Cause-of-Death Contributions to Socioeconomic Inequalities in Mortality in the United States

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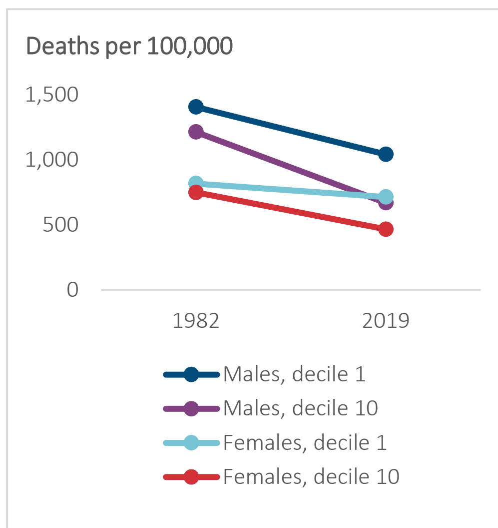
Executive Summary

This study of socioeconomic inequalities in mortality builds on a previous report in which we identified a large and growing gradient in life expectancy between 1982 and 2019 across U.S. counties classified into 10 socioeconomically homogeneous categories (Barbieri 2020). Using area-level information from the 2000 census, counties were grouped into socioeconomic deciles based on the population's level of education, income distribution and occupation as well as local rates of unemployment, income inequalities, housing price and housing quality. This information was combined to produce a Socioeconomic Index Score (SIS) unique to each county. Counties were ranked based on their SIS and distributed into 10 groups of equal demographic size. Each SIS decile thus represents about 10% of the total U.S. population.

In this report, we seek to identify the particular causes of death contributing to the growing disadvantage in mortality between populations in the least and most affluent deciles as previously defined. Using official mortality data from the National Center for Health Statistics and population data from the Census Bureau, age-standardized death rates were calculated for each SIS decile by sex, for broad age groups, and by medical causes of death grouped into large categories (i.e., cardiovascular diseases, cancer, infectious and respiratory diseases, other diseases, external causes, and ill-defined and unknown causes).

- **We confirmed our earlier finding of a large socioeconomic gradient in the age-standardized death rates for Americans of both sexes at all ages in 1982, which increased over the following four decades.**

  Mortality declined in all SIS deciles, but the drop was much faster for the most affluent than for the least affluent. The mortality of males in the first SIS decile declined about half as much as it did for males in the 10th decile. For females, the first-decile decline was one-third the drop in the 10th decile.

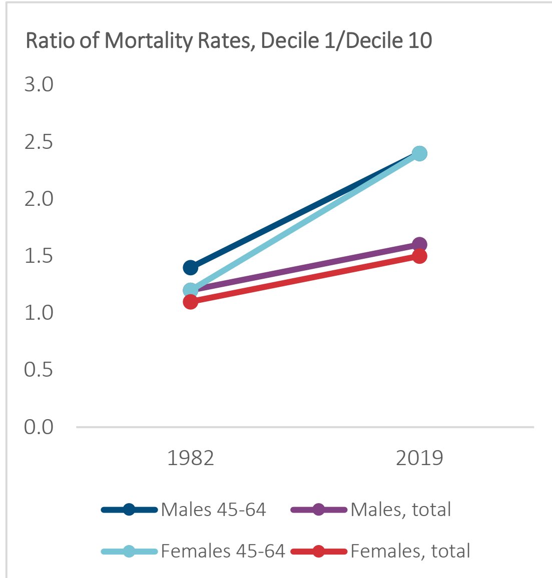


- **The increasing mortality divergence across SIS deciles was attributable to the four broad disease categories: cancer, cardiovascular diseases, infectious and respiratory diseases, and other diseases.**

  The other causes of death had a mixed impact on the relative changes in mortality. Death from external causes reduced the gap between deciles for males but increased the gap for females. Mortality from ill-defined and unknown causes declined for the least affluent deciles throughout the period to reach the low level exhibited by the most affluent deciles. In this way, it reduced the gap between first and 10th deciles for both sexes.

