

Mortality Relative Risks by Smoking, Race/Ethnicity, and Education



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Introduction: The impact of cigarette smoking on mortality is well studied, with estimates of the relative mortality risks for the overall population widely available. However, age-specific mortality estimates for different sociodemographic groups in the U.S. are lacking.

Methods: Using the 1987–2018 National Health Interview Survey Linked Mortality Files through 2019, all-cause mortality relative risks (RRs) were estimated for current smokers or recent quitters and long-term quitters compared with those for never smokers. Stratified Cox proportional hazards regression models were used to estimate RRs by age, gender, race/ethnicity, and educational attainment. RRs were also assessed for current smokers or recent quitters by smoking intensity and for long-term quitters by years since quitting. The analysis was conducted in 2021–2022.

Results: All-cause mortality RRs among current smokers or recent quitters were generally highest for non-Hispanic White individuals than for never smokers, followed by non-Hispanic Black individuals, and were lowest for Hispanic individuals. RRs varied greatly by educational attainment; generally, higher-education groups had greater RRs associated with smoking than lower-education groups. Conversely, the RRs by years since quitting among long-term quitters did not show clear differences across race/ethnicity and education groups. Age-specific RR patterns varied greatly across racial/ethnic and education groups as well as by gender.

Conclusions: Age-specific all-cause mortality rates associated with smoking vary considerably by sociodemographic factors. Among high-education groups, lower underlying mortality rates for never smokers result in correspondingly high RR estimates for current smoking. These estimates can be incorporated in modeling analyses to assess tobacco control interventions' impact on smoking-related health disparities between different sociodemographic groups.

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INTRODUCTION

Cigarette smoking has declined significantly in the U.S., yet the extent of the decrease varies by sociodemographic factors,^{1,2} resulting in persistent disparities between different sociodemographic groups.^{1–7} Smoking behaviors and related mortality vary by several factors, including age, gender, race/ethnicity, SES, and region.^{8–13} Cigarette smoking is estimated to cause >480,000 deaths each year in the U.S.,^{1,14} but this mortality burden is unequally distributed across the nation. People with lower levels of educational attainment are known to smoke at higher rates than those with more education,^{6,13,15–17} but the

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smoking-related mortality rate they face has not been well studied. Mortality rates associated with smoking likely vary by race/ethnicity as well,^{8,18} although this is also an understudied topic. One recent study by Inoue-Choi et al.¹⁹ found that the RR of all-cause mortality for current daily smoking compared with that for never smoking was higher in non-Hispanic White individuals than in non-Hispanic Black or Hispanic individuals. Mortality rates are also known to vary by smoking intensity, measured by the number of cigarettes smoked per day or month among current smokers and by time since quitting among former smokers, though this is also understudied for specific subpopulations.^{8,10,19}

Empirical estimates of mortality rates associated with current and former smoking are necessary both to quantify the impact of smoking on mortality in a given population and to make projections about the future burden of smoking—typically assessed using tobacco simulation models.^{20–22} Although previous research has produced detailed age- and gender-specific all-cause mortality RRs for the general U.S. population,²³ such estimates are comparatively absent for specific sociodemographic groups—an impediment to future research that aims to both quantify and monitor smoking-related disparities over time. Recent data for the general U.S. population suggest that the risks of mortality from cigarette smoking relative to never smoking may be increasing.^{1,24} This further shows the need for up-to-date analyses of the mortality impacts of cigarette smoking across the whole U.S. population, in addition to specific subgroups.

Assessing the long-term consequences of cigarette smoking in specific populations requires detailed estimates of their smoking-related health risks by age and smoking history. However, as discussed earlier, current estimates of smoking-related mortality RRs in the U.S. do not have the required details to inform simulation models of the health consequences of smoking for relevant sociodemographic groups. To address these gaps, nationally representative data were used to estimate age-specific all-cause mortality RRs for current smokers or recent quitters who quit smoking <2 years ago and long-term quitters who quit smoking at least 2 years ago compared with those of never smokers, stratified by gender, race/ethnicity, and educational attainment.

METHODS

Study Sample

The National Health Interview Survey (NHIS) collects annual data on demographic characteristics and health information of the civilian non-institutionalized population of the U.S. Adult tobacco use data have been collected since 1965. On the basis of the availability and consistency of smoking data/questions, including use frequency and intensity, data from 1987, 1988, 1990, 1994, 1995,

and 1997–2018 NHIS surveys linked with mortality data from the 2019 National Death Index were utilized.^{25–27} Covariates included age; gender; race/ethnicity; education; and cigarette smoking variables such as use status (never, current, former), smoking intensity measured by the average number of cigarettes smoked per day (CPD), and years since quitting (YSQ) for former smokers. People who were not eligible for mortality follow-up (27,215) and missing information for smoking status (20,434), race/ethnicity (583), or education (2,862) were excluded. A total of 611,275 participants aged 30–84 years were included in the race/ethnicity analysis, and 608,996 participants were included in the education analysis. Individuals were followed for all-cause mortality for 10 years of follow-up from their survey interview; a total of 27,976 and 26,662 deaths were observed for males and females in the race/ethnicity analysis, respectively, and a total of 27,813 and 26,523 deaths were observed for males and females in the education analysis, respectively.

