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Association Between Educational Attainment and Causes of Death Among White and Black US Adults, 2010-2017

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IMPORTANCE There are substantial and increasing educational differences in US adult life expectancy. To reduce social inequalities in mortality, it is important to understand how specific causes of death have contributed to increasing educational differences in adult life expectancy in recent years.

OBJECTIVE To estimate the relationship of specific causes of death with increasing educational differences in adult life expectancy from 2010 to 2017.

DESIGN, SETTING, AND PARTICIPANTS Serial cross-sectional study of 4 690 729 deaths recorded in the US National Vital Statistics System in 2010 and 2017.

EXPOSURES Sex, race/ethnicity, and educational attainment.

MAIN OUTCOMES AND MEASURES Life expectancy at age 25 years and years of life lost between ages 25 and 84 years by cause of death.

RESULTS The analysis included a total of 2 211 633 deaths in 2010 and 2 479 096 deaths in 2017. Between 2010 and 2017, life expectancy at age 25 significantly declined among white and black non-Hispanic US residents from an expected age at death of 79.34 to 79.15 years (difference, −0.18 [95% CI, −0.23 to −0.14]). Greater decreases were observed among persons with a high school degree or less (white men: −1.05 years [95% CI, −1.15 to −0.94], white women: −1.14 years [95% CI, −1.24 to −1.04], and black men: −0.30 years [95% CI, −0.56 to −0.04]). White adults with some college education but no 4-year college degree experienced similar declines in life expectancy (men: −0.89 years [95% CI, −1.07 to −0.73], women: −0.59 years [95% CI, −0.77 to −0.42]). In contrast, life expectancy at age 25 significantly increased among the college-educated (white men: 0.58 years [95% CI, 0.42 to 0.73], white women: 0.78 years [95% CI, 0.57 to 1.00], and black women: 1.70 years [95% CI, 0.91 to 2.53]). The difference between high- and low-education groups increased from 2010 to 2017, largely because life-years lost to drug use increased among those with a high school degree or less (white men: 0.93 years [95% CI, 0.90 to 0.96], white women: 0.50 years [95% CI, 0.47 to 0.52], black men: 0.75 years [95% CI, 0.71 to 0.79], and black women: 0.28 years [95% CI, 0.25 to 0.31]).

CONCLUSIONS AND RELEVANCE In this serial cross-sectional study, estimated life expectancy at age 25 years declined overall between 2010 and 2017; however, it declined among persons without a 4-year college degree and increased among college-educated persons. Much of the increasing educational differences in years of life lost may be related to deaths attributed to drug use.

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L ife expectancy at birth in the United States decreased by 0.3 years from 2014 to 2017—the largest decline since 1993.[1,2] Although originally attributed to rising midlife mortality among white non-Hispanic US residents, decreases in life expectancy have since been observed in other race/ethnic groups.[3,4] The rise in mortality has been attributed to deaths due to unhealthy alcohol use, drug use, and suicide, which were not evenly shared across socioeconomic strata.[5]

Since the late 1980s, differences in mortality rates and adult life expectancy have increased substantially between education and income groups.[6-9] By 2010, the gap in life expectancy at age 25 years between high school noncompleters and college-educated US residents had ranged from 4.6 to 11.9 years across major race-sex groups.[10] A total of 60% to 80% of the gap was attributed to cardiovascular diseases, smoking-related diseases, and external causes of death.[11] Moreover, life expectancy among low-educated white adults declined from 1990 to 2010 predominantly due to external causes, which included (but did not disaggregate) drug use, alcohol use, and suicide. A subsequent study found that by 2011, drug use deaths accounted for 15% to 20% of the educational gradient in adult life expectancy among white non-Hispanic individuals.[12] By contrast, educational differences in life expectancy attributed to smoking declined for men (but not women) from 1986 to 2006.[13] All of those studies reported persistent and increasing socioeconomic differences in life expectancy, but also pointed to rapid changes in the causes of death underlying those differences.

Using Vital Statistics data, this study estimated the extent to which major causes of death were related to increasing educational differences in adult life expectancy from 2010 to 2017.

