to 9.0	5.5	4.7 to 6.2	1.97	1.64 to 2.38
MO	11.4	10.2 to 12.6	7.2	6.0 to 8.4	6.0	4.9 to 7.1	1.91	1.54 to 2.36
NY	9.8	8.9 to 10.6	5.2	4.5 to 5.8	5.1	4.6 to 5.7	1.90	1.66 to 2.18
IN	10.3	9.2 to 11.4	6.8	5.7 to 8.0	5.4	4.4 to 6.4	1.90	1.53 to 2.36
SD	9.7	6.7 to 12.7	4.7	2.5 to 6.8	5.2	2.8 to 7.6	1.86	1.06 to 3.24
AR	13.0	11.2 to 14.9	8.8	6.7 to 11.0	7.1	5.2 to 9.1	1.83	1.34 to 2.49
MS	16.3	13.4 to 19.1	8.8	6.6 to 11.0	8.9	6.5 to 11.3	1.83	1.33 to 2.51
UT	7.6	5.7 to 9.6	6.2	4.6 to 7.7	4.2	2.9 to 5.5	1.81	1.22 to 2.68
CO	9.0	7.4 to 10.7	5.5	4.4 to 6.6	5.0	4.2 to 5.8	1.80	1.41 to 2.29
PA	10.9	10.1 to 11.7	6.7	5.8 to 7.6	6.1	5.3 to 6.8	1.79	1.56 to 2.07
NE	11.1	8.7 to 13.4	6.3	4.6 to 8.0	6.3	4.6 to 8.0	1.76	1.24 to 2.48
OH	10.2	9.4 to 11.0	6.6	5.7 to 7.4	6.1	5.3 to 7.0	1.67	1.43 to 1.95
MN	8.7	7.4 to 10.1	5.9	5.0 to 6.9	5.9	4.9 to 6.9	1.48	1.18 to 1.86
ME	9.3	7.3 to 11.4	5.8	3.8 to 7.7	6.7	4.8 to 8.7	1.38	0.97 to 1.99
AK	6.8	3.6 to 9.9	4.2	2.0 to 6.4	5.2	2.5 to 7.9	1.29	0.65 to 2.57
WY	8.0	4.8 to 11.3	7.6	4.5 to 10.7	6.4	3.0 to 9.9	1.25	0.64 to 2.45
DE	7.2	4.7 to 9.7	8.1	4.6 to 11.7	6.2	3.5 to 8.9	1.15	0.66 to 2.01
United States	11.3	11.1 to 11.5	6.7	6.5 to 6.8	5.3	5.2 to 5.5	2.13	2.06 to 2.20

NOTE. Rates are per 100,000 persons, age-adjusted to the 2000 US standard population and averaged from 2008 to 2010.
Abbreviations: CRC, colorectal cancer; RR, rate ratio.
*States are ranked in descending order according to rate ratio.

64-year-old age group accounted for 78% of the deaths among those age 25 to 64 years.

Figure 3 shows the self-reported use of CRC screening by educational attainment (≤ 12 years and ≥ 16 years of education) and state among people of all races age 50 to 64 years. Screening prevalence ranged from 39% in Wyoming to 67% in Delaware in the least educated persons and from 58% in North Dakota to 78% in New Hampshire in the most educated persons. The absolute difference in

Table 2. CRC Death Rates in Non-Hispanic Blacks Age 25 to 64 Years by Educational Attainment and RR in the Least Versus the Most Educated Persons by State, 2008-2010