Measures

Ever smokers were defined as individuals who smoked 100 cigarettes or more during their lifetime. They were classified as current smokers if they reported smoking every day or some days and former smokers if they reported not smoking at all at the time of the survey interview. Former smokers were categorized into 2 groups: recent quitters (i.e., those who quit smoking <2 years ago) versus long-term quitters (i.e., those who quit smoking 2 or more years ago). In the main analysis, current smokers and recent quitters were combined into a single group because recent quitters are (1) much more likely to relapse back to smoking^{28–30} and (2) more likely to have quit as a response to smoking-related disease or disability.^{31–33} Thus, their mortality rate is inherently higher than that of an established former smoker. Age was categorized into 5 groups: 30–44, 45–54, 55–64, 65–74, and 75–84 years. Race/ethnicity was categorized into 5 groups: non-Hispanic White (NHW), non-Hispanic Black (NHB), and Hispanic. Non-Hispanic individuals of other racial backgrounds were excluded from the race/ethnicity-specific analyses owing to insufficient sample sizes. Education was categorized into 5 groups: ≤8th grade, 9th–11th grade, high school graduate or GED, some college, and at least a college degree.

Statistical Analysis

RRs of all-cause mortality, measured as Cox hazard ratios, and their 95% CIs were estimated using Cox proportional hazards models, accounting for the complex sample design of the NHIS using Taylor series linearization. Gender-specific RRs were estimated for current smokers or recent quitters versus never smokers and for long-term quitters versus never smokers. Separate stratified analyses were conducted by age and race/ethnicity and by age and educational attainment as an SES indicator.

First, RRs for all-cause mortality were estimated for current smokers or recent quitters and long-term quitters versus never smokers in the U.S. population. Further analyses were then conducted splitting the current smokers or recent quitters by smoking intensity (<10, 10–19, 20, ≥21 CPD or 1–5, 6–15, 16–25, ≥26 CPD) and the long-term quitters by the length of abstinence (2 to <5, 5 to <15, ≥15 YSQ). Analyses were conducted using the SURVEYPHREG procedure in SAS software, Version 9.4.

RESULTS

Table 1 summarizes the demographic characteristics of the study sample, stratified by smoking status: never smoker, current smoker, former smoker (YSQ<2, 2≤YSQ<5, 5≤YSQ<15, YSQ≥15). About 40% or above were in the age group 30–44 years in all smoking categories, except for former users who quit smoking 15 or more years ago. This group of former users was considerably older than those in other smoking status groups. A higher percentage of females than males were never smokers. The proportion of NHB individuals was higher in current smokers than in former smokers. The proportion of individuals with at least a college degree was lowest in current smokers and highest in never smokers, increasing with a longer length of smoking cessation among former smokers. Conversely, the percentage of individuals with 9th–11th-grade education or high

school education or GED was highest in current smokers and lowest in never smokers, with decreasing proportion by more YSQ in former users.

For both genders, all-cause mortality RRs for current smokers or recent quitters were highest in NHW individuals, followed by NHB individuals and then Hispanic individuals in most age groups (Table 2 and Figure 1). Mortality RRs increased until ages 55–64 years, then declined in NHW males. Conversely, RRs were relatively constant between ages 30 and 54 years, then increased and peaked at ages 65–74 years, and then decreased in ages 75–84 years in NHB males. RRs were highest at ages 65–74 years, the second highest at ages 30–44 years, and relatively constant at the other age groups in Hispanic males. RRs in NHW females showed similar age patterns as in NHS males. The RRs in NHB females are similar across all age groups. Among current smokers or recent quitters, the difference in RRs between

Table 1. Demographic Characteristics in Different Cigarette Use Groups in 1987–2018 NHIS Data

