American Journal of Epidemiology
Copyright © 2002 by the Johns Hopkins Bloomberg School of Public Health

Vol. 156, No. 1
Printed in U.S.A.
DOI: 10.1093/aje/kwf001

All-Cause and Cause-specific Death Rates by Educational Status for Two Million People in Two American Cancer Society Cohorts, 1959–1996

Kyle Steenland[1], Jane Henley[2], and Michael Thun[2]

[1] National Institute for Occupational Safety and Health, Cincinnati, OH.
[2] American Cancer Society, Atlanta, GA.

Received for publication October 25, 2001; accepted for publication March 15, 2002.

Low socioeconomic status is associated with high mortality, but the extent to which socioeconomic status affects particular diseases and whether socioeconomic status effects have changed over time are uncertain. The authors used education as a marker for socioeconomic status in a study of two large American Cancer Society cohorts (follow-up, 1959–1996). Low education was associated with higher death rates in both cohorts from all causes and most specific causes, except breast cancer and external causes among women. Life expectancy in the more recent cohort was 4.8 years shorter for men and 2.7 years shorter for women for the least versus the most educated. The inverse relation between education and mortality was strongest for coronary heart disease, lung cancer, diabetes, and chronic obstructive pulmonary disease; moderate for colorectal cancer, external causes (men only), and stroke; weak for prostate cancer; and reversed for external causes among women. The direction of a weak gradient for breast cancer differed for those with and without prevalent breast cancer at baseline. Adjustment for conventional risk factors, probable intermediate variables between education and mortality, diminished but did not eliminate the observed educational/mortality gradients. Temporal trends showed increasing mortality differences by education for coronary heart disease, diabetes, and lung cancer for women. *Am J Epidemiol* 2002;156:11–21.

education; mortality; social class

Abbreviations: CI, confidence interval; CPS-I, Cancer Prevention Study I; CPS-II, Cancer Prevention Study II; ICD-7, *International Classification of Diseases,* Seventh Revision; ICD-9, *International Classification of Diseases,* Ninth Revision.

Several large cohort studies in the United States have shown that all-cause, heart disease, and cancer mortality rates are higher among persons with lower education or income, compared with more educated or affluent people (1–5). This association is only partly accounted for by standard risk factors that correlate with education or income. Similar findings have come from Canada and Europe (6–8).

Several studies have looked at trends in mortality over time by education or occupation in the United States. A principal finding has been that the declines in all-cause and coronary heart disease mortality since World War II through the mid–1980s have been largest for those with higher education or income (9–12); similar findings through the early 1990s have recently come from Denmark and Sweden (13, 14).

There are few data for more recent years for the United States. We have looked at mortality by education for all causes and several common causes of death from 1959–1972 and 1982–1996 in two large American Cancer Society cohorts (Cancer Prevention Study I (CPS-I) and Cancer Prevention Study II (CPS-II). This paper examines death rates by education before and after adjustment for conventional risk factors.

Educational attainment is closely related to income and socioeconomic status. Differences in educational attainment thus reflect differences in socioeconomic status and are a measure of social inequality within a society. The importance of documenting differences in mortality by education lies in making explicit the ultimate consequences of this inequality (lower life expectancy for the less educated). We document in this paper which causes of death show the strongest relation with education and how these patterns have changed over time. For some outcomes, differences in

Reprint requests to Dr. Kyle Steenland, Robert A. Taft Laboratories, National Institute for Occupational Safety and Health, 4676 Columbia Parkway, Cincinnati, OH 45226-1998 (e-mail: nsteenland@cdc.gov).

mortality by education have continued to increase in the 1990s. We discuss the degree to which known risk factors account for mortality differences by education.

MATERIALS AND METHODS

The CPS-I cohort consisted of 1,051,038 men and women enlisted by American Cancer Society volunteers in 1959. Participants, aged 30 years or older, came from 25 states. The mean age was 54 (range, 30–108) years. Vital status was determined by volunteers, organized at the county level, who generally knew the study participants for whom they were responsible. Vital status was also determined via questionnaires sent in 1961, 1963, 1971, and 1975, as well as via checks of vital status data in selected states for all state residents (15). An estimated 98 percent of the cohort was successfully traced. By December 1972, 18 percent had died, and death certificates were obtained for 97 percent and coded to the *International Classification of Diseases*, Seventh Revision. We excluded all those missing education (1 percent) and anyone whose person-time was limited to less than age 45 years (2 percent), leaving a cohort of 445,126 men and 577,184 women for our analysis. Exclusion of person-time less than age 45 years was necessary in calculating directly standardized rates because some age- and sex-specific cells had no person-time.

The CPS-II cohort consisted of 1,184,657 men and women enlisted by American Cancer Society volunteers in 1982. Participants, aged 30 years or older, were enrolled nationwide. The mean age was 57 (range, 30–111) years. Vital status was determined by volunteers through 1998 and by the National Death Index subsequently. Comparison of the two methods indicated that the National Death Index found 93 percent of deaths identified by volunteers in 1985 (16). We estimate that CPS-II follow-up from 1982 to 1996, which involves a mix of volunteers and the National Death Index, would underestimate death rates by approximately 3–4 percent in relation to CPS-I, which involved solely volunteers. By December 1996, 18 percent of the CPS-II cohort had died, and death certificates were obtained for 97 percent and coded to the *International Classification of Diseases*, Ninth Revision. We first excluded all those missing education (2 percent) and then those with person-time limited to less than age 45 (1 percent) years, leaving a cohort of 499,265 men and 663,051 women for analysis.

Questionnaire data for education were available and reasonably comparable for both CPS-I (five levels) and CPS-II (six levels). Data on income were not available, and data on occupation were limited in CPS-I, motivating our choice of education as an indicator of socioeconomic status.

At baseline, participants in both CPS-I and CPS-II completed a brief questionnaire, which included data on smoking history, diet, alcohol intake, history of illnesses, menopausal status, height, weight, retirement status, and education. Education was categorized as grammar school (less than high school, less than ninth grade), some high school, high school (completion of the 12th grade), some college, college graduate, and postgraduate (available in CPS-II only).