	Years of Education							
	≤ 12		13-15		≥ 16		RR ≤ 12 *v* ≥ 16	
State*	Rate	95% CI	Rate	95% CI	Rate	95% CI	RR	95% CI
VA	17.3	14.3 to 20.2	7.4	5.1 to 9.7	7.2	4.6 to 9.7	2.41	1.62 to 3.59
TX	21.5	18.6 to 24.4	11.4	9.3 to 13.4	9.1	6.9 to 11.3	2.37	1.79 to 3.13
MD	16.4	13.6 to 19.1	10.4	7.8 to 12.9	7.4	5.3 to 9.6	2.20	1.58 to 3.07
SC	16.8	14.1 to 19.5	11.3	7.9 to 14.7	7.7	4.0 to 11.4	2.17	1.31 to 3.60
CA	18.3	15.1 to 21.5	10.8	8.9 to 12.8	8.9	6.8 to 11.0	2.06	1.54 to 2.77
MI	16.4	13.4 to 19.4	10.7	7.8 to 13.5	8.1	4.7 to 11.5	2.02	1.28 to 3.19
OH	15.7	12.8 to 18.6	8.2	5.8 to 10.7	7.9	4.0 to 11.7	2.00	1.19 to 3.36
LA	23.8	20.1 to 27.6	10.0	7.1 to 13.0	12.1	7.3 to 17.0	1.96	1.28 to 3.02
AL	20.3	16.8 to 23.7	10.9	7.6 to 14.1	11.3	6.3 to 16.3	1.80	1.12 to 2.89
PA	14.0	11.4 to 16.6	11.4	7.6 to 15.2	7.8	3.9 to 11.7	1.79	1.05 to 3.04
IL	18.8	15.9 to 21.7	11.0	8.5 to 13.4	10.6	7.4 to 13.7	1.78	1.27 to 2.50
MO	15.4	11.2 to 19.5	9.1	5.9 to 12.3	8.7	3.8 to 13.7	1.76	0.93 to 3.30
TN	20.4	15.8 to 25.1	12.2	7.7 to 16.7	12.1	6.2 to 18.0	1.69	0.99 to 2.89
NJ	16.3	12.7 to 19.9	11.3	7.6 to 15.1	10.0	6.5 to 13.4	1.64	1.09 to 2.47
NY	12.9	11.1 to 14.6	9.7	7.8 to 11.6	7.9	6.1 to 9.8	1.62	1.23 to 2.13
FL	15.5	13.4 to 17.6	10.7	8.4 to 12.9	10.9	8.1 to 13.7	1.42	1.06 to 1.90
NC	14.5	12.3 to 16.7	11.5	8.7 to 14.2	10.6	7.5 to 13.7	1.37	0.98 to 1.90
MS	16.2	13.2 to 19.1	11.0	7.4 to 14.6	19.3	11.6 to 26.9	0.84	0.54 to 1.30
US	16.7	16.1 to 17.4	10.4	9.8 to 10.9	9.2	8.6 to 9.9	1.82	1.68 to 1.97

NOTE. Rates are per 100,000 persons, age-adjusted to the 2000 US standard population and averaged from 2008 to 2010.
Abbreviations: CRC, colorectal cancer; RR, rate ratio.
*States are ranked in descending order according to rate ratio.

screening uptake between the least and the most educated persons within state ranged from 4% in Delaware to 25% in Nevada. In general, across states, the screening prevalence is lower in western and southern states and higher in the northeastern states, especially among the least educated persons. Appendix Table A1 (online only) provides screening prevalence point estimates and 95% CIs for all three levels of educational attainment, including 13 to 15 years.

DISCUSSION

Our findings illustrate that the least educated men and women age 25 to 64 years have a disproportionately higher burden of CRC mortality, regardless of state of residence, and that substantial geographic disparities exist even within education levels. The majority of CRC deaths in southern states and half the deaths nationwide would have been avoided if racial/ethnic, socioeconomic, and geographic inequalities were absent. The findings were remarkably similar when we restricted the analyses to individuals age 50 to 64 years for whom screening is recommended, because CRC deaths occurring in the 50- to 64-year-old age group accounted for the majority (78%) of deaths between the ages of 25 and 64 years.