Characteristics	Never smoker (n=330,500), % (95% CI)	Current smoker (n=133,448), % (95% CI)	Former smoker			
			YSQ<2 (n=4,337), % (95% CI)	2≤YSQ<5 (n=16,895), % (95% CI)	5≤YSQ<15 (n=44,674), % (95% CI)	YSQ≥15 (n=82,004), % (95% CI)
Age group, years						
30–44	41.3 (41.0, 41.6)	44.6 (44.3, 45.0)	46.9 (45.0, 48.7)	43.0 (42.0, 43.9)	38.0 (37.5, 38.6)	10.0 (9.7, 10.3)
45–54	23.1 (22.9, 23.3)	27.2 (26.9, 27.5)	21.3 (19.6, 23.0)	22.3 (21.5, 23.1)	22.4 (21.9, 22.9)	20.1 (19.8, 20.5)
55–64	16.9 (16.7, 17.1)	17.6 (17.4, 17.9)	17.8 (16.4, 19.3)	18.6 (17.9, 19.3)	19.6 (19.2, 20.1)	26.3 (25.9, 26.7)
65–74	11.3 (11.1, 11.4)	8.0 (7.9, 8.2)	10.9 (9.9, 12.1)	11.9 (11.3, 12.5)	14.2 (13.8, 14.6)	25.9 (25.6, 26.3)
75–84	7.4 (7.3, 7.5)	2.5 (2.4, 2.6)	3.1 (2.5, 3.8)	4.3 (3.9, 4.6)	5.7 (5.5, 6.0)	17.6 (17.2, 17.9)
Sex						
Male	41.5 (41.3, 41.8)	53.0 (52.6, 53.3)	55.2 (53.4, 57.0)	54.5 (53.5, 55.5)	55.1 (54.5, 55.7)	58.4 (57.9, 58.8)
Female	58.5 (58.2, 58.7)	47.0 (46.7, 47.4)	44.8 (43.0, 46.6)	45.5 (44.5, 46.5)	44.9 (44.3, 45.5)	41.6 (41.2, 42.1)
Race/ethnicity						
Non-Hispanic White	67.2 (66.7, 67.6)	76.1 (75.6, 76.5)	79.8 (78.3, 81.1)	77.4 (76.6, 78.3)	79.1 (78.6, 79.7)	84.2 (83.8, 84.6)
Non-Hispanic Black	12.1 (11.8, 12.5)	12.3 (11.9, 12.7)	9.1 (8.2, 10.2)	9.0 (8.5, 9.5)	8.0 (7.7, 8.4)	6.5 (6.2, 6.7)
Hispanic	6.5 (6.3, 6.7)	3.5 (3.3, 3.7)	3.2 (2.5, 4.1)	3.9 (3.5, 4.3)	3.7 (3.5, 4.0)	2.7 (2.5, 2.9)
Non-Hispanic other	14.2 (13.9, 14.6)	8.1 (7.9, 8.4)	7.9 (7.0, 8.9)	9.7 (9.1, 10.3)	9.1 (8.8, 9.5)	6.7 (6.4, 6.9)
Education						
≤8th grade	6.8 (6.6, 7.0)	6.3 (6.1, 6.5)	7.4 (6.6, 8.3)	5.9 (5.5, 6.4)	5.9 (5.7, 6.2)	6.3 (6.1, 6.5)
9–11th grade	5.6 (5.5, 5.7)	12.8 (12.6, 13.0)	9.8 (8.8, 10.9)	8.1 (7.6, 8.6)	7.6 (7.3, 7.9)	6.9 (6.7, 7.1)
HSG or GED	27.2 (27.0, 27.5)	40.2 (39.9, 40.6)	36.4 (34.7, 38.2)	33.9 (33.0, 34.8)	32.1 (31.5, 32.6)	29.5 (29.1, 29.9)
Some college	25.1 (24.9, 25.3)	27.7 (27.4, 28.1)	26.6 (24.9, 28.3)	29.2 (28.4, 30.1)	29.0 (28.5, 29.6)	27.6 (27.2, 28.0)
At least a college degree	35.3 (34.9, 35.7)	12.9 (12.6, 13.2)	19.8 (18.3, 21.4)	22.9 (22.0, 23.7)	25.4 (24.8, 25.9)	29.7 (29.2, 30.2)
Cigarettes per day ^a						
<6		22.0 (21.7, 22.3)	15.9 (14.5, 17.4)	14.7 (13.3, 16.2)	15.3 (14.4, 16.1)	19.8 (19.1, 20.6)
6–15		32.4 (32.1, 32.8)	27.3 (25.6, 29.0)	26.7 (24.9, 28.5)	25.5 (24.5, 26.5)	26.4 (25.6, 27.2)
16–25		31.7 (31.3, 32.0)	33.6 (31.8, 35.4)	32.7 (30.9, 34.6)	33.4 (32.3, 34.4)	31.7 (30.9, 32.6)
≥26		13.9 (13.6, 14.2)	23.3 (21.8, 24.8)	25.9 (24.4, 27.5)	25.8 (24.9, 26.8)	22.1 (21.4, 22.8)

^aAverage number of cigarettes smoked per day (current smokers) and average number of cigarettes usually smoked per day when they smoked regularly (former smokers). Information for average cigarettes per day for former smokers was only available in 5 years of the survey: 1987, 1988, 1990, 2005, 2010.

HSG, high school graduate; NHIS, National Health Interview Survey; YSQ, years since quitting.

Table 2. All-Cause Mortality RRs for Current Smoker or Recent Quitters and Long-Term Quitters by Race/Ethnicity