- **Important variations in this pattern occurred by age groups.**

  The risks of death for Americans in the least affluent socioeconomic deciles increased at all ages relative to those of Americans in the most affluent decile, but the deterioration was especially pronounced at ages 45–64 years. In this age group, the ratio of the age-standardized death rate in the first (least affluent) to 10th (most affluent) decile increased from 1.4 to 2.4 for males and from 1.2 to 2.4 for females between the ages of 45 and 64.



- **In 1982, the difference in the risks of death between Americans in the least and most affluent socioeconomic deciles was overwhelmingly attributable to mortality from the diseases of the circulatory (cardiovascular) system, especially for females, as well as from external causes and from the "other diseases" category (see table on page 6).**

  By contrast, cancer mortality was higher for the most affluent. For females in particular, the gap in the age-standardized mortality rate between the first and 10th deciles would have been about one-third larger without the offsetting impact of cancer. Infectious and respiratory diseases contributed little to the difference.

- **By 2019 for all ages combined, the socioeconomic gradient in mortality became more pronounced for nearly all cause-of-death categories, including cancer (where a typical gradient emerged), cardiovascular diseases, infectious and respiratory diseases, and all other diseases (see table page 6).**

  In contrast, the gradient for mortality from external causes was relatively stable. The gap in mortality from ill-defined and unknown causes declined, but it represents a very small share of overall mortality throughout the period.

- **The large number of causes of death contributing to the increasing socioeconomic gradient in mortality between 1982 and 2019 suggests that the pattern cannot be attributed to a single factor but by multiple drivers.**

Age-Standardized Death Rates in Deciles 1 and 10, 1982 and 2019, by Sex and Cause-of-Death Category

Cause-of-Death Category	1982				2019				Change, 2019 vs. 1982	
	Decile 1	Decile 10	Absolute Gap	Relative Gap (%)	Decile 1	Decile 10	Absolute Gap	Relative Gap (%)	Absolute Gap	Relative Gap (%)
Males										
Infectious/respiratory diseases	120	102	19	10	130	70	60	16	41	23
Cancer	276	285	−8	−4	205	150	55	15	64	35
Cardiovascular diseases	677	611	66	34	323	208	115	31	49	27
Other diseases	158	134	24	12	241	164	77	21	53	29
External causes	139	73	66	34	134	71	63	17	−3	−2
Ill-defined/unknown causes	38	10	27	14	11	7	4	1	−23	−13
All causes	1,408	1,215	193	100	1,043	670	374	100	181	100
Females										
Infectious/respiratory diseases	52	49	3	4	98	52	46	19	44	24
Cancer	160	183	−24	−35	141	113	28	11	51	28
Cardiovascular diseases	430	386	44	65	210	135	75	30	31	17
Other diseases	116	96	19	28	204	134	71	28	52	29
External causes	42	30	12	18	53	28	25	10	12	7
Ill-defined/unknown causes	20	6	13	20	8	5	3	1	−10	−6
All causes	818	751	68	100	715	467	248	100	181	100

Section 1: Motivation

In a recent project, we showed a clear and increasing gradient in life expectancy by socioeconomic groupings of counties in the United States (Barbieri 2020). Reducing health inequalities is a major goal of public health in the United States (Penman-Aguilar et al. 2016), and mortality disparities represent the ultimate outcome of health inequalities. To improve and monitor policy measures and health interventions and to increase efficiencies in resource allocation, it is necessary to identify the factors driving these disparities. A better understanding of the mechanisms at play would also help actuaries refine their mortality improvement models.

In this new study, we analyze cause-of-death statistics from the National Center for Health Statistics for years since 1982 to throw light on the determinants of socioeconomic variations in mortality. More specifically, we seek to identify the causes of death that (1) most contribute to the differences in life expectancy at birth and age-specific mortality rates across socioeconomic deciles of counties (differentiating three age categories: children and young adults, working-age adults, and older adults) and (2) drive the divergence that has been growing between Americans living in the least and most affluent counties. We investigate whether these causes are similar for males and for females and whether the differential cause-of-death pattern is consistent across all deciles.

Section 2: Data and Methods

In previous work, we constructed complete life tables for groups of counties based on their relative socioeconomic position. The position of each county was determined from a single multidimensional Socioeconomic Index Score (SIS) calculated from the levels of education, income, income inequality, unemployment, occupation, housing cost and housing quality in each county (Barbieri 2020). These socioeconomic variables were selected because of their strong relationships with mortality (Adler and Newman 2002; Singh 2003; Singh and Siahpush 2006). They were extracted for each county from the 2000 census. All U.S. counties were ranked based on their SISs, weighted by their population and stratified into 10 deciles so that each decile of counties represents about 10% of the total U.S. population.