Methods

Data Sources
This study analyzed deidentified, government-issued public use data, which according to the Office for Human Research Protections regulations does not require institutional review board approval. All data were obtained from 2 sources: the number of deaths from the US National Vital Statistics System (NVSS) and midyear population estimates from the IPUMS American Community Survey (ACS).[14,15] The ACS data, which replaced the long form of the decennial census, are provided by the US Census Bureau after imputing missing information (race: 1.5% in 2010 and 1.6% in 2017; educational attainment: 5.6% in 2010 and 8.5% in 2017).[16] Although the true nonsampling error is unknown, the ACS has high total population coverage rates (96.6% in 2010; 91.6% in 2017) and low unit non-response rates (2.5% in 2010; 6.3% in 2017).[16,17]

Exposure
The main variables of interest were race/ethnicity, sex, and educational attainment. These measures were self-reported in the ACS and completed or verified on the death certificate (NVSS) by a funeral director. In both cases, race is recorded in fixed categories with an open-ended "other" category. However, because the ACS allows multiple-race categorization, some categories differ across the 2 data sources. The National Center for Health Statistics provides bridged-race population corrections to adjust for differences in race categorization across the 2 data sources, which were also applied in this study.[18] The analysis was limited to white and black non-Hispanic individuals aged 25 years and older because other race/ethnic groups were either too small or less reliably identified in the NVSS.[10,19]

Educational attainment was recoded into 3 categories based on completed years of schooling or highest degree attained: (1) low, defined as high school graduate or lower; (2) middle, defined as some college education but no 4-year college degree; and (3) high, defined as 4-year college graduate or higher. These education categories were chosen for 2 reasons. First, whereas in the past declines in life expectancy were observed only among those who did not graduate from high school, life expectancy has recently declined nationwide and among wider populations, including high school graduates.[7,10,20] Second, using broad categories minimizes the potential misclassification bias that results from minor discrepancies in education reporting across the 2 data sources.[21]

Outcomes
The study examined 2 outcome variables: (1) life expectancy at age 25 years and (2) the mean number of years of life lost (YLL) between ages 25 and 84 years by cause of death. The study focused on YLL between ages 25 and 84 years because educational attainment is generally completed by age 25, at least at the college level, and because recorded causes of death among the oldest old are less reliable due to comorbidities.[22,23]

The underlying cause of death ("disease or injury that initiated the events resulting in death") was determined by the medical professional who certified the death and recorded it on the death certificate.[24] Causes of death followed the *International Statistical Classification of Diseases and Related Health Problems, Tenth Revision (ICD-10)*, which were recoded in this study into 9 categories: circulatory diseases, smoking-related diseases, cancer (excluding smoking-related), diabetes, drug use (*ICD-10* codes: F11-F16, F19 Mental and behavioral disorders due to psychoactive substance use; X40-X44 Accidental poisoning by and exposure to drugs; Y10-Y14 Poisoning by and exposure to drugs, undetermined intent), alcohol use (*ICD-10* codes: F10, K70, X45, Y15), suicide (*ICD-*

Key Points

Question Has there been an association between educational attainment and causes of death among US adults?

Findings In this serial cross-sectional study that included 4 690 729 deaths among US adults, estimated life expectancy at age 25 years declined overall between 2010 and 2017; however, it declined among persons without a 4-year college degree and increased among college-educated persons. Much of the increasing educational differences in years of life lost may be related to deaths attributed to drug use.

Meaning Increasing differences in life expectancy based on educational attainment have occurred between 2010 and 2017.

codes: X60-X84, Y87.0), firearm deaths (*ICD-10* codes: W32-W34, X93-X95, Y22-Y24, Y35.0; excluding intentional self-harm), and all remaining ("other") causes of death. A complete list of *ICD* codes is available in eTable 1 in the Supplement.

Smoking-related causes were defined as those in which the smoking-attributable fraction of deaths exceeds 65% in both sexes combined: cancers of the lip, pharynx, oral cavity, esophagus, larynx, trachea, lung, and bronchus, as well as bronchitis, emphysema, and chronic airway obstruction.[25] This category was designed to gauge trends in smoking behavior across race, sex, and education groups, rather than accurately capture all deaths due to smoking.