Analyses were done for each sex and cohort (CPS-I and CPS-II). Initial analyses examined sex-specific and education-specific rates directly standardized for age (5-year categories) to the age-specific person-time distribution of the combined cohorts.

Temporal trends in rates by education within each cohort were examined via Poisson regression, using 5-year attained age categories for person-time. Calendar time-specific rates were created by dividing the follow-up period for each cohort into biennial periods (person-time and deaths were cross-classified by both age and calendar time). The increase in the rate ratio per 1-year decrease in education (the educational gradient) was calculated within CPS-I and CPS-II, using years of schooling as a continuous variable (6 for less than high school, 10 for some high school, 12 for high school, 14 for some college, 16 for completion of college, and 18 for graduate school).

Cox regression was also used to calculate sex-specific rate ratios by education, adjusted for either 1) age alone or 2) age, smoking (never any type, current cigarette, former cigarette, current pipe/cigar, former pipe/cigar, mixed current, mixed former), body mass index (<18.5, 18.5–<25, 25–<30, ≥30 kg/m^2), menopausal status (women only), diet (none vs. some intake of fruit, vegetables, and salad, each separately), alcohol (current drinker >1 day, <1 day, vs. not current), and hypertension (self-report). We had no data on the validity of self-reported hypertension, but there was a high correlation between self-reported disease and self-reported medication use for that disease. Parity and age at first birth were included in breast cancer analyses. Follow-up time was used to represent time in Cox regression; analyses were stratified by 1-year age groups.

Death rates were calculated for all causes combined and for other major causes. These included coronary heart disease (*International Classification of Diseases,* Ninth Revision (ICD-9), codes 410–414; *International Classification of Diseases,* Seventh Revision (ICD-7), code 420), stroke (ICD-9 codes 430–438, ICD-7 codes 330–334), diabetes (ICD-9 code 250, ICD-7 code 260), lung cancer (ICD-9 code 162, ICD-7 codes 162 and 163), breast cancer (ICD-9 code 174, ICD-7 code 170), colorectal cancer (ICD-9 and ICD-7 codes 153 and 154), prostate cancer (ICD-9 code 185, ICD-7 code 177), chronic obstructive pulmonary diseases (ICD-9 codes 490–492 and 496, ICD-7 codes 500–502 and 527), and external causes (ICD-9 and ICD-7 codes E800–E999).

Life expectancy (i.e., the mean years of life expected from age 45 until death) was calculated for each educational group in CPS-II, for men and women separately. A yearly life table for each educational group was constructed, and the sum of the yearly survival function was used to estimate life expectancy (17).

We retained in the analysis those who had prevalent disease at baseline under the assumption that, if education were related to new disease and subsequent death, it would be related to prevalent disease, and deleting these subjects would dilute the actual effect of educational differences. We conducted additional analyses in CPS-II for those with and without prevalent disease at baseline for coronary heart disease (prevalence, 9.0 percent), stroke (1.4 percent), diabetes (5.1 percent), chronic obstructive pulmonary disease (5.1 percent), lung cancer (0.1 percent), colorectal cancer (0.6 percent), breast cancer (2.9 percent), and prostate cancer (0.6 percent). For most diseases mortality patterns by education were similar in those with and without prevalent disease; we do not comment on these analyses except when they differed.

RESULTS

Table 1 describes the educational attainment of CPS-I and CPS-II. The level of education of these cohorts was higher than that of the US population. The percentage of the US population aged 25 years or older with a high school education or higher was approximately 45 percent in 1959 and 70 percent in 1982 (www.census.gov/prod/2000pubs/p20-528.pdf); the corresponding percentages for CPS-I and CPS-II were 60 percent and 86 percent.

Table 2 shows that death rates dropped sharply from CPS-I to CPS-II. Lower education was associated with higher death rates in both sexes and cohorts, with the gradient strongest for men in CPS-II. Adjustment for six risk factors in addition to age reduced the size of the gradient, explaining about one half to one third of the excess risk for the lowest educational stratum versus the highest.

All-cause death rates in the American Cancer Society cohorts were about two thirds of US death rates. In CPS-II, age-adjusted standardized death rates for men and women over 45 years were 1,623 and 994 per 100,000, respectively, compared with 2,704 and 1,778 for the United States in 1990. The lower death rates in American Cancer Society cohorts themselves reflect the higher socioeconomic status of these cohorts compared with that of the United States.

Figure 1 shows the educational gradient for all-cause mortality, as well as for coronary heart disease and all cancers except breast for men and women in CPS-I and CPS-II. The consistent inverse gradient between education and mortality for all causes is evident in both sexes and both studies, although it is larger for men than women.

For men in CPS-II, life expectancy (given survival to age 45 years) was decreased by 4.8 years (from age 83.0 to 78.2 years) for the lowest educational group versus the highest educational group. For women in CPS-II, the decrease was only 2.7 years (from age 87.3 to 84.6 years), because of the counterbalancing association of higher education with higher breast cancer mortality.

The gradient in rate ratios associated with education was larger in those less than age 65 years in CPS-II for all-cause and coronary heart disease mortality (figures 2 and 3).

Table 3 presents the rate ratios for coronary heart disease mortality by education, sex, and study. Rates dropped sharply between study periods. The inverse (lower education, higher mortality) gradient is evident across both sexes and both studies but is stronger in CPS-II compared with CPS-I. Adjustment for measured risk factors decreases this gradient by about one third to one half. Tables 4–11 provide the data for stroke, diabetes, lung cancer, colorectal cancer, breast cancer, prostate cancer, chronic obstructive pulmonary disease, and external causes, respectively. Because of space limitations, these tables themselves are not presented here but can be viewed on the Internet (www.aje.oupjournals.org; follow links to this issue of the *Journal*). Below we describe the principal findings from these tables.

Death rates from stroke decreased markedly from CPS-I to CPS-II with the largest proportional decrease among the more educated (table 4). Inclusion of measured risk factors decreased but did not eliminate this gradient.