Factors that contribute to CRC disparities are complex and multifactorial. Differences in income, education, insurance status, and geographic residence between sociodemographic groups result in inequalities in the prevalence of CRC risk factors and in access to screening and treatment services.[16] Racial disparities in CRC death rates may be explained by differences in the use, availability, and quality of screening and treatment services,[17,18] even within the same level of

Table 3. CRC Death Rates in Hispanics Age 25 to 64 Years by Educational Attainment and RR in the Least Versus the Most Educated Persons by State, 2008-2010

	Years of Education							
	≤ 12		13-15		≥ 16		RR ≤ 12 *v* ≥ 16	
State*	Rate	95% CI	Rate	95% CI	Rate	95% CI	RR	95% CI
NY	7.6	6.4 to 8.7	6.1	4.3 to 7.9	4.0	2.3 to 5.6	1.91	1.24 to 2.94
FL	8.8	7.5 to 10.0	6.7	5.1 to 8.3	4.6	3.4 to 5.8	1.90	1.42 to 2.54
CA	6.1	5.6 to 6.6	6.0	5.0 to 6.9	3.9	2.9 to 4.8	1.58	1.22 to 2.04
TX	7.5	6.8 to 8.2	6.3	5.1 to 7.5	5.2	3.7 to 6.7	1.44	1.07 to 1.94
United States	6.7	6.4 to 7.0	5.9	5.4 to 6.4	4.3	3.8 to 4.8	1.54	1.36 to 1.74

NOTE. Rates are per 100,000 persons, age-adjusted to the 2000 US standard population and averaged from 2008 to 2010.
Abbreviations: CRC, colorectal cancer; RR, rate ratio.
*States are ranked in descending order according to rate ratio.