Variables	Males		Females		Current smoker or recent quitter, ^a Males/females RR ratio	Long-term quitter, ^b Males/females RR ratio
	Current smoker or recent quitter, ^a	Long-term quitter, ^b	Current smoker or recent quitter, ^a	Long-term quitter, ^b		
	RR (95% CI)	RR (95% CI)	RR (95% CI)	RR (95% CI)		
All races, years						
30–44	2.14 (1.86, 2.46)	1.16 (0.92, 1.44)	2.28 (1.93, 2.70)	1.09 (0.81, 1.45)	0.94	1.06
45–54	2.66 (2.37, 2.97)	1.19 (1.02, 1.37)	2.60 (2.31, 2.93)	1.16 (0.98, 1.37)	1.02	1.03
55–64	3.38 (3.09, 3.69)	1.41 (1.28, 1.56)	3.20 (2.91, 3.51)	1.44 (1.29, 1.61)	1.06	0.98
65–74	3.35 (3.12, 3.60)	1.51 (1.41, 1.62)	2.96 (2.77, 3.17)	1.55 (1.45, 1.67)	1.13	0.97
75–84	2.36 (2.20, 2.53)	1.40 (1.32, 1.47)	2.72 (2.57, 2.88)	1.47 (1.40, 1.55)	0.87	0.95
Non-Hispanic White, years						
30–44	2.29 (1.92, 2.74)	1.18 (0.87, 1.58)	3.10 (2.46, 3.91)	1.34 (0.93, 1.93)	0.74	0.88
45–54	3.15 (2.74, 3.63)	1.17 (0.96, 1.41)	2.81 (2.40, 3.29)	1.21 (0.98, 1.49)	1.12	0.97
55–64	3.75 (3.38, 4.16)	1.51 (1.33, 1.70)	3.60 (3.21, 4.04)	1.51 (1.32, 1.72)	1.04	1.00
65–74	3.45 (3.16, 3.76)	1.51 (1.39, 1.64)	3.22 (2.98, 3.48)	1.62 (1.50, 1.76)	1.07	0.93
75–84	2.43 (2.24, 2.64)	1.41 (1.32, 1.50)	2.82 (2.65, 3.00)	1.51 (1.43, 1.59)	0.86	0.93
Non-Hispanic Black, years						
30–44	1.99 (1.43, 2.77)	1.44 (0.86, 2.42)	2.01 (1.40, 2.87)	1.48 (0.66, 3.34)	0.99	0.97
45–54	1.84 (1.47, 2.30)	1.51 (1.08, 2.09)	2.31 (1.83, 2.91)	1.21 (0.87, 1.68)	0.80	1.25
55–64	2.76 (2.25, 3.40)	1.48 (1.18, 1.86)	2.26 (1.89, 2.71)	1.51 (1.17, 1.95)	1.22	0.98
65–74	3.08 (2.61, 3.63)	1.60 (1.33, 1.93)	2.30 (1.96, 2.69)	1.39 (1.17, 1.66)	1.34	1.15
75–84	2.01 (1.68, 2.42)	1.21 (1.04, 1.42)	1.99 (1.67, 2.37)	1.10 (0.96, 1.28)	1.01	1.10
Hispanic, years						
30–44	2.26 (1.58, 3.24)	1.51 (0.92, 2.48)	1.17 (0.72, 1.88)	1.10 (0.54, 2.24)	1.93	1.37
45–54	1.73 (1.25, 2.37)	1.34 (0.95, 1.89)	1.81 (1.20, 2.75)	1.35 (0.79, 2.30)	0.96	0.99
55–64	1.84 (1.36, 2.49)	0.98 (0.72, 1.35)	2.19 (1.52, 3.15)	1.42 (0.97, 2.07)	0.84	0.69
65–74	2.58 (2.03, 3.27)	1.52 (1.20, 1.92)	1.56 (1.15, 2.11)	1.42 (1.08, 1.87)	1.65	1.07
75–84	1.65 (1.27, 2.15)	1.17 (0.94, 1.46)	2.14 (1.59, 2.89)	1.41 (1.12, 1.78)	0.77	0.83

Note: Data for all-cause mortality within a 10-year follow-up period ranges from 1987 to 2019. RR (i.e., hazard ratio) was estimated from the Cox proportional hazard regression analysis.

^aRecent quitters are individuals who quit smoking <2 years ago.

^bLong-term quitters are individuals who have been quitting smoking ≥ 2 years.

females and males varied by age and race/ethnicity, although the differences were not statistically significant in some categories, in which 95% CIs for males and females were overlapping. In NHW individuals, the RRs were lower in males than in females for the age groups 30–44 and 75–84 years. The RRs were higher in NHB males than in females at ages 65–74 years. RRs in Hispanic individuals do not show a clear pattern by gender. The RRs for long-term quitters versus never smokers increased until ages 65–74 years and then declined in both NHW males and females, but there were no clear age patterns in NHB and Hispanic populations (Table 2 and Appendix Figure 1, available online).

Table 3 and Figure 1 show RR estimates by educational attainment. The results show in general a positive gradient in all-cause mortality RRs for current smokers or recent quitters by educational attainment level among males aged 30–44, 45–54, and 55–64 years. RRs were generally higher among lower-education groups than

among higher-education groups in males aged 65–74 years, but they were lowest in the ≤ 8 th grade and some college groups and highest in the at-least-a-college-degree group in males aged 75–84 years. The RRs patterns by educational attainment level in females differed from those in males. The RRs in females with at least a college degree were lowest in ages 30–44 years but became highest in ages 65–74 and 75–84 years. In addition, there was a clear positive gradient in all-cause mortality RRs by educational attainment level among females aged 65–74 and 75–84 years. The age pattern in RRs varied depending on educational attainment, but in general, it increased by age and peaked either at ages 55–64 or at 65–74 years and then declined in males. In contrast, RRs increased by age among females with at least a college degree, but the age pattern is less clear in the other education groups in females. Gender differences in RRs for current smokers or recent quitters varied by age and educational attainment, although differences