We then used the Detailed Mortality Files for years 1982–2019 from the National Center for Health Statistics (NCHS) at the Centers for Disease Control in combination with July 1 population estimates to build a life table series for each SIS decile and each calendar year from 1982 through 2019, following the methods of the Human Mortality Database (Wilmoth et al. 2021). The protocol relied mainly on classic demographic techniques, including the extinct cohort method and the survival ratio method to more accurately estimate mortality at high ages. To account for the fact that the age structure of the population might vary across SIS deciles, we standardized the resulting mortality rates by age to facilitate comparisons, using the age distribution of the national U.S. population in the 2000 census as the standard. Note, however, that because the population data is only provided up to an open-age interval of 85 years and above, it was not possible to standardize rigorously the death rates over this threshold. Assuming an older age structure of the population in the most affluent deciles, this limitation in the data results in underestimating the difference in mortality with the least affluent deciles, since even in the absence of differences in underlying mortality risks at each single year of age, the most affluent deciles will register more deaths just because of their older populations.

The mortality data were provided by the NCHS under a special agreement due to the confidential nature of some information included in the files. To protect privacy, we were not authorized to publish or display in any form (text, tables and figures) any count, rate or percentage for sub-national geographies (including county groupings) if based on one to nine observations. Consequently, all cell values below this threshold have been suppressed and, for the purpose of rate calculations, replaced by an imputed figure randomly selected between 1 and 9.

We used the same data (with the same restrictions) for the current project. The Detailed Mortality Files contain information for all deaths occurring in the country and, more specifically for this study, the sex, age and county of residence of the deceased and the underlying cause of death coded to the fourth digit of the International Classification of Disease (ICD). The ICD is periodically revised to account for medical and diagnostic progress as well as for the emergence of new diseases. During the period under consideration, the ICD was revised once, in 1999, when the 10th revision of the ICD was first implemented. To take into account the disruptions in cause-specific death rates introduced by the transition from the ninth to the 10th revision of the ICD (i.e., from ICD-9 to ICD-10), we redistributed deaths from ICD-9 to ICD-10 by applying transition coefficients from a 1996 bridge coding study before we computed cause-specific death rates. The 1996 bridge coding study was conducted by the NCHS to understand the impact of the transition from ICD-9 to ICD-10 in the United States (Anderson et al. 2001). The change from ICD-9 to ICD-10 introduces disruptions in the cause-of-death data series that complicate the interpretation of trends, hence the need to redistribute deaths in categories that are consistent over time. For more details on the redistribution procedure, see Appendix B of this report.

We tabulated death counts by calendar year, county, sex, age and cause of death from the restricted data, then grouped the death counts by SIS decile and for 57 mutually exclusive and exhaustive cause-of-death categories (see Appendix A for the corresponding ICD codes). We also investigated the mortality disparities by socioeconomic categories for the separate and combined impact of "diseases of despair," defined as the combination of deaths from drug overdoses, alcoholism and suicide (Case and Deaton 2020), which are major public-health issues in the United States (Gomes et al. 2018). For this purpose, we created a separate category to identify deaths from drug overdose and from alcohol abuse,[1] which overlap with several of our 57 categories.

From these tabulations of deaths by cause, we computed cause-of-death fractions, and applied the fractions to the age-specific mortality rates in the life tables calculated in the previous project to compute sex-, age- and cause-specific death rates by sex for each SIS decile in each calendar year 1982 to 2019. Using as before the total U.S. population at the 2000 census as the age structure of reference, we then computed the age-standardized death rates for all ages combined and for ages below 20, at ages 20–64 years, and at 65 years and above. For specific causes, we also calculated the age-standardized death rates for smaller age groups (below 20, 20–44, 45–64, 65–84 and 85 years and above). Standardization was carried out to account for differences in the age structure of the population in each SIS quintile and over time. The 57 cause-of-death categories were additionally combined into six broad groups of causes to simplify the analysis. The six broad cause-of-death categories are cardiovascular diseases, cancer, infectious and respiratory diseases, all other diseases, external causes, and ill-defined and unknown causes.