Death rates from diabetes (table 5) decreased slightly from CPS-I to CPS-II but only among the more educated. The gradient of increasing rates with decreasing education was stronger than for any other single cause, particularly for women. Multivariate analyses reduced the gradient, especially in CPS-II. Examination of those in CPS-II with and without prevalent diabetes at baseline showed that among men the gradient was stronger among those without prevalent diabetes at baseline, while weak and uneven for those with prevalent diabetes. Among women, a strong gradient was observed in both groups.

Table 6 gives the lung cancer data. Rates increased between study periods for both men and women. For men, lung cancer death rates were higher in the lower educational strata for both studies, and the gradient was larger in CPS-II than in CPS-I. For women, only those who had completed college had markedly lower rates in the 1960s (CPS-I), whereas by the 1980s (CPS-II) a more linear gradient of higher rates with lower education was apparent. Restriction of the CPS-II data to lifelong nonsmokers showed that an educational gradient was present in this group for men (a 50 percent excess for the least educated), but not women, possibly reflecting sex differences in occupational exposures.

Table 7 shows that the death rates from colorectal cancer decreased between study periods, predominantly in the more educated. No consistent educational gradient was seen for either sex in CPS-I, whereas the most educated men and women in CPS-II had 20–30 percent lower death rates. Adjustment for risk factors reduced this gradient by about one third. The inverse educational gradient was slightly stronger in CPS-II for both sexes for those with prevalent colorectal cancer at baseline, compared with those without prevalent disease.

Age-adjusted breast cancer death rates were approximately 20 percent higher among the most educated compared with the least educated in both cohorts (table 8). The positive gradient decreased in multivariate analyses including parity and age at first birth. However, the positive gradient was not consistent for those with and without prevalent breast cancer at baseline in CPS-II. In each group only those with the lowest education showed any educational effect. For those in CPS-II without prevalent breast cancer at baseline, there was little evidence of a decreased risk of breast cancer with decreased education, except a weak effect in the lowest educational group (age-adjusted rate ratio = 0.89, 95 percent confidence interval (CI): 0.76, 1.03; multivariate-adjusted rate ratio = 0.91, 95 percent CI: 0.77, 1.07). Among those with prevalent disease, those with the least education had an increased risk (age-adjusted rate ratio = 1.22, 95 percent CI: 1.07, 1.47), which was reduced in multivariate analysis (multivariate-adjusted rate ratio = 1.11, 95 percent CI: 0.82, 1.34).

TABLE 1. Number of people and deaths from all causes by study, sex, and educational attainment,* United States, 1959–1972 and 1982–1996

Education	People		Deaths	
	No.	%	No.	%
Cancer Prevention Study I, men, 1959–1972, aged ≥45 years				
Grammar school (<9th grade)	107,215	24	36,725	35
Some high school	91,714	21	23,157	22
High school graduate	79,910	18	13,687	13
Some college/nursing/vocational	80,059	18	16,890	16
College graduate	86,228	19	15,303	14
Total no.	445,126		105,762	
% of deaths aged <65 years				37
Cancer Prevention Study I, women, 1959–1972, aged ≥45 years				
Grammar school (<9th grade)	103,659	18	25,441	33
Some high school	115,778	20	16,902	22
High school graduate	149,484	26	13,371	17
Some college/nursing/vocational	125,983	22	13,441	18
College graduate	82,280	14	7,620	10
Total no.	577,184		76,775	
% of deaths aged <65 years				28
Cancer Prevention Study II, men, 1982–1996, aged ≥45 years				
Grammar school (<9th grade)	37,177	7	16,969	13
Some high school	43,495	9	16,340	13
High school graduate/vocational	133,164	27	34,773	28
Some college	102,615	21	25,176	20
College graduate	88,948	18	17,087	14
Graduate school	93,866	19	16,053	13
Total no.	499,265		126,398	
% of deaths aged <65 years				20
Cancer Prevention Study II, women, 1982–1996, aged ≥45 years				
Grammar school (<9th grade)	36,942	6	13,114	13
Some high school	55,786	8	13,827	13
High school graduate/vocational	242,285	37	34,797	33
Some college	161,586	24	21,858	21
College graduate	97,285	15	12,424	12
Graduate school	69,167	10	8,401	8
Total no.	663,051		104,421	
% of deaths aged <65 years				18

* Some high school means finishing education in grades 9–11; high school means completion through grade 12.

TABLE 2. All-cause mortality rates and rate ratios by educational attainment, United States, 1959–1972 and 1982–1996

	Rate*	RR†,‡	95% CI†	RR§	95% CI	Educational gradient¶	95% CI
Cancer Prevention Study I, men, 1959–1972, aged ≥45 years							
Grammar school	2,952.7	1.25	1.23, 1.28	1.14	1.12, 1.16		1.12, 1.16
Some high school	2,924.4	1.27	1.25, 1.30	1.16	1.14, 1.18		
High school graduate	2,726.3	1.19	1.16, 1.22	1.11	1.09, 1.14		
Some college	2,719.6	1.17	1.15, 1.2	1.10	1.08, 1.13		
College graduate	2,367.0	1.00		1.00		1.024	1.021, 1.026
Cancer Prevention Study I, women, 1959–1972, aged ≥45 years							
Grammar school	1,667.9	1.32	1.28, 1.35	1.24	1.21, 1.28		
Some high school	1,483.9	1.19	1.16, 1.22	1.15	1.11, 1.18		
High school graduate	1,447.5	1.16	1.13, 1.19	1.13	1.1, 1.16		
Some college	1,328.5	1.08	1.05, 1.11	1.06	1.03, 1.09		
College graduate	1,254.6	1.00		1.00		1.032	1.029, 1.035
Cancer Prevention Study II, men, 1982–1996, aged ≥45 years							
Grammar school	2,353.6	1.57	1.54, 1.61	1.28	1.25, 1.31		
Some high school	2,285.3	1.59	1.55, 1.62	1.30	1.28, 1.33		
High school graduate	1,881.6	1.37	1.34, 1.39	1.20	1.17, 1.22		
Some college	1,791.3	1.30	1.28, 1.33	1.16	1.14, 1.19		
College graduate	1,506.1	1.09	1.07, 1.12	1.04	1.02, 1.06		
Graduate school	1,381.3	1.00		1.00		1.044	1.041, 1.047
Cancer Prevention Study II, women, 1982–1996, aged ≥45 years							
Grammar school	1,287.3	1.33	1.29, 1.37	1.18	1.15, 1.22		
Some high school	1,215.6	1.31	1.28, 1.35	1.16	1.13, 1.2		
High school graduate	1,008.6	1.17	1.14, 1.19	1.09	1.07, 1.12		
Some college	942.6	1.09	1.06, 1.12	1.04	1.01, 1.07		
College graduate	870.5	1.02	0.99, 1.05	1.01	0.98, 1.04		
Graduate school	854.2	1.00		1.00		1.032	1.029, 1.036