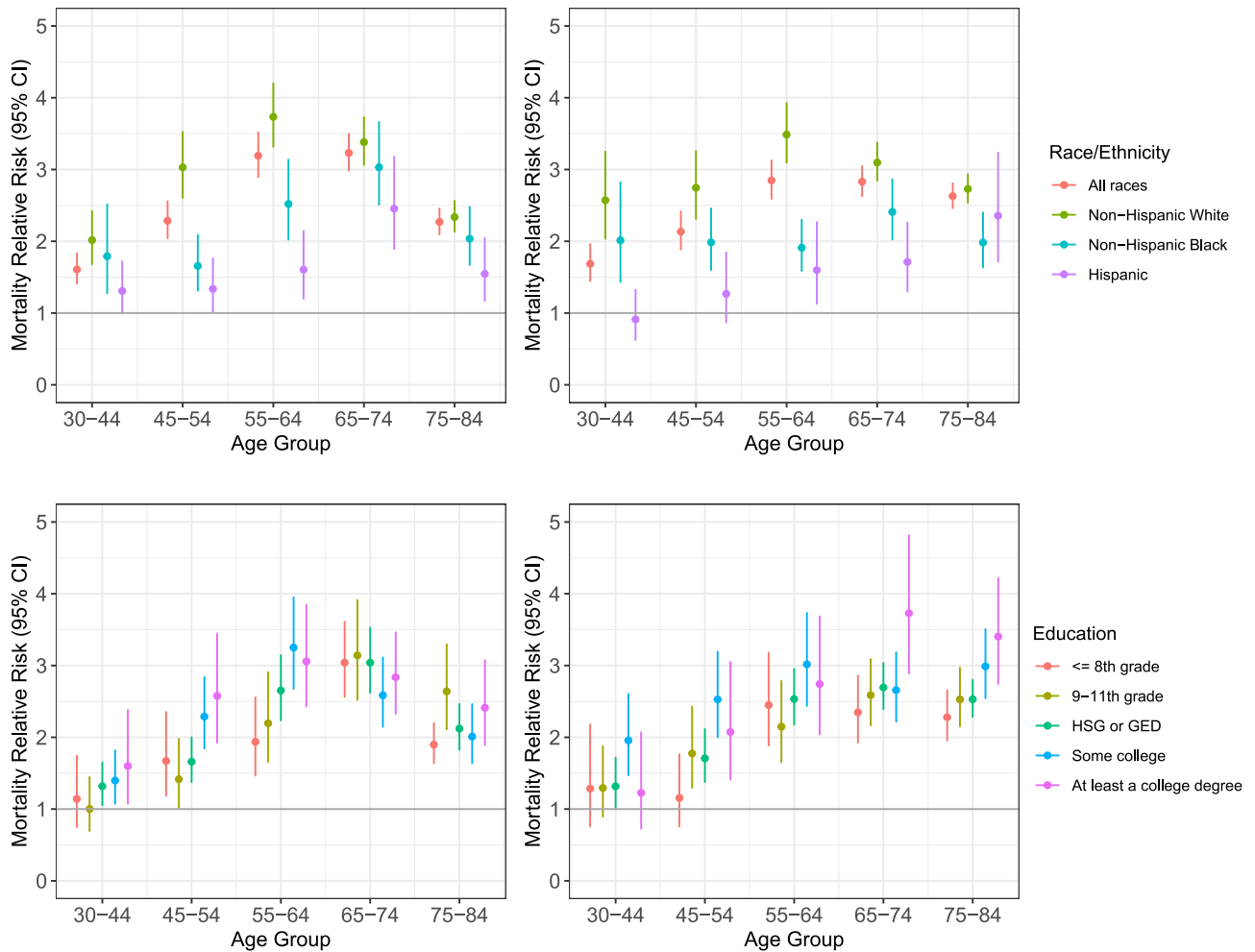


Figure 1. RRs of all-cause mortality for current smokers or recent quitters versus for never smokers by age group and race/ethnicity (top panels) and by age group and educational attainment level (bottom panels).

Note: These RRs are hazard ratios estimated from the Cox proportional hazard regression analysis stratified by gender (males, left panels; females, right panels). Recent quitters are individuals who quit smoking <2 years ago. All denotes all race/ethnicity combined. HSG, high school graduate.

were not statistically significant in some categories (95% CIs were overlapping). The RRs for those with at least a college degree were higher in males than in females in ages below 65 years but lower after age 65 years; they were lower in males than in females with some college education at ages 30–44 and 75–84 years. No clear RR patterns were observed by educational attainment level for long-term quitters versus never smokers (Table 3 and Appendix Figure 1, available online).