Section 3: Results

This section first describes the SIS gradient we found in the age-standardized death rates. We then report the cause-of-death structure across deciles, and then discuss the impact of each cause-of-death category on socioeconomic disparities.

[1] Deaths due to drug overdoses are identified as deaths with an underlying cause coded to ICD-10 X40–X44, X85, Y10–Y14, Y45, Y47 and Y49, and deaths due to alcohol abuse are identified by the ICD-10 codes F10, G62.1, G31.2, G72.1, I42.6, K29.2, K70.0–K70.4, K70.9, K85.2, K86.0, Q86.0 and P04.3 (corresponding to the 13 100% alcohol-attributable causes), as recommended by the Centers for Disease Control.

3.1 THE SIS GRADIENT IN THE AGE-STANDARDIZED DEATH RATES

While our previous study found clear socioeconomic inequalities in life expectancy at birth, the present study finds a corresponding and equally clear socioeconomic gradient in the age-standardized death rates (ASDR).

3.1.1 ALL AGES

In 1982, the all-causes ASDR for all ages combined ranged from 1,408 deaths per 100,000 population in the first SIS decile to 1,215 in the top decile for males and from 818 to 751 for females, respectively (Table 1 and Figure 1). In 2019, the range from first to 10th decile had broadened: for males, there were 1,043 deaths per 100,000 in the first decile and 670 per 100,000 in the 10th; for females, the corresponding death rates were 715 and 467. In percentage terms, this means the age-standardized all-causes death rate for males in the 10th decile was 45% smaller in 2019 than in 1982, while the decline for males in the first decile was only 26%. For females, death rates in 2019 were 38% smaller for decile 10 and only 13% smaller for decile 1. Thus, the mortality decline for both sexes was much faster in the most affluent decile than in the least affluent. Mortality also declined faster for males overall than for females. Comparing the most underprivileged with the most privileged, mortality fell by about half for males and by one-third for females between 1982 and 2019.

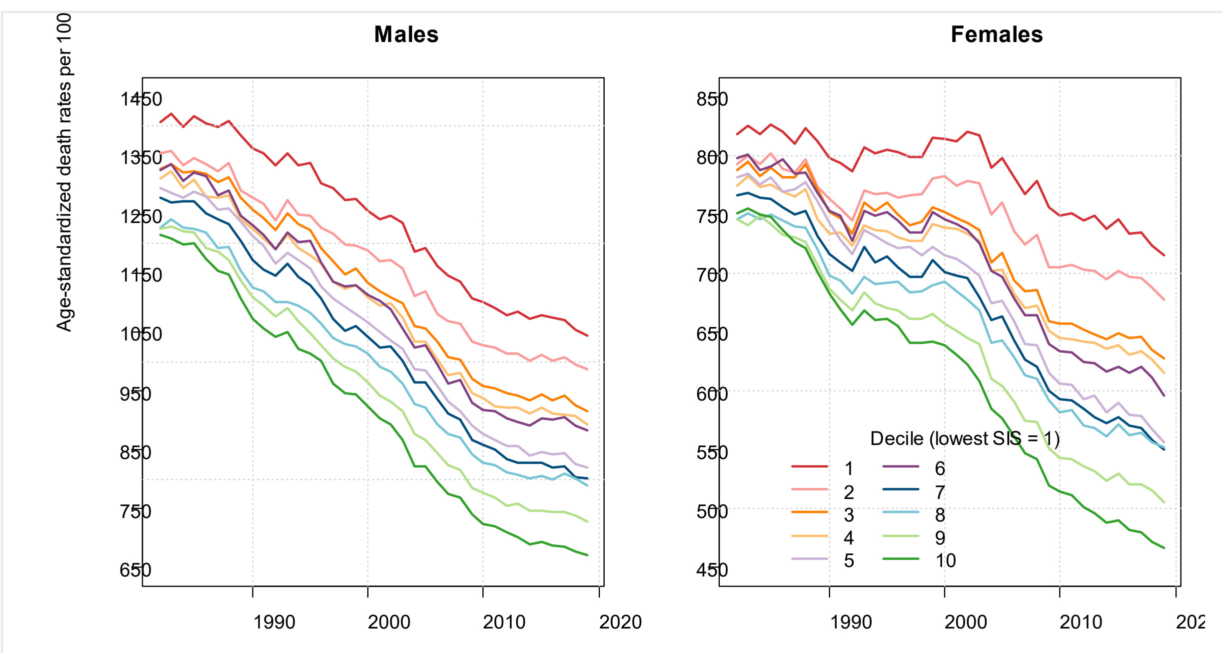
Table 1

Age-Standardized Death Rates per 100,000 for SIS Deciles 1 and 10, by Sex, 1982 vs. 2019