* Directly standardized rates per 100,000, 5-year age intervals.
† RR, rate ratio; CI, confidence interval.
‡ Age-adjusted rate ratio from Cox regression (1-year age strata).
§ Multivariate-adjusted rate ratio from Cox regression, adjusted for smoking, body mass index, diet, alcohol, prevalent hypertension, and menopausal status (women).
¶ Rate ratio for each year less of education, calculated via use of education as a continuous variable, age adjusted only (5-year age intervals), using Poisson regression.

An inverse (although weak) gradient in prostate cancer death rates was seen with education in men (table 9). This gradient was somewhat stronger in CPS-II men with prevalent prostate cancer at baseline.

Death rates for chronic obstructive pulmonary disease increased markedly between study periods, especially in women and less educated men (table 10). The inverse gradient between chronic obstructive pulmonary disease mortality and education became stronger in both sexes from CPS-I to CPS-II. Adjustment for other risk factors diminished the gradient for men more than for women.

Death rates from external causes decreased from CPS-I to CPS-II (table 11). Among men, death rates from external causes decreased moderately with higher educational status, whereas the opposite was true for women.

Table 12 shows the yearly percentage of change in rates by education during the CPS-I and CPS-II follow-up periods for coronary heart disease, lung cancer, and diabetes. The annual decrease in coronary heart disease rates in CPS-I involved predominantly more educated men and women. Annual decreases were even greater in CPS-II, for all educational strata, but especially among the most educated men. Clear differences in decreasing rates by education were not apparent for women in CPS-II. We further analyzed coronary heart disease death rates among married women in CPS-II, classified by their husbands' educational status

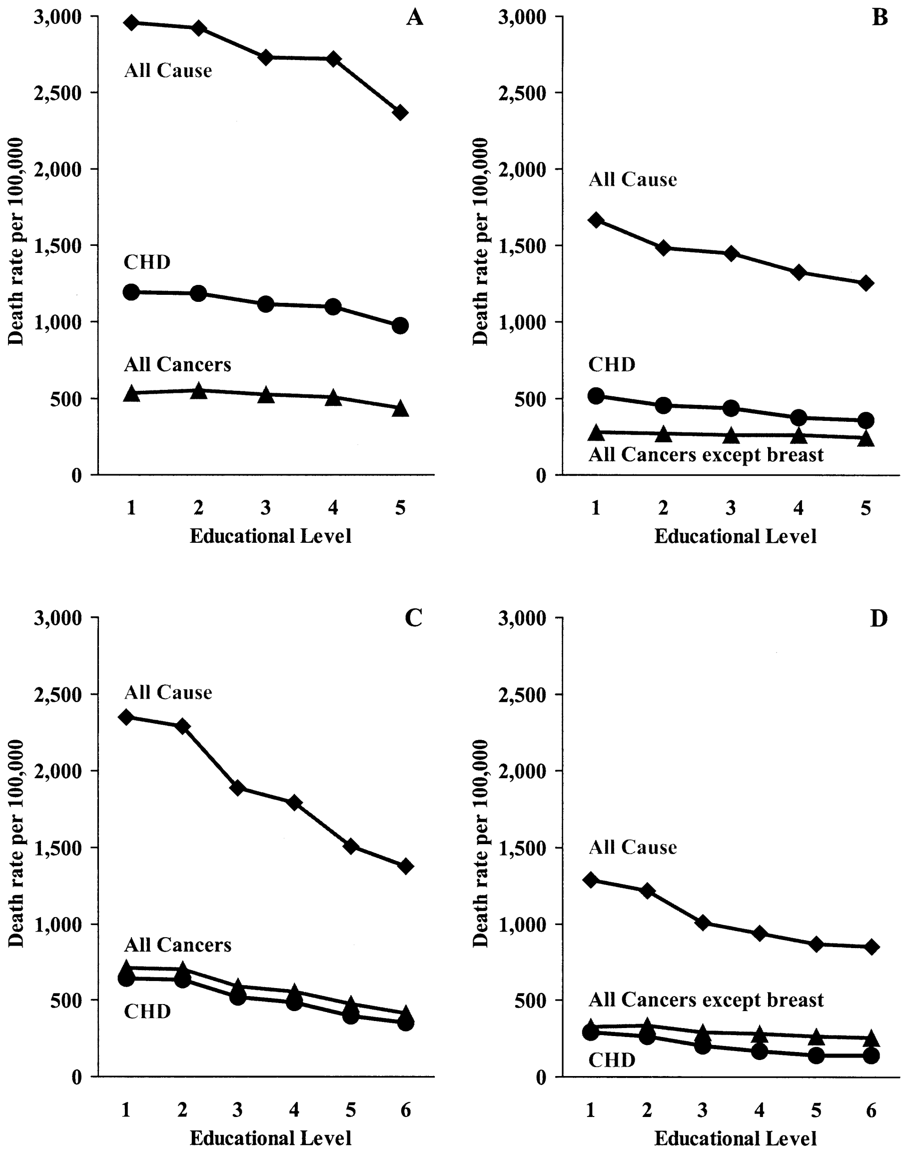

FIGURE 1. Death rates per 100,000 person-years for men and women in Cancer Prevention Study I (CPS-I), 1959–1972, and Cancer Prevention Study II (CPS-II), 1982–1996, by educational attainment (1 = less than ninth grade; 2 = some high school; 3 = high school graduate; 4 = some college; 5 = college graduate; 6 = graduate school). A, CPS-I men, 1959–1972; B, CPS-I women, 1959–1972; C, CPS-II men, 1982–1996; D, CPS-II women, 1982–1996; CHD, coronary heart disease.