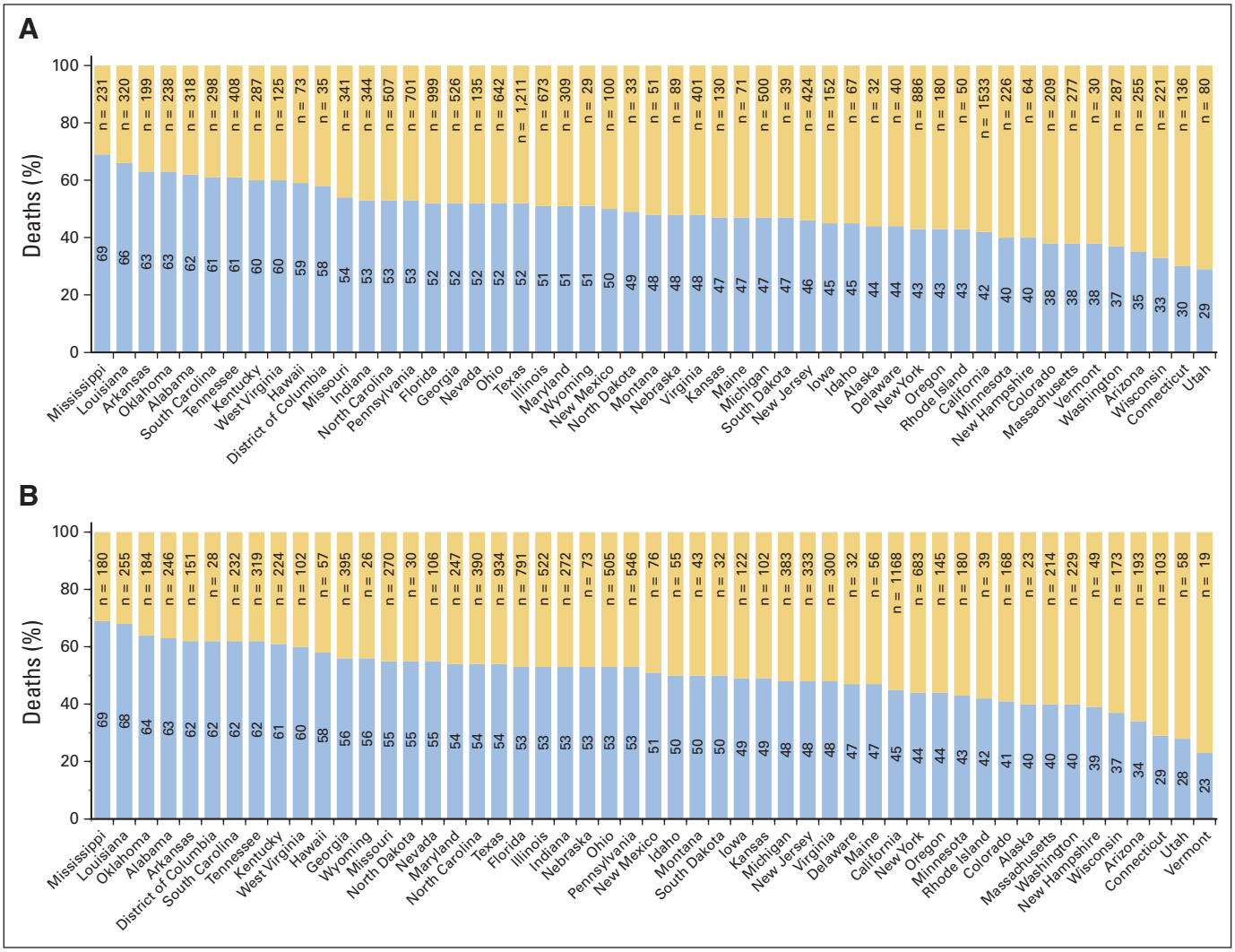

Fig 2. Proportion of colorectal cancer deaths that could be avoided annually in each state by eliminating racial/ethnic, socioeconomic, and geographic inequalities. (A) Age 25 to 64 years; (B) age 50 to 64 years. Number given for each state reflects the average annual number of colorectal cancer deaths in each state from 2008 to 2010.

educational attainment. Low CRC mortality rates among Hispanics partly reflect the lower risk of disease in their countries of origin, given that 37% of Hispanics are foreign-born.[19] However, it is notable that we observed an educational gradient for Hispanics in our analysis despite low death rates. Persons with lower SES such as the uninsured are less likely to be up-to-date for CRC screening tests according to recommendations.[20] For example, in 2010, the CRC screening rate was 19% among uninsured Americans compared with 62% among those with private insurance coverage.[21] As a result, compared with patients with CRC who have private insurance, uninsured patients are twice as likely to present with stage III to IV versus stage I disease[22] and are 41% more likely to die after adjusting for other factors.[23] Lower screening rates in underserved populations are contributed to by a reduced likelihood of both receipt of a physician recommendation for screening[24] and compliance with a recommendation.[25]

The prevalence of behavioral risk factors for CRC varies geographically and is generally inversely associated with SES. Obesity, cigarette smoking, and red meat consumption increase CRC risk, whereas physical activity and anti-inflammatory drug use decrease risk.[26,27] Although obesity prevalence has increased in all socioeconomic groups over the past few decades, it remains higher among adults with lower incomes and fewer years of education.[28] A similar socioeconomic gradient exists for the prevalence of recreational physical activity.[29,30] Likewise, progress in reducing smoking prevalence has been slower in persons with lower SES. For example, smoking prevalence in 2008 was three times as high among persons with a high school diploma or less education (29%) than among those with a bachelor's degree or higher level of education (9%).[31] A recent study estimated that obesity and other behavioral risk factors account for 43% of the association between educational attainment and CRC risk.[32]

Although a substantial proportion of CRC deaths are potentially avoidable in every state in the absence of racial/ethnic, socioeconomic, and geographic disparities, the proportion is largest in southern states. This may reflect the disproportionately higher percentage of disadvantaged populations (eg, blacks and persons with lower SES) in the south, who are less likely to receive standard of care for CRC and other conditions.[9,33-35] Moreover, southern states generally had higher CRC