Statistical Analyses
Missing information on educational attainment in the NVSS data was imputed with Stata version 15's multiple imputation routine (StataCorp), using multinomial regression on age, race, and sex. All subsequent statistical analyses were conducted in R version 3.5.2 (R Project for Statistical Computing). Multiple-decrement period life tables were constructed, in 5-year age groups, by race, sex, and educational attainment for 2010 and 2017. Life expectancy at age 25 years and YLLs between ages 25 and 84 years were estimated from the life tables. YLLs were decomposed by cause of death using a novel decomposition method that has several advantages (eMethods in the Supplement).[26] First, it allows a decomposition of the absolute number of YLLs in a single point in time, as well as the change between 2 points in time, by cause of death. Second, it does not assume that causes of death are independent from one another. Third, the number of YLLs to each cause are additive to the total number of years lost to all-cause mortality.

Results

Study Population Characteristics
The study population in 2017 was 48.2% male and 51.8% female; 84.8% of the population was white and 15.2% was black. In the same year, 42.6% of the population consisted of the low-education group (compared with 46.9% in 2010), 23.8% of the middle-education group (compared with 23.5% in 2010), and 33.6% of the high-education group (compared with 29.5% in 2010). The analysis included a total of 2 211 633 deaths in 2010 (50.8% female and 12.2% black US adults) and 2 479 096 deaths in 2017 (49.4% female and 13.0% black US adults). Educational attainment was missing from the NVSS in 2.2% and 1.6% of death certificates in 2010 and 2017, respectively, and was imputed. The numbers of exposures in each of the race, sex, and education groups, as well as number of deaths by cause, are shown in eTable 2 in the Supplement.

Changes in Adult Life Expectancy by Education
The estimated life expectancy at age 25 years significantly declined in the study population between 2010 and 2017, from an expected age at death of 79.34 to 79.15 years (difference, −0.18 [95% CI, −0.23 to −0.14]). However, while life expec-

tancy decreased significantly for white adults—from 77.55 to 77.31 years among men (difference, −0.24 [95% CI, −0.31 to −0.16]) and from 81.93 to 81.82 years among women (difference, −0.11 [95% CI, −0.18 to −0.04])—it had not changed significantly for black men and increased significantly among black women, from 79.23 to 79.86 years (difference, 0.63 [95% CI, 0.39 to 0.86]).

From 2010 to 2017, estimated educational differences in adult life expectancy increased for white and black men and women. In almost all race-sex groups, this was associated with both decreasing life expectancy among persons with less than a 4-year college education and increasing life expectancy among the college educated (**Table**).

Among white men, the expected age at death—conditional on survival to age 25 years—significantly declined in the low-education group from 74.52 to 73.47 years (difference, −1.05 [95% CI, −1.15 to −0.94]) and in the middle-education group from 77.81 to 76.92 years (difference, −0.89 [95% CI, −1.07 to −0.73]). However, the high-education group had gained 0.58 years (95% CI, 0.42 to 0.73), with the expected age at death increasing from 82.51 to 83.09 years. A similar pattern was observed among white women: the expected age at death decreased from 80.12 to 78.99 years (difference, −1.14 [95% CI, −1.24 to −1.04]) in the low-education group, decreased from 81.82 to 81.23 years (difference, −0.59 [95% CI, −0.77 to −0.42]) in the middle-education group, and increased from 85.47 to 86.25 years (difference, 0.78 [95% CI, 0.57 to 1.00]) in the high-education group.

The expected age at death (at age 25 years) significantly decreased for black men in the low-education group from 71.56 to 71.26 years (difference, −0.30 [95% CI, −0.56 to −0.04]), but had not changed significantly in the other education groups. Among black women, the expected age at death significantly increased in the low-education group by 0.36 years (95% CI, 0.06 to 0.67) from 77.94 to 78.30; however, the high-education group experienced a greater increase of 1.70 years (95% CI, 0.91 to 2.53) from 82.20 to 83.89, the largest increase among all race-sex groups.

Changes in YLLs by Cause of Death
Changes in the mean number of YLLs between ages 25 and 84 years, from 2010 to 2017, were estimated and decomposed into 9 cause-of-death groupings: circulatory diseases, cancer, smoking-related diseases, diabetes, drug use, alcohol use, suicide, firearm, and all other causes. The results are shown by race and sex in **Figure 1**.

The breakdown of estimated YLLs by cause of death shows that circulatory diseases, cancer, and smoking-related disease were the leading disorders associated with life years lost across all race-sex groups. Modest decreases in YLL to circulatory diseases were observed in all race-sex groups: white men, −0.08 (95% CI, −0.10 to −0.06); white women, −0.03 (95% CI, −0.05 to −0.02); black men, −0.08 (95% CI, −0.16 to −0.02); and black women, −0.15 (95% CI, −0.19 to −0.09). Greater decreases were observed in YLLs to smoking-related diseases, particularly among white men (−0.25 [95% CI, −0.26 to −0.23]) and black men (−0.37 [95% CI, −0.41 to −0.34]).