(possibly a more accurate reflection of a married woman's socioeconomic status). The decrease in coronary heart disease mortality was greatest for women with the most educated husbands (annual decrease of –0.9 percent, 0.6 percent, 1.5 percent, 2.6 percent, 2.9 percent, and 4.0 percent from lowest to highest level of the husband's education).

Table 12 shows that lung cancer was decreasing among men during CPS-II without any clear differences by education, but increasing for women, especially for those with less education (5.1 percent a year for the least educated, 0.2 percent a year for the most educated). Diabetes mortality was increasing more rapidly for the most educated during CPS-I, but it was increasing more rapidly for the least educated during CPS-II.

DISCUSSION

We found that those with less education had higher death rates for all major causes except breast cancer and external causes among women. Based on CPS-II data (1982–1996), this resulted in a 4.8-year lower life expectancy for the least educated versus the most educated men. By way of comparison, among male British doctors the decrease in life expectancy for those who smoked at age 35 years versus never smokers was 7.5 years (18). For women the difference in life

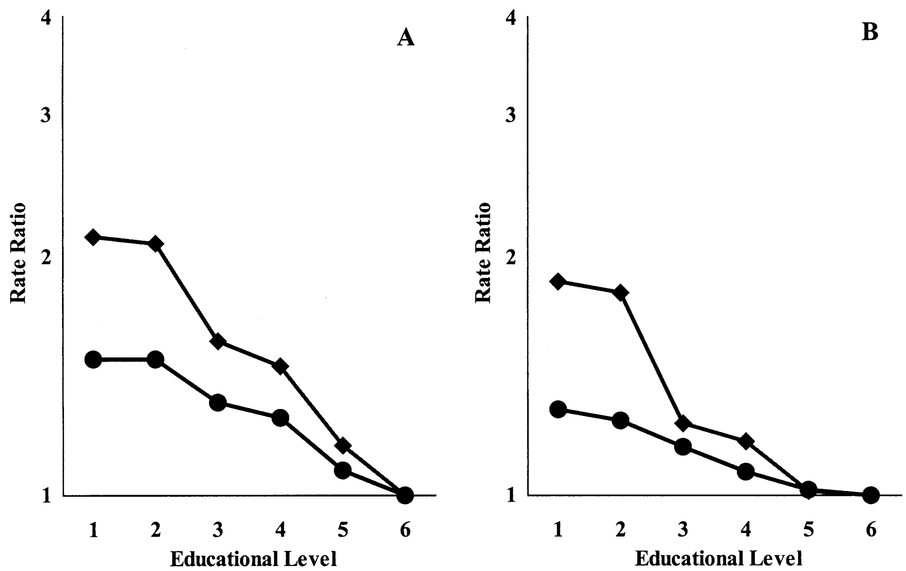

FIGURE 2. Rate ratios for all-cause mortality comparing men and women having a graduate school education with those having other educational levels (1 = less than ninth grade; 2 = some high school; 3 = high school graduate; 4 = some college; 5 = college graduate; 6 = graduate school) in Cancer Prevention Study II (CPS-II), 1982–1996, by age at risk. Diamonds, rate ratios for ages 45–64 years; circles; rate ratios for ages ≥65 years. A, CPS-II men; B, CPS-II women.

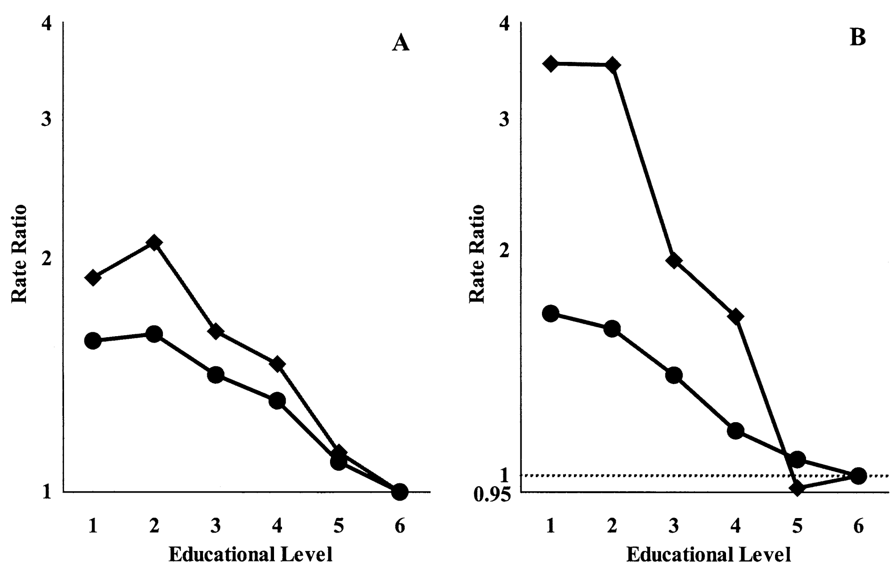

FIGURE 3. Rate ratios for coronary heart disease mortality comparing men and women having a graduate school education with those having other educational levels (1 = less than ninth grade; 2 = some high school; 3 = high school graduate; 4 = some college; 5 = college graduate; 6 = graduate school) in Cancer Prevention Study II (CPS-II), 1982–1996, by age at risk. Diamonds, rate ratios for ages 45–64 years; circles, rate ratios for ages ≥65 years. A, CPS-II men; B, CPS-II women.

expectancy associated with the best education was only 2.7 years, reflecting the countervailing tendency of breast cancer mortality.