Age-specific patterns of all-cause mortality RRs by smoking intensity groups (1–5, 6–15, 16–25, and ≥26 CPD) for each race/ethnic subgroup are shown in Appendix Tables 1 and 5 (available online) and Appendix Figures 2 and 6 (available online). RRs increased with higher CPD levels for both males and females. However, some estimates, especially among individuals with ≥26 CPD, had large 95% CIs owing to small sample

sizes. Among long-term quitters, RRs tended to decrease by increasing YSQ across racial/ethnic groups and gender. RRs declined to the level of never smokers for individuals with ≥15 YSQ, especially among those who were younger than age 65 years (Appendix Tables 2 and 6, available online, and Appendix Figures 3 and 7, available online).

Age-specific all-cause mortality RRs by smoking intensity for each education group are shown in Appendix Tables 3 and 7 (available online) and Appendix Figures 4 and 8 (available online). Mortality RRs increased by increasing smoking intensity across education groups in general. RRs for long-term quitters decreased by increasing YSQ across all education groups (Appendix Tables 4 and 8, available online, and Appendix Figures 5 and 9, available online). Overall all-cause mortality RR estimates adjusted by age for each gender, race/ethnic

Table 3. All-Cause Mortality RRs for Current Smoker or Recent Quitters and Long-Term Quitters by Education

Variables	Males		Females		Current smoker or recent quitter, ^a Males/females RR ratio	Long-term quitter, ^b Males/females RR ratio
	Current smoker or recent quitter, ^a	Long-term quitter, ^b	Current smoker or recent quitter, ^a	Long-term quitter, ^b		
	RR (95% CI)	RR (95% CI)	RR (95% CI)	RR (95% CI)		
≤8th grade, years						
30–44	1.56 (0.98, 2.49)	1.15 (0.53, 2.47)	1.85 (1.00, 3.45)	–	0.84	–
45–54	1.97 (1.31, 2.97)	0.88 (0.53, 1.48)	2.11 (1.39, 3.22)	1.61 (0.78, 3.32)	0.93	0.55
55–64	2.52 (1.92, 3.30)	1.47 (1.08, 2.01)	3.03 (2.34, 3.93)	1.71 (1.17, 2.50)	0.83	0.86
65–74	3.22 (2.69, 3.84)	1.70 (1.42, 2.03)	2.46 (2.04, 2.97)	1.80 (1.47, 2.22)	1.31	0.94
75–84	2.00 (1.74, 2.29)	1.28 (1.15, 1.44)	2.40 (2.07, 2.77)	1.43 (1.26, 1.63)	0.83	0.90
9th–11th grade, years						
30–44	1.69 (1.10, 2.59)	0.47 (0.20, 1.10)	2.30 (1.46, 3.63)	2.25 (0.90, 5.63)	0.73	0.21
45–54	1.39 (1.02, 1.89)	0.66 (0.41, 1.08)	2.69 (1.96, 3.70)	1.70 (0.97, 2.98)	0.52	0.39
55–64	2.44 (1.85, 3.21)	1.34 (0.97, 1.84)	2.47 (1.94, 3.14)	1.69 (1.24, 2.31)	0.99	0.79
65–74	2.95 (2.39, 3.64)	1.58 (1.28, 1.95)	2.71 (2.30, 3.19)	1.74 (1.45, 2.09)	1.09	0.91
75–84	2.41 (1.95, 2.97)	1.69 (1.42, 2.02)	2.51 (2.16, 2.92)	1.66 (1.46, 1.88)	0.96	1.02
HSG or GED, years						
30–44	1.78 (1.40, 2.25)	0.91 (0.63, 1.33)	1.76 (1.33, 2.33)	1.04 (0.62, 1.75)	1.01	0.88
45–54	2.02 (1.68, 2.43)	1.00 (0.79, 1.28)	1.89 (1.54, 2.32)	1.06 (0.80, 1.42)	1.07	0.94
55–64	2.63 (2.25, 3.07)	1.24 (1.04, 1.48)	2.85 (2.45, 3.30)	1.52 (1.25, 1.83)	0.92	0.82
65–74	2.97 (2.60, 3.40)	1.49 (1.30, 1.70)	2.76 (2.46, 3.09)	1.60 (1.43, 1.79)	1.08	0.93
75–84	2.34 (2.05, 2.67)	1.41 (1.28, 1.54)	2.60 (2.38, 2.85)	1.62 (1.49, 1.75)	0.90	0.87
Some college, years						
30–44	1.65 (1.27, 2.13)	1.21 (0.83, 1.78)	2.44 (1.83, 3.27)	1.18 (0.74, 1.86)	0.68	1.03
45–54	2.62 (2.12, 3.24)	1.29 (0.99, 1.70)	2.57 (2.07, 3.18)	1.01 (0.74, 1.37)	1.02	1.28
55–64	3.04 (2.55, 3.64)	1.25 (1.02, 1.53)	3.15 (2.59, 3.83)	1.33 (1.07, 1.65)	0.97	0.94
65–74	2.67 (2.28, 3.12)	1.26 (1.08, 1.46)	2.73 (2.35, 3.18)	1.41 (1.20, 1.65)	0.98	0.89
75–84	2.00 (1.66, 2.41)	1.28 (1.13, 1.45)	2.96 (2.57, 3.40)	1.42 (1.27, 1.60)	0.68	0.90
At least a college degree, years						
30–44	2.09 (1.44, 3.03)	1.52 (0.93, 2.48)	1.52 (0.91, 2.54)	1.02 (0.57, 1.80)	1.38	1.49
45–54	3.06 (2.30, 4.07)	1.51 (1.12, 2.04)	2.32 (1.58, 3.40)	1.32 (0.92, 1.89)	1.32	1.14
55–64	3.54 (2.79, 4.50)	1.42 (1.16, 1.74)	2.73 (2.07, 3.60)	1.38 (1.08, 1.77)	1.30	1.03
65–74	3.06 (2.57, 3.65)	1.33 (1.14, 1.54)	3.78 (3.01, 4.75)	1.58 (1.25, 2.00)	0.81	0.84
75–84	2.56 (2.08, 3.15)	1.27 (1.12, 1.44)	3.76 (3.11, 4.55)	1.40 (1.20, 1.62)	0.68	0.91