Table. Expected Age at Death at Age 25 Years by Race, Sex, and Education, 2010-2017[a]

Education Level[b]	% of Group in 2017	Expected Age at Death, y		
		2010	2017	Change (95% CI)
White Men				
Low	41.9	74.52	73.47	−1.05 (−1.15 to −0.94)
Middle	22.5	77.81	76.92	−0.89 (−1.07 to −0.73)
High	35.6	82.51	83.09	0.58 (0.42 to 0.73)
Total	100	77.55	77.31	−0.24 (−0.31 to −0.16)
White Women				
Low	40.1	80.12	78.99	−1.14 (−1.24 to −1.04)
Middle	24.0	81.82	81.23	−0.59 (−0.77 to −0.42)
High	35.9	85.47	86.25	0.78 (0.57 to 1.00)
Total	100	81.93	81.82	−0.11 (−0.18 to −0.04)
Black Men				
Low	56.5	71.56	71.26	−0.30 (−0.56 to −0.04)
Middle	24.8	76.15	75.67	−0.48 (−1.20 to 0.25)
High	18.7	79.75	80.65	0.92 (−0.14 to 1.93)
Total	100	73.63	73.77	0.14 (−0.10 to 0.38)
Black Women				
Low	47.3	77.94	78.30	0.36 (0.06 to 0.67)
Middle	28.7	79.35	79.02	−0.33 (−0.90 to 0.27)
High	24.0	82.20	83.89	1.70 (0.91 to 2.53)
Total	100	79.23	79.86	0.63 (0.39 to 0.86)
Total Population				
Total		79.34	79.15	−0.18 (−0.23 to −0.14)

[a] Non-Hispanic white and black US adults aged 25 years and older. The sample included 770 200 white men, 823 077 white women, 97 020 black men, and 113 220 black women.

[b] Education categories were defined as follows: low = high school graduate or lower, middle = some college education but no 4-year college degree, and high = 4-year college graduate or higher.

By contrast, YLLs to drug use, alcohol use, and suicide increased significantly in all 4 race-sex groups. Increases in YLLs to drug use were most pronounced—white men, 0.52 (95% CI, 0.50 to 0.53); white women, 0.21 (95% CI, 0.19 to 0.21); black men, 0.53 (95% CI, 0.50 to 0.55); and black women, 0.16 (95% CI, 0.14 to 0.17)—whereas increases in YLLs to alcohol use were smaller. For example, the largest increases in YLLs to alcohol use and suicide were observed among white men, estimated at 0.08 (95% CI, 0.06 to 0.08) and 0.07 (95% CI, 0.06 to 0.09), respectively.

Changes in YLLs by Cause of Death and Education

Changes in YLLs by cause of death, in each education group, are shown in **Figure 2** (white men and women) and **Figure 3** (black men and women). Among white adults of both sexes, YLLs to cancer and smoking-related diseases significantly decreased in all education groups, whereas YLLs to drug use increased across both sexes and all education groups. However, increases were larger among the low- and middle-education groups. Among white men, YLLs to drug use had increased by 0.93 (95% CI, 0.90 to 0.96) in the low-education group, by 0.53 (95% CI, 0.50 to 0.55) in the middle-education group, and by 0.11 (95% CI, 0.10 to 0.12) in the high-education group. Among white women, the same increases were estimated at 0.50 (95% CI, 0.47 to 0.52) in the low-education group, 0.24 (95% CI, 0.22 to 0.26) in the middle-education group, and 0.03 (95% CI, 0.02 to 0.04) in the high-education group. Smaller increases in YLLs to alcohol use and suicide were observed across education groups (with the exception of white and black women in the high-education group).

Similar patterns were observed among black adults, with significant decreases in YLLs to smoking-related diseases and, in some education groups, also in circulatory diseases and cancer. However, these decreases in YLLs were offset by increases due to drug use in both men (low education: 0.75 [95% CI, 0.71 to 0.79]; middle education: 0.36 [95% CI, 0.32 to 0.41]; high education: 0.10 [95% CI, 0.07 to 0.12]) and women (low education: 0.28 [95% CI, 0.25 to 0.31]; middle education: 0.12 [95% CI, 0.09 to 0.15]). Also noteworthy were YLLs to firearm deaths among low-educated black men, which significantly increased by 0.35 (95% CI, 0.30 to 0.41) between 2010 and 2017. Estimates for all causes of death, by race, sex, and education, are available in eTables 3 through 6 in the Supplement.