The inverse educational gradient was strongest for coronary heart disease, lung cancer, chronic obstructive pulmonary disease, and diabetes; moderate for colorectal cancer, external causes (men only), and stroke; and weakest for prostate cancer. A moderate increase in risk with educational status was evident for women for external cause mortality, while for breast cancer a weak educational gradient existed

TABLE 3. Coronary heart disease mortality rates and rate ratios by educational attainment, United States, 1959–1972 and 1982–1996

	Rate*	RR†,‡	95% CI†	RR§	95% CI	Educational gradient¶	95% CI
Cancer Prevention Study I, men, 1959–1972, aged ≥45 years							
Grammar school	1,193.5	1.22	1.18, 1.25	1.10	1.06, 1.13		
Some high school	1,182.8	1.24	1.2, 1.28	1.13	1.09, 1.17		
High school graduate	1,114.8	1.19	1.15, 1.23	1.11	1.07, 1.15		
Some college	1,097.4	1.15	1.11, 1.19	1.08	1.04, 1.11		
College graduate	969.9	1.00		1.00		1.021	1.019, 1.024
Cancer Prevention Study I, women, 1959–1972, aged ≥45 years							
Grammar school	521.4	1.48	1.4, 1.55	1.36	1.29, 1.43		
Some high school	452.9	1.32	1.26, 1.4	1.25	1.19, 1.32		
High school graduate	436.3	1.29	1.22, 1.36	1.24	1.17, 1.31		
Some college	376.3	1.11	1.05, 1.17	1.08	1.02, 1.15		
College graduate	357.8	1.00		1.00		1.045	1.040, 1.051
Cancer Prevention Study II, men, 1982–1996, aged ≥45 years							
Grammar school	641.7	1.62	1.55, 1.69	1.31	1.25, 1.36		
Some high school	635.9	1.68	1.61, 1.75	1.37	1.31, 1.43		
High school graduate	519.1	1.46	1.41, 1.51	1.27	1.22, 1.32		
Some college	480.8	1.35	1.3, 1.4	1.20	1.16, 1.25		
College graduate	392.7	1.10	1.06, 1.15	1.06	1.01, 1.10		
Graduate school	353.9	1.00		1.00		1.050	1.045, 1.054
Cancer Prevention Study II, women, 1982–1996, aged ≥45 years							
Grammar school	292.7	1.73	1.62, 1.84	1.42	1.33, 1.51		
Some high school	264.2	1.68	1.58, 1.78	1.40	1.32, 1.49		
High school graduate	197.8	1.41	1.33, 1.49	1.28	1.2, 1.35		
Some college	166.5	1.19	1.12, 1.26	1.13	1.06, 1.2		
College graduate	143.7	1.05	0.98, 1.12	1.04	0.97, 1.11		
Graduate school	137.3	1.00		1.00		1.064	1.057, 1.070

* Directly standardized rates per 100,000, 5-year age intervals.
† RR, rate ratio; CI, confidence interval.
‡ Age-adjusted rate ratio from Cox regression (1-year age strata).
§ Multivariate-adjusted rate ratio from Cox regression, adjusted for smoking, body mass index, diet, alcohol, prevalent hypertension, and menopausal status (women).
¶ Rate ratio for each year less of education, calculated via use of education as a continuous variable, age adjusted only (5-year age intervals), via Poisson regression.

that differed in direction for those with and without prevalent disease at baseline. The diseases with the strongest gradients are related strongly to smoking (lung cancer and chronic obstructive pulmonary disease) and/or obesity (diabetes, coronary heart disease), factors which are known to vary inversely by educational status and socioeconomic status. The lower death rate from colorectal cancer among the more educated may reflect socioeconomic differences in diet, physical activity, and use of screening. Stroke mortality is primarily related to blood pressure, which is higher for the less educated. External cause mortality includes homicide, suicide, and motor vehicle accidents, all of which are known to have higher rates among lower socioeconomic status groups, especially among males.

Breast cancer incidence is known to be higher among the better educated, presumably because of altered reproductive patterns such as delayed child bearing and fewer children (19). The higher incidence rates for higher socioeconomic status groups result in higher mortality rates, at least in analyses without adjustment for reproductive risk factors. On the other hand, there is evidence that breast cancer survival is worse for those with lower socioeconomic status (20). Our data for breast cancer tended to confirm this pattern, although only a weak effect was seen, limited to those with

TABLE 12. Annual change in mortality rates over follow-up by study, sex, cause of death, and educational attainment, by percentage, United States, 1959–1972 and 1982–1996

	Coronary heart disease (%)	Lung cancer (%)	Diabetes (%)
Cancer Prevention Study I, men, 1959–1972, aged ≥45 years			
Grammar school	–0.6	4.1	0.0
Some high school	–0.6	3.1	1.9
High school graduate	–1.7	2.9	6.9
Some college	–1.6	4.4	6.3
College graduate	–2.1	2.2	6.6
All	–1.1	3.4	2.5
Cancer Prevention Study I, women, 1959–1972, aged ≥45 years			
Grammar school	–0.6	9.7	–1.7
Some high school	–0.5	5.7	2.7
High school graduate	–1.5	6.3	–2.8
Some college	–0.3	8.1	5.8
College graduate	–1.3	5.9	4.3
All	–0.7	7.0	–0.6
Cancer Prevention Study II, men, 1982–1996, aged ≥45 years			
Grammar school	–2.9	–1.6	6.4
Some high school	–2.9	0.1	7.9
High school graduate	–2.4	–0.3	9.3
Some college	–2.8	1.0	4.1
College graduate	–3.4	–0.3	6.2
Graduate school	–4.6	0.4	6.4
All	–3.1	–0.1	6.1
Cancer Prevention Study II, women, 1982–1996, aged ≥45 years			
Grammar school	–2.2	5.1	6.6
Some high school	–0.8	3.5	10.2
High school graduate	–2.2	3.5	8.2
Some college	–1.8	3.5	7.6
College graduate	–2.6	2.2	4.0
Graduate school	–1.2	0.2	2.9
All	–1.9	3.2	6.2

the lowest education. The lowest educational group in CPS-II had a slightly reduced risk among those reporting no breast cancer at baseline but a slightly increased risk of mortality among those with breast cancer at baseline.