Note: Data for all-cause mortality within a 10-year follow-up period ranges from 1987 to 2019. RR (i.e., hazard ratio) was estimated from the Cox proportional hazard regression analysis.

^aRecent quitters are individuals who quit smoking <2 years ago.

^bLong-term quitters are individuals who have been quitting smoking ≥2 years.

HSG, high school graduate.

group, and education group are also shown in [Appendix Tables 9–13](#) (available online).

DISCUSSION

This study estimated all-cause mortality RRs associated with smoking in the U.S. stratified by age, gender, race/ethnicity, and educational attainment. Among current smokers or recent quitters who quit smoking <2 years ago, all-cause mortality RRs were generally higher in NHW individuals than in NHB or Hispanic individuals compared with those among never smokers. RRs also

increased by the level of educational attainment, with higher RRs seen for higher-education groups. In the analyses further stratified by smoking intensity among current smokers or recent quitters, RRs generally increased in both genders with higher levels of smoking intensity across racial/ethnic and education groups. Gender differences in RRs for current smokers or recent quitters varied by age, race/ethnicity, and educational attainment. Interestingly, females tended to have higher RRs than males among individuals aged >65 years who had some college education or at least a college degree. The all-cause mortality RRs for long-term quitters were

negatively associated with the length of abstinence from smoking in all racial/ethnic and education groups for both genders, with mortality rates similar to those in never smokers for individuals with 15 years or more of quitting smoking, particularly among those who were younger than age 65 years.

Among current smokers or recent quitters, the age pattern of all-cause mortality RRs from smoking varied by gender, race/ethnicity, and educational attainment. In general, RRs increased at younger ages, peaking at age 55–64 or 65–74 years and then declining, although differences were not statistically significant for some age categories (overlapping 95% CIs). However, there were some noticeable departures from this pattern. For instance, the RRs in females with at least a college degree kept increasing by age and became highest at ages 65–74 and 75–84 years. Moreover, the RRs for long-term quitters were lower in younger ages, 30–44 and 45–54 years, than in the older age groups in both NHW males and females, but there was no clear age pattern among other racial/ethnic or education groups.

The results are generally consistent with previous literature. A pooled cohort analysis based on follow-up time from 2000 to 2010 in 5 U.S. cohort studies showed that all-cause mortality is much higher in males than in females, but the all-cause mortality RRs between current and never smokers is similar in both genders within the same age stratum: 2.92 (95% CI=2.69, 3.18), 3.00 (95% CI=2.89, 3.13), and 2.36 (95% CI=2.24, 2.48) among males and 2.64 (95% CI=2.43, 2.86), 2.87 (95% CI=2.76, 2.99), and 2.47 (95% CI=2.37, 2.58) among females for ages 55–64, 65–74, and ≥ 75 years, respectively.¹ A recent study also based on the 1997–2018 NHIS adults aged 25–84 years who were followed up for mortality through 2019 showed that all-cause mortality RRs for current smokers versus those for never smokers were 2.91 (95% CI=2.79, 3.04), 2.21 (95% CI=2.02, 2.41), and 1.99 (95% CI=1.77, 2.24) among NHW, NHB, and Hispanic males and 3.15 (95% CI=3.03, 3.28), 2.20 (95% CI=2.02, 2.41), and 2.05 (95% CI=1.80, 2.33) among NHW, NHB, and Hispanic females, respectively.³⁴ The RRs by age and gender for all races/ethnicity combined in this study are consistent with these studies, although this present analysis combined current smokers or recent quitters in a single group. Another study using pooled 1997–2003 NHIS adult samples aged 50–84 years linked to the National Death Index through 2006 found an all-cause mortality hazard ratio of 1.49 for NHB males relative to that for NHW males after adjusting for age at baseline, BMI, and survey year. This estimate decreased to 1.39 after additional adjustment for smoking status⁸ and decreased further to 1.15 when marital status, education, family income, and region

were also adjusted. These results suggest that smoking and SES are important determinants of racial disparities in overall mortality. A study by Inoue-Choi and colleagues¹⁹ showed that the RR of all-cause mortality increases by the number of CPD up to the hazard ratio of 2.94 (95% CI=2.75, 3.14) in current daily smokers who smoked >30 CPD. This is slightly lower than this study's age-adjusted hazard ratio for current smokers or recent quitters who smoked >26 CPD (hazard ratio=3.57; 95% CI=3.36, 3.78 and hazard ratio=3.99; 95% CI=3.68, 4.32 for males and females, respectively).