Educational differences in YLLs increased from 2010 to 2017 in all race-sex groups, with drug use deaths associated with the largest contribution to the increase (eTable 7 in the Supplement). Among white men, the difference in YLLs to all causes of death between the low- and high-education groups had increased by 1.40 years (95% CI, 1.31 to 1.50) from 2010 to 2017, of which 0.82 years (95% CI, 0.79 to 0.86) were attributed to drug use. Among white women, the same difference increased by 1.32 years (95% CI, 1.23 to 1.40), of which 0.47 years (95% CI, 0.44 to 0.50) were due to drug use. Among black men, the difference increased by 1.18 years (95% CI, 0.82 to 1.55), of which 0.65 years (95% CI, 0.61 to 0.70) were due to drug use. Among black women, the difference increased by 0.65 years (95% CI, 0.38 to 0.91), with 0.27 years (95% CI, 0.23 to 0.31) attributed to drug use.

Figure 1. Estimated Change in Years of Life Lost by Cause of Death Between 2010 and 2017
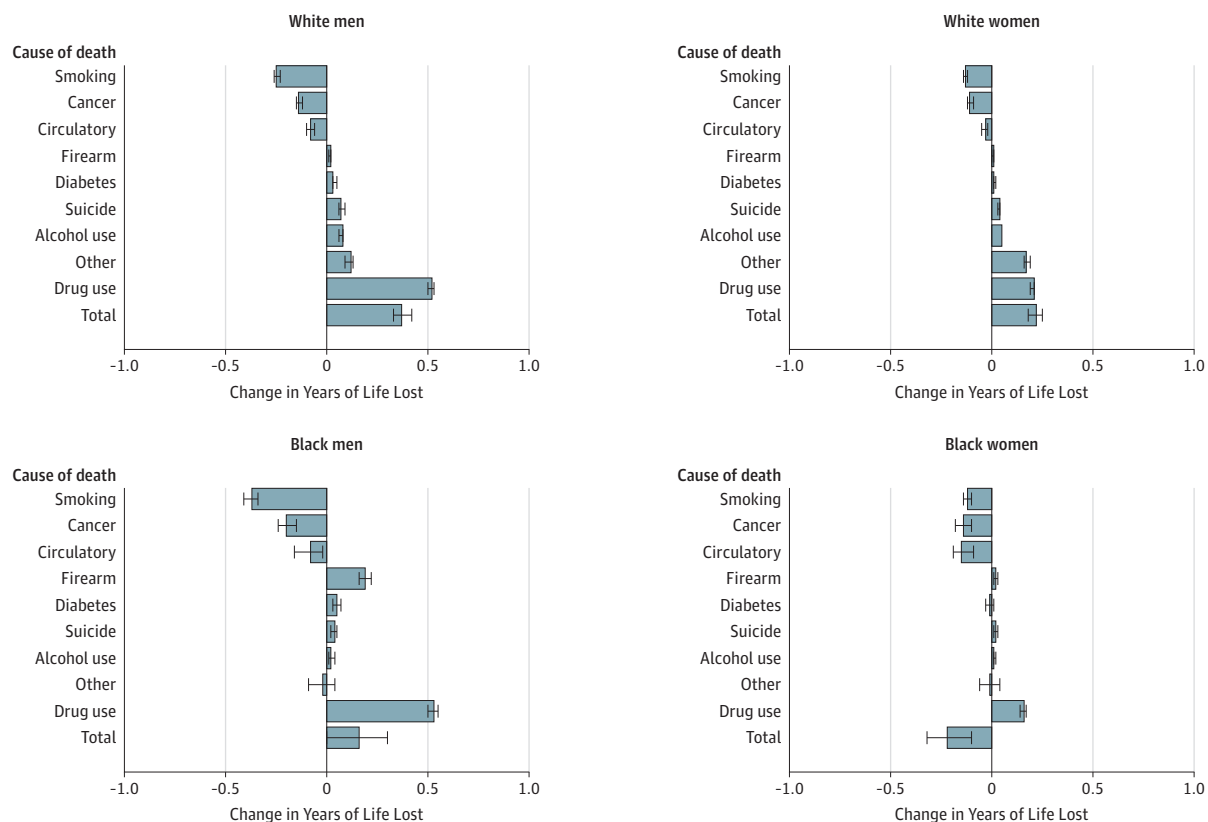
The graphs show the years of life lost between ages 25 and 84 years among non-Hispanic white and black US adults. The error bars indicate 95% CIs.