Adjustment for a number of risk factors (smoking, diet, body mass index, hypertension, alcohol) did not eliminate the association with education for all causes of death and for specific causes, although it diminished the effect by about one third to one half. These risk factors are presumably intermediate variables between education and mortality. We have therefore emphasized the effect estimates adjusted only for age (21). For diseases highly related to smoking (lung cancer and chronic obstructive pulmonary disease), the failure of adjustment for smoking to explain more of the educational gradient may be partly due to the fact that smoking data were collected at baseline and therefore do not reflect differences in quitting by educational groups.

Our findings parallel others in the literature, particularly those of Davey Smith et al. (2) for men in the MrFit (Multiple Risk Factor Intervention Trial) cohort (1974–1990). These investigators found either strong or moderate inverse gradients with income (correlated with education) for the same outcomes we did. We have included more recent years (and found the socioeconomic status patterns to be continuing), and we have included women (for whom socioeconomic status effects generally show the same pattern as in men for all outcomes except breast cancer and external causes). Other comparable US studies of large data sets have generally covered earlier years and a small number of outcomes (3, 9–12).

We did not adjust for race/ethnicity in our analyses under the assumption that race/ethnicity serves, in part, as a marker for socioeconomic status and adjusting for it would have been inappropriate. Only 3 percent of the CPS-I population and 5 percent of the CPS-II population were Black. We did compare the association between education and coronary heart disease death rates among Black and White men and women in CPS-II. For women, Whites and Blacks showed a similar and strong educational gradient. For men, the educational gradient was larger for Whites. This may suggest that, among Black men, educational differences are less important markers of socioeconomic status, or that other factors (e.g., the negative effects of racism) increase risk across all socioeconomic groups, diminishing the educational effect.

Educational gradients were particularly evident in CPS-II (1982–1996) compared with CPS-I (1959–1972). However, the educational categories were not comparable between the two populations. In CPS-I, 20 percent of the population had less than a high school education, and 16 percent had a college degree. The corresponding proportions for CPS-II were 6 percent and 30 percent. The 6 percent in CPS-II may represent a group with relatively lower socioeconomic status (compared with other educational groups in CPS-II) than did the 20 percent in CPS-I, contributing to the steeper education gradient in CPS-II.

For coronary heart disease, the inverse education gradient was particularly strong for those under age 65 years. This may reflect the tendency of relative risks for any specific factor for heart disease to be higher at earlier ages when the absolute heart disease rates are lower, differential access of different socioeconomic groups to good medical care prior to eligibility for Medicare, and/or age-specific differences in the combination of risk factors represented by education.

Analysis of trends over time revealed the expected decrease over time in coronary heart disease mortality (about 1 percent a year in CPS-I and 2 percent a year in CPS-II). The decrease was most pronounced for those with higher socioeconomic status among men. This same pattern was revealed for women but only in analyses considering the husband's rather than the wife's education. The sharper decrease in coronary heart disease mortality for those with more education parallels similar findings by other investigators for earlier time periods (9). Our data suggest that this trend of increasing disparity in coronary heart disease rates over time is continuing in recent years. Increasing disparities in coronary heart disease rates in our data have occurred at the same time that inequality in the United States has been increasing. In 1985 the households in the lowest 20 percent of family income received 4.0 percent of the national income, while the upper 20 percent of households received 45.3 percent. In 1996, the comparable values were 3.6 percent and 49.4 percent (www.census.gov/hhes/income/income97/in97dis.html).

The overall decrease in coronary heart disease mortality over the recent period may be due more to access to good medical care than to improvements in risk factor profiles. Evidence points to little or no decline in coronary heart disease incidence (as measured by hospital admissions) in recent years while mortality has continued to markedly decline (22–25). There are counterarguments to this view. For example, if milder cases were being admitted to the hospital over time, which otherwise might not have been admitted, this might artificially increase incidence rates over time. The most recent US data (26), however, do not tend to support this hypothesis.

Regardless of the relative importance of risk factors versus treatment in recent declines in coronary heart disease mortality, medical treatment certainly plays a role in survival and affects mortality rates. Numerous data show that both access to medical care and quality of medical treatment differ by socioeconomic status. For example, in 1998, data from the National Health Interview Survey (www.cdc.gov/nchs/nhis.htm) for adults aged 35–64 years showed that, among those with the lowest 21 percent of income, 34 percent had no medical insurance (John Pleiss, National Center for Health Statistics, Centers for Disease Control and Prevention, personal communication, 2001). Among those with income ranging from the 22nd to 44th percentile, 12 percent had no health insurance, while for those with income above the 44th percentile only 4 percent had no health insurance. Even when medical care is universally available, socioeconomic differences appear to play a role in the treatment given to coronary heart disease patients. For example, a Canadian study of 51,000 myocardial infarction patients showed that income was strongly related to the use of angiography and to the 1-year survival rate (27). Two US studies (28, 29) have shown that survival after myocardial infarction was worse for those in lower socioeconomic status groups, even after adjusting for baseline health status, while a third study (30) has documented less frequent use of appropriate postinfarction medication for those in lower socioeconomic status groups.

Lung cancer also showed important differences in time trends by educational status. Lung cancer increased rapidly across all educational groups during CPS-I, especially for women, who had taken up smoking after World War II, later than men. After the 1964 Surgeon General's report, smoking prevalence has decreased in the United States, more sharply for the better educated (31). By CPS-II, the increase in lung cancer mortality had slowed to 3.2 percent a year in women, and lung cancer was decreasing slightly in men. Among women, the most educated showed hardly any increase, while the least educated showed the highest increase.