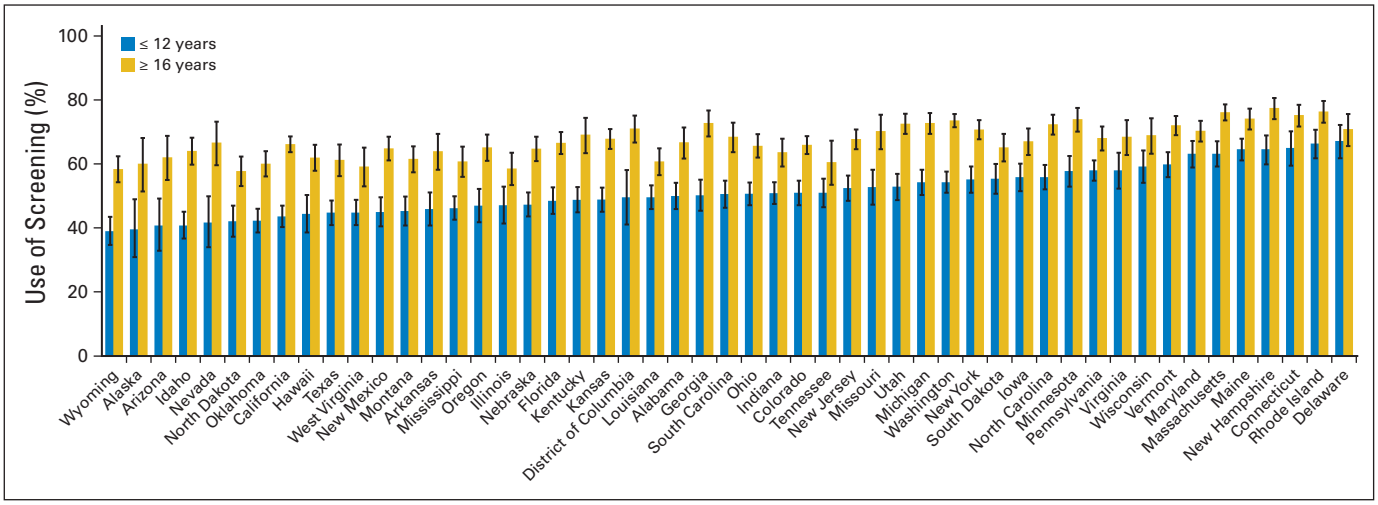

Fig 3. Prevalence of colorectal cancer screening among individuals age 50 to 64 years by educational attainment and state, 2010. Vertical bars indicated 95% CIs. Screening test was either a fecal occult blood test within the past year or sigmoidoscopy or colonoscopy within the past 10 years.

death rates than other states at each level of educational attainment in both whites and blacks, suggesting an overall higher prevalence of unfavorable risk factors and/or limited access to and use of high-quality CRC screening and treatment.

The strength of our study is the use of individual-level educational attainment to document heterogeneity in CRC death rates by race/ethnicity and SES across states and to estimate the excess premature deaths from CRC associated with these factors. Death rates by individual-level SES, race/ethnicity, and state are valuable for assessing the impact of the Affordable Care Act (ACA). The law is designed to address long-standing racial and socioeconomic inequalities by improving access to quality health care for all Americans through expansion of state Medicaid programs and health insurance exchange subsidies. The ACA also removes cost as a barrier to preventive health services, including CRC screening, tobacco-dependence counseling and treatment, and obesity screening and counseling. A recent study estimated that nearly 20 million Americans have already gained insurance coverage under the ACA,[36] despite expansion of Medicaid programs to low-income qualified residents in only 27 states and the District of Columbia. Future studies could examine premature mortality from CRC and other conditions in states that have expanded the Medicaid program versus those states that have not. Notably, Delaware showed the smallest difference in CRC mortality rates and screening prevalence between the least and the most educated persons (Table 1 and Fig 3), likely reflecting its implementation of universal access to CRC screening and treatment in 2002.[37] In an effort to increase screening nationwide, several organizations, including the American Cancer Society and the Centers for Disease Control and Prevention, are supporting an initiative to increase CRC screening rates to 80% by 2018, largely by focusing on patients and clinicians in community health centers and other safety-net providers.[38]

Our study has several limitations. First, inaccuracies in underlying cause of death from death certificates may potentially bias the interpretation of mortality data. However, the concordance between the underlying cause of death from death certificates and medical records for CRC in the United States is quite high (nearly 90%).[39] Second, educational information recorded on the death certificates reported by next of kin and proxy-reported education tends to be higher than self-reported, especially when differentiating between less than 12 and exactly 12 years of education.[40,41] However, we combined 12 years of schooling with less than 12 years to mitigate such misclassification in the interpretation of our results. Third, there are inaccuracies in recording race in death certificates and census estimates, especially for races other than white and black.[42] Fourth, the estimates on CRC screening are based on self-report and thus are subject to recall bias.[43] Fifth, we provide the potential proportion of avoidable deaths but not the proportion that could be avoided in practice through implementation of policies such as the ACA to address health inequalities, which will be the subject of a future study. Finally, some of the deaths in our college-educated referent group that were used to estimate potentially avoidable deaths are also avoidable because CRC screening uptake and the prevalence of known risk factors, such as smoking and obesity, have not yet reached optimum levels in this population segment.[31]