Discussion

This study documented an overall decline in life expectancy at age 25 years between 2010 and 2017. Although adult life expectancy increased among college-educated persons, it was counterbalanced by a decline in life expectancy among persons without a 4-year college degree. An analysis of the causes of death for 2010-2017 suggests that much of the increasing educational differences in YLLs may be related to deaths attributed to drug use, particularly among white men and women. These findings are consistent with other research that has shown that drug use significantly contributed to increasing educational differences in adult life expectancy in the 1990s up to 2011.[12] In addition, firearm deaths contributed to increased educational differences in life expectancy among black men.

The magnitude of the recent changes in educational differences in mortality shown here appears large given the brevity of the period. Inequality in the mean number of life years lost between ages 25 and 84 years increased substantially for white and black US residents over the 7-year study period. Among white men and women, there was increasing inequality largely related to rising mortality among all education groups without a 4-year college education, but especially among persons with a high school degree or less, while the college-

educated group continued to improve. The finding that improving life expectancy was largely restricted to only well-educated US residents in the most recent period supports an increasing role of inequality in the national trend in life expectancy. Nevertheless, drug use mortality increased over the 7-year period even among the college educated.

Changes in adult life expectancy from 2010 to 2017 should be interpreted in the context of overall trends in longevity since 1990. From 1990 to 2010, life expectancy continued to increase among white adults despite increasing educational differences.[10] Since 2010, however, adult life expectancy declined among white men and women, largely due to the decline in adult life expectancy among all non–college-educated groups. Among black adults, life expectancy improved despite increasing educational differences associated with the greater improvement in life expectancy among college-educated men and women. Nevertheless, increases in life expectancy among black adults were substantially reduced in the 2010-2017 period. Particularly among black men, the stagnation in adult life expectancy during those 7 years ended a 2-decade long improvement in life expectancy for this group.

The nature of the recent declines in adult life expectancy among white US residents and the increase in educational differences across all race-sex groups remains unclear. Prior research attributed the rise in mortality to "deaths of despair," which consist of drug use, alcohol use, and suicide.[5] These