Interestingly, the study findings suggest lower mortality RRs from smoking for those with lower education, who have higher smoking prevalence than those with higher education.^{6,15,17,35–40} This apparently counterintuitive finding is likely due to greater competing mortality risks from nonsmoking sources among those with lower education, which affect all never, current, and former smokers.^{41–43} In contrast, those with higher educational levels have fewer comorbidities or competing causes of risk, which likely then results in higher RRs when comparing people who smoke with those who never smoke. This phenomenon, in addition to differences in other relevant factors such as smoking intensity and duration,³⁴ might also help to explain higher mortality RRs among NHW than among NHB individuals, given the higher overall mortality rates in the black than in White populations in the U.S.^{44–47}

Smoking-related all-cause mortality RRs vary greatly by age, gender, race/ethnicity, and educational attainment. It is thus crucial to characterize the differences in RRs between key population subgroups and to consider these when assessing the impact of tobacco control interventions on smoking-related health outcomes and disparities.^{48–53} Not doing so can result in over/underestimation of the burden and impact of interventions in specific subgroups and mischaracterize how different interventions could affect smoking-related health disparities.

This study used nationally representative data of the U.S. non-institutionalized population covering mortality data with a large sample from 1987 to 2019. These data provided detailed smoking information on use status, intensity, and YSQ as well as the other demographic variables, which allowed extensive analyses of all-cause mortality for people with different smoking experiences in various combinations of age, gender, and race/ethnicity or educational attainment. The estimates from this study can be readily incorporated into smoking and mortality simulation models to assess the impact of smoking tobacco control interventions on these subgroups.^{1,48–50} The large differences in mortality patterns between subgroups found in this study suggest that

group-specific estimates are essential for models to properly capture smoking risks and the impact of interventions in different sociodemographic groups.

Previously, all-cause mortality RRs for current (by smoking intensity) and former smokers versus for never smokers by age and gender have been used as input parameters for the development of the Cancer Intervention and Surveillance Modeling Network-Lung Working Group Smoking History Generator (SHG) for the U.S. population. The SHG is a microsimulation model that generates detailed smoking histories by gender and birth cohort for the U.S. population, which are inputs for multiple simulation models.^{21,22,54–58} The new estimates in this study will facilitate the extension of the SHG and other models to simulate racial/ethnic- and educational attainment level-specific individual smoking histories. Combined with the smoking parameters provided by Meza et al.⁵ and Cao and colleagues,⁶ these all-cause mortality RRs by race/ethnicity and education will offer relevant data to inform modeling, evaluation, and surveillance tools, which can evaluate the impact of specific tobacco control interventions on smoking-related health disparities.^{50,59,60}

Limitations

This study has some limitations. Although data were combined from multiple NHIS surveys, sample sizes in some subgroups were relatively small, resulting in wide CIs. This was particularly true when estimating RRs by smoking intensity among current smokers or recent quitters and by the length of abstinence among long-term quitters. The mortality analysis did not account for underlying tobacco-related and nontobacco-related comorbidities and other health risks, which may partially explain the lower mortality RRs from smoking among lower-education or NHB individuals than among higher-education or NHW individuals. Plans to extend this analysis using the Tobacco Longitudinal Mortality Study (TLMS) are underway; this links the 1993–2019 Tobacco Use Supplement to the Current Population Survey and the National Death Index and has considerably larger sample sizes. Using the TLMS data, additional covariates can be accounted for when investigating differences in smoking-related mortality by race/ethnicity or education. Cox proportional hazard regression analyses did not adjust for any other relevant smoking determinants, such as income, U.S. region, BMI, health insurance coverage, and education (for the race/ethnicity analysis) and race/ethnicity (for the education analysis).^{8–11,19,61} This is because simulation models usually do not include all of these covariates, so unadjusted estimates for specific subgroups are required to inform such models.^{1,22,49,50,52–54,62} Another limitation is that all Hispanic individuals are combined into a single

group. Some studies have suggested that smoking patterns are different between Hispanic subgroups^{63,64} as well as between other U.S. subpopulations (e.g., Asian subpopulations and American Indian and Alaskan Native subgroups). Future analyses using larger samples (TLMS) should attempt to estimate RRs for these subpopulations.

CONCLUSIONS

All-cause mortality RRs associated with smoking vary by age, gender, race/ethnicity, and educational attainment. RRs are lower in Hispanic and NHB individuals than in NHW individuals and increase by level of educational attainment. The resulting estimates can be incorporated into simulation models for smoking and related health outcomes to evaluate the potential differential impact of tobacco control policies on different sociodemographic groups and on smoking-related health disparities.

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SUPPLEMENTAL MATERIAL

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