In conclusion, we found that the least educated persons in the United States have a disproportionately higher burden of CRC death rate, regardless of race or state of residence. The majority of premature deaths from CRC in southern states and half the deaths nationwide are potentially avertable through the elimination of racial/ethnic, socioeconomic, and geographic inequalities. Future studies could examine the effect of the ACA in reducing such inequalities through increased access to preventive care services, including CRC screening.

AUTHORS' DISCLOSURES OF POTENTIAL CONFLICTS OF INTEREST

Disclosures provided by the authors are available with this article at www.jco.org.

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Inequalities in Premature Death From Colorectal Cancer by State

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Appendix

Table A1. Prevalence Percentage of CRC Screening Among Individuals Age 50-64 Years by Educational Attainment and State, 2010

	Years of Education								
	≤ 12			13-15			≥ 16		
State	No.	%	95% CI	No.	%	95% CI	No.	%	95% CI
AL	565	50.0	45.9 to 54.1	415	63.0	57.6 to 68.0	436	66.8	61.7 to 71.4
AK	87	39.6	30.9 to 49.0	118	64.0	54.8 to 72.3	138	60.1	51.4 to 68.1
AZ	206	40.8	32.9 to 49.2	316	51.7	43.8 to 59.5	423	62.1	55.0 to 68.8
AR	247	45.9	40.8 to 51.1	197	59.4	52.9 to 65.7	252	64.0	58.2 to 69.4
CA	663	43.6	40.3 to 47.0	910	61.2	58.1 to 64.2	1600	66.2	63.7 to 68.6
CO	521	51.0	47.1 to 54.8	673	60.0	56.4 to 63.6	1136	66.0	63.1 to 68.7
CT	352	65.0	59.5 to 70.2	334	71.2	65.7 to 76.2	787	75.3	71.7 to 78.5
DE	315	67.2	61.8 to 72.2	254	64.9	58.6 to 70.6	394	70.9	65.6 to 75.6
DC	145	49.6	41.1 to 58.1	123	58.4	48.5 to 67.7	600	71.1	66.7 to 75.1
FL	2189	48.5	44.4 to 52.7	2010	62.3	58.3 to 66.2	2282	66.6	63.1 to 70.0
GA	352	50.2	45.4 to 55.1	321	64.0	58.7 to 69.0	469	72.8	68.6 to 76.7
HI	238	44.4	38.6 to 50.3	391	59.9	55.0 to 64.7	674	62.0	57.9 to 66.0
ID	340	40.8	36.7 to 45.1	353	47.1	42.5 to 51.7	475	64.1	59.8 to 68.2
IL	236	47.1	41.4 to 52.9	280	53.5	47.7 to 59.2	451	58.6	53.4 to 63.5
IN	749	50.9	47.5 to 54.3	537	57.8	53.5 to 62.0	621	63.7	59.2 to 67.9
IA	369	55.9	51.5 to 60.1	360	55.5	51.0 to 60.0	466	67.1	62.8 to 71.1
KS	449	48.9	45.1 to 52.6	505	55.6	51.8 to 59.4	771	67.9	64.7 to 70.9
KY	718	48.8	44.9 to 52.8	420	61.1	55.8 to 66.2	444	69.2	63.4 to 74.4
LA	506	49.6	45.9 to 53.3	386	57.1	52.5 to 61.6	431	60.8	56.5 to 64.9