Figure 2. Estimated Change in Years of Life Lost by Education and Cause of Death Between 2010 and 2017 Among Non-Hispanic White US Residents
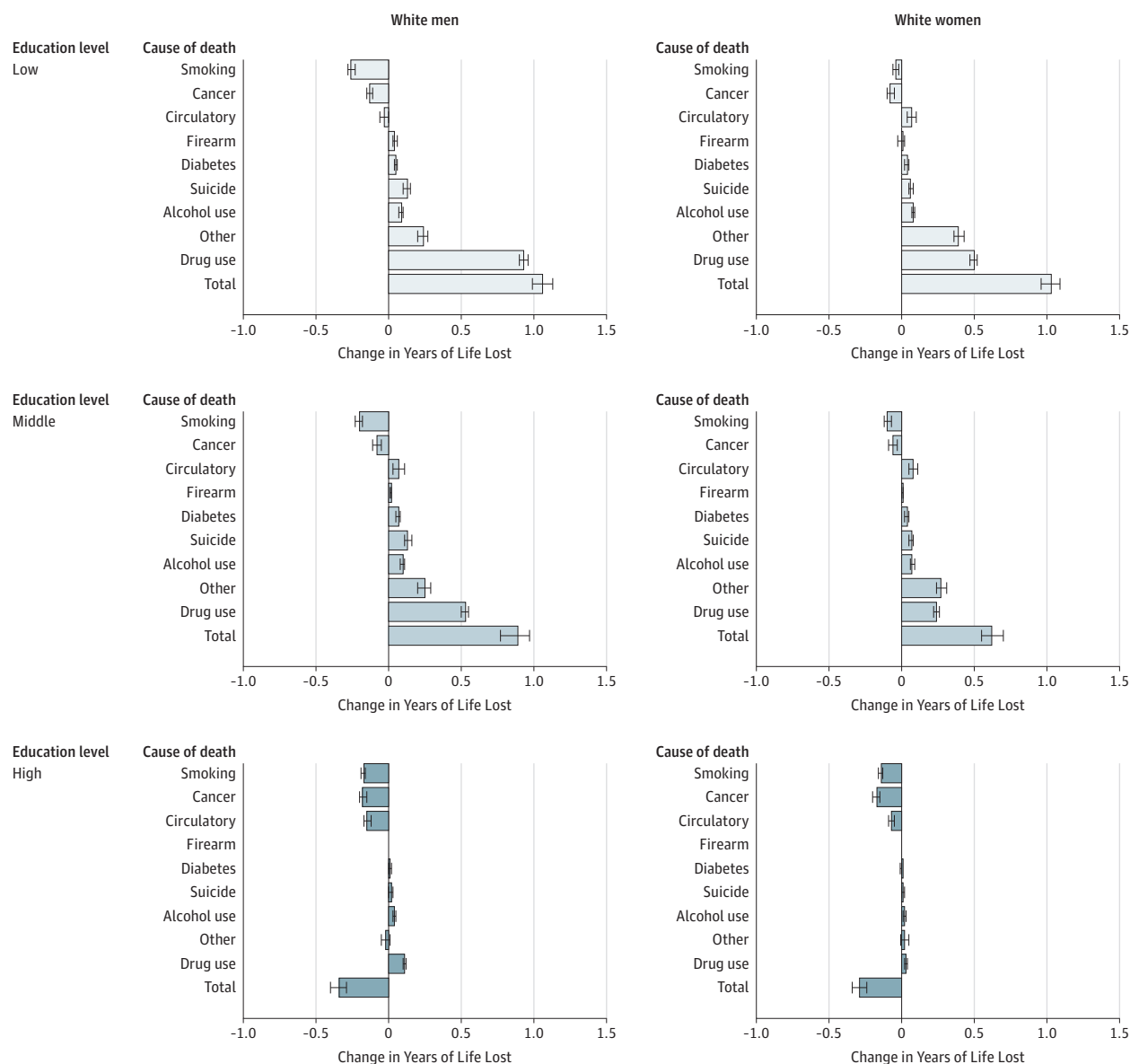
The graphs show the years of life lost between ages 25 and 84 years. The error bars indicate 95% CIs. Education categories are as follows: low = high school graduate or lower, middle = some college education but no 4-year college degree, and high = 4-year college graduate or higher.

deaths, it was argued, collectively reflect self-destructive behaviors linked to the growing social isolation, economic distress, and downward social mobility that have characterized large segments of the US working class.[27-29] However, deteriorating economic conditions at the county level appear to explain less than one-tenth of the rise in drug- and opioid-related deaths.[30] Furthermore, consistent with prior research, this study finds that increases in life years lost to drug use were substantially larger than increases associated with alcohol use and suicide.[31]

Limitations

This study has several limitations. First, it relied on unlinked ACS and NVSS data to estimate educational differences in

adult mortality. Unlinked data are less accurate than self-reported survey data and are prone to misclassification bias.[21] However, general population surveys are insufficient in studying trends in cause-specific mortality and have been shown to overstate life expectancy, irrespective of education, because their populations are healthier than the general US population.[32,33] By contrast, the NVSS records all deaths in the United States and allows the study of cause-specific mortality, which is important in understanding the contributing factors for national trends.

Second, changes in the proportions of the population in various education strata can introduce selection effects and exaggerate differences in mortality.[34] If the low-education group diminished in size over time, it may consist