Diabetes also showed differences in temporal trends by education. In CPS-I the diabetes mortality rates increased markedly among the most educated, while remaining constant or decreasing among the least educated, a pattern especially seen among women. By CPS-II this pattern was reversed, with diabetes increasing most strongly among the least educated. These patterns may reflect temporal trends in obesity. There is evidence that, in the 1970s, obesity was increasing more rapidly in better-educated women, but this pattern was reversed in the 1980s and 1990s (31).

REFERENCES

1. Bucher H, Ragland DR. Socioeconomic indicators and mortality from coronary heart disease and cancer: a 22-year follow-up of middle-aged men. Am J Public Health 1995;85:1231–6.
2. Davey Smith G, Neaton JD, Wentworth D, et al. Socioeconomic differentials in mortality risk among men screened for the Multiple Risk Factor Intervention Trial: I. White men. Am J Public Health 1996;86:486–96.
3. Sorlie P, Backlund R, Keller J. US mortality by economic, demographic, and social characteristics: the National Longitudinal Mortality Study. Am J Public Health 1995;85:949–56.
4. Lantz P, House J, Lepkwoski J, et al. Socioeconomic factors, health behaviors, and mortality. JAMA 1998;279:1703–8.
5. Howard G, Anderson R, Russell G, et al. Race, socioeconomic status, and cause-specific mortality. Ann Epidemiol 2000;10:214–23.
6. Kunst AE, Groenhof F, Mackenbach JP, et al. Occupational class and cause specific mortality in middle aged men in 11 European countries: comparison of population based studies. EU Working Group on Socioeconomic Inequalities in Health. BMJ 1998;216:1636–42.
7. Martikainen P, Valkonen T, Martelin T. Change in male and female life expectancy by social class: decomposition by age and cause of death in Finland 1971–1995. J Epidemiol Community Health 2001;55:494–9.
8. Mao Y, Hu J, Ugnat A, et al. Socioeconomic status and lung cancer risk in Canada. Int J Epidemiol 2001;30:809–17.
9. Pappas G, Queen S, Hadden W, et al. The increasing disparity in mortality between socioeconomic groups in the US, 1960–1986. N Engl J Med 1993;329:103–9.
10. Feldman J, Makuc D, Lkeinman J, et al. National trends in educational differentials in mortality. Am J Epidemiol 1989; 129:919–33.
11. Rogot E, Jrubec Z. Trends in mortality from coronary heart disease and stroke among US veterans 1954–1979. J Clin Epidemiol 1989;42:245–56.
12. Pell S, Fayerweather W. Trends in the incidence of myocardial infarction and in associated mortality and morbidity in a large employed population, 1957–1983. N Engl J Med 1985; 312:1005–11.
13. Hallqvist J, Lundberg M, Diderichsen F, et al. Socioeconomic differences in risk of myocardial infarction 1971–1994 in Sweden. Int J Epidemiol 1998;27:410–15.
14. Tuchsen F, Endahl L. Increasing inequality in ischaemic heart disease mortality among employed men in Denmark 1981–1993: the need for a new preventive policy. Int J Epidemiol 1999;28:640–4.
15. Garfinkel L. Selection, follow-up, and analysis in the American Cancer Society prospective studies. Natl Cancer Inst Monogr 1985;67:49–52.
16. Calle EE, Terrell DD. Utility of the National Death Index for ascertainment of mortality among Cancer Prevention Study II participants. Am J Epidemiol 1993;137:235–41.
17. Lee E. Statistical methods for survival data analysis. Belmont, CA: Lifetime Learning, 1980.
18. Doll R, Peto R, Wheatley K, et al. Mortality in relation to smoking: 40 years' observations on male British doctors. BMJ 1994;309:901–10.
19. Yost K, Perkins C, Cohen R, et al. Socioeconomic status and breast cancer incidence in California for different race/ethnic groups. Cancer Causes Control 2001;12:703–11.
20. Gordon N, Crowe K, Brumberg D, et al. Socioeconomic factors and race in breast cancer recurrence and survival. Am J Epidemiol 1992;135:609–18.
21. Kaufman JS, Kaufman S. Assessment of structured socioeconomic effects on health. Epidemiology 2001;12:157–67.
22. McGovern P, Pankow J, Shahar E, et al. Recent trends in acute coronary heart disease. N Engl J Med 1996;334:884–90.
23. Rosamond W, Chambless L, Folsom A, et al. Trends in the incidence of myocardial infarction and in mortality due to coronary heart disease, 1987–1994. N Engl J Med 1998;339:861–7.
24. McGovern P, Jacobs D, Sharhar E, et al. Trends in acute coronary heart disease mortality, morbidity, and medical care from 1985–1997. Circulation 2001;104:19–24.
25. Goldberg RJ, Yarzebski J, Lessard D, et al. A two-decades (1975 to 1995) long experience in the incidence, in-hospital, and long-term case-fatality rates of acute myocardial infarction: a community-wide perspective. J Am Coll Cardiol 1999;33: 1533–9.
26. Rosamond WD, Folsom AR, Chambless LE, et al. Coronary heart disease trends in four United States communities: The Atherosclerosis Risk in Communities (ARIC) study 1987–1996. Int J Epidemiol 2001;30(suppl 1):S17–22.
27. Alter D, Naylor D, Austin P, et al. Effects of socioeconomic status on access to invasive cardiac procedures and on mortality after acute myocardial infarction. N Engl J Med 1999;341: 1359–67.
28. Ikovics J, Viscoli C, Horwitz R. Functional recovery after myocardial infarction in men: the independent effects of social class. Ann Intern Med 1997;127:518–25.
29. Williams R, Barefoot J, Califf R, et al. Prognostic importance of social and economic resources among medically treated patients with angiographically documented coronary artery disease. JAMA 1992;267:520–4.
30. Rathore S, Berger A, Weinfurt K, et al. Race, sex, poverty, and the medical treatment of acute myocardial infarction in the elderly. Circulation 2000;102:642–8.
31. National Center for Health Statistics. Health, United States 1998. Hyattsville, MD: National Center for Health Statistics, 1998. (DHHS publication no. (PHS) 98-1232).