ME	675	64.6	61.1 to 67.9	521	70.7	66.8 to 74.4	837	74.2	70.8 to 77.3
MD	620	63.2	58.9 to 67.2	523	70.4	65.8 to 74.7	948	70.4	67.0 to 73.5
MA	979	63.2	59.2 to 67.1	850	71.8	67.8 to 75.5	1793	76.2	73.6 to 78.6
MI	565	54.3	50.3 to 58.2	651	68.1	64.4 to 71.6	786	72.8	69.4 to 75.9
MN	480	57.8	52.9 to 62.5	622	62.4	57.8 to 66.8	907	74.0	70.1 to 77.5
MS	580	46.2	42.6 to 49.9	396	57.0	52.3 to 61.6	443	60.8	56.0 to 65.4
MO	384	52.8	47.3 to 58.2	259	59.2	52.9 to 65.2	371	70.3	64.6 to 75.4
MT	368	45.3	40.8 to 49.8	433	51.1	46.7 to 55.6	547	61.6	57.4 to 65.5
NE	881	47.3	43.6 to 51.1	867	53.4	49.4 to 57.4	949	64.8	60.9 to 68.5
NV	167	41.7	34.0 to 49.9	254	53.3	46.2 to 60.3	284	66.7	59.6 to 73.2
NH	380	64.6	59.9 to 68.9	406	71.0	66.2 to 75.3	704	77.5	74.0 to 80.6
NJ	670	52.5	48.5 to 56.4	565	60.9	56.7 to 65.0	1121	67.8	64.6 to 70.8
NM	356	45.0	40.5 to 49.6	336	52.3	47.4 to 57.2	631	64.9	61.1 to 68.5
NY	492	55.2	51.0 to 59.2	426	67.2	62.8 to 71.4	917	70.8	67.7 to 73.7
NC	866	55.9	52.1 to 59.7	638	63.2	58.8 to 67.4	1043	72.4	69.2 to 75.4
ND	209	42.1	37.3 to 47.0	303	52.7	47.9 to 57.3	330	57.8	53.1 to 62.3
OH	710	50.7	47.1 to 54.2	561	58.8	54.5 to 62.9	760	65.7	62.0 to 69.3
OK	400	42.3	38.6 to 46.0	398	52.4	48.1 to 56.6	464	60.1	56.1 to 64.0
OR	229	47.0	41.8 to 52.2	340	61.4	56.7 to 65.8	453	65.2	61.0 to 69.2
PA	906	58.0	54.8 to 61.1	518	63.4	59.1 to 67.5	861	68.1	64.2 to 71.7
RI	458	66.4	61.8 to 70.7	361	67.7	62.5 to 72.4	730	76.4	72.9 to 79.7
SC	729	50.6	46.3 to 54.8	494	63.9	58.5 to 68.9	621	68.5	63.7 to 72.9
SD	369	55.4	50.7 to 60.0	353	57.1	52.2 to 61.8	484	65.2	60.8 to 69.4
TN	484	51.0	46.5 to 55.4	340	59.6	54.1 to 65.0	274	60.6	53.5 to 67.3
TX	816	44.8	40.9 to 48.6	771	55.5	51.0 to 59.8	1253	61.3	56.2 to 66.1
UT	478	52.9	48.7 to 56.9	603	60.0	56.2 to 63.7	813	72.6	69.4 to 75.7
VT	464	59.9	55.9 to 63.7	399	68.3	63.7 to 72.5	812	72.1	69.0 to 75.0
VA	380	58.0	52.3 to 63.5	303	62.0	55.9 to 67.8	489	68.5	62.8 to 73.7
WA	927	54.3	51.0 to 57.6	1594	66.4	63.9 to 68.8	2145	73.6	71.5 to 75.6
WV	354	44.8	40.9 to 48.8	198	56.2	50.2 to 62.0	210	59.2	53.0 to 65.1
WI	339	59.2	54.1 to 64.2	329	62.9	57.6 to 67.9	375	69.0	63.2 to 74.3
WY	249	39.0	34.7 to 43.5	390	55.8	51.6 to 60.0	445	58.4	54.3 to 62.4

NOTE. Screening was performed by either a fecal occult blood test within the past year or sigmoidoscopy or colonoscopy within the past 10 years. Prevalence estimates of percentage are weighted; counts (number) are unweighted.