Figure 3. Estimated Change in Years of Life Lost by Education and Cause of Death Between 2010 and 2017 Among Non-Hispanic Black US Residents
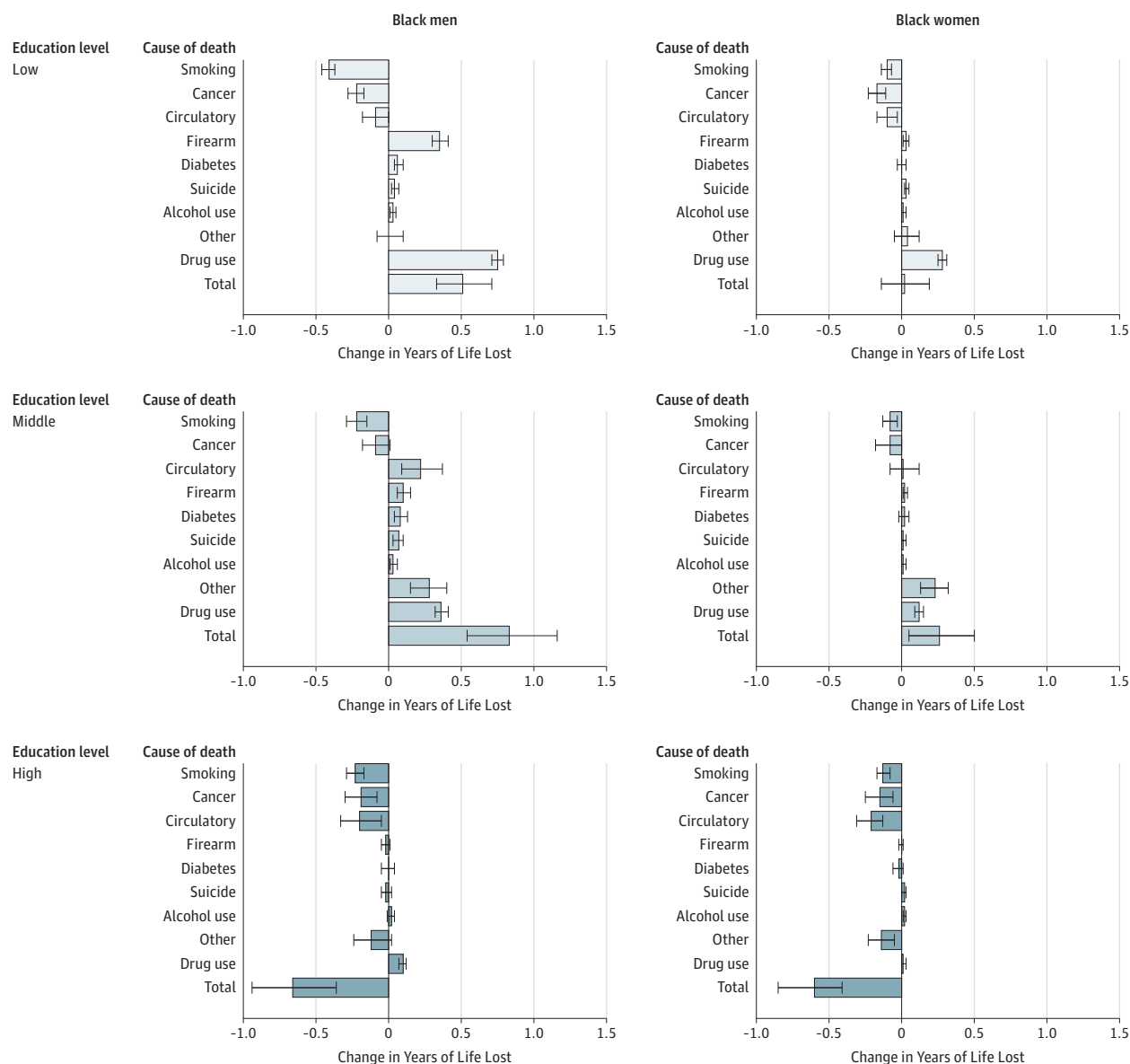
The graphs show the years of life lost between ages 25 and 84 years. The error bars indicate 95% CIs. Education categories are as follows: low = high school graduate or lower, middle = some college education but no 4-year college degree, and high = 4-year college graduate or higher.

of individuals who are more disadvantaged—for example, with respect to early-life social conditions—and their health could decline irrespective of educational attainment later in life. However, because this study focused on a short period of time in which the change in educational composition was small, selection effects would be minimal. Previous studies have shown that declines in life expectancy among low-education groups persisted even after adjusting for compositional changes.[35]

Third, the ACS data are subject to both sampling and nonsampling errors, as are all probability samples. Although the accuracy of the data is unknown, the ACS has high population coverage rates and low nonresponse rates, which likely minimize the potential error.[17]

Conclusions

In this serial cross-sectional study, estimated life expectancy at age 25 years declined overall between 2010 and 2017; however, it declined among persons without a 4-year college degree and increased among college-educated persons. Much of the increasing educational differences in years of life lost may be related to deaths attributed to drug use.

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