	Males			Females		
Deciles	1982	2019	% Change	1982	2019	% Change
1st SIS decile (least affluent)	1,408	1,043	25.9	818	715	12.6
10th SIS decile (most affluent)	1,215	670	44.9	751	467	37.8
Ratio, 1st/10th decile	1.2	1.6	57.7	1.1	1.5	33.3

Figure 1

Age-Standardized Death Rates by SIS Decile, Each Sex, 1982–2019



Moreover, females experienced a strange pattern of mortality during the 1990s, with a quick dip in 1992 after several years of decline, followed by a rebound. For the two most affluent deciles, the rebound was immediately followed by a further decline, but for all other deciles, it was followed by either a plateau (deciles 3–8) or by additional increases up to the early 2000s (deciles 1 and 2). This pattern is entirely attributable to mortality trends at older ages (65 years and above), described in subsection 3.1.2.

3.1.2 BY AGE GROUP

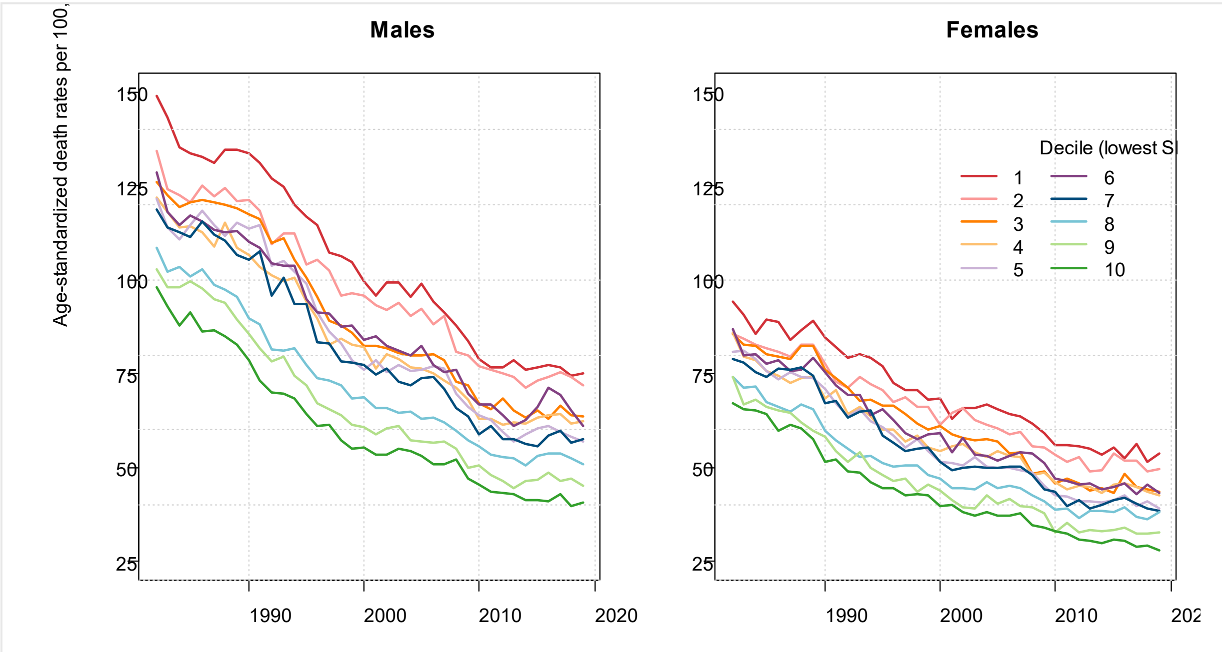
The socioeconomic gradient in mortality affects all ages except for the oldest (85 years and above), with some variations from one group to the next and by sex (Table 2).

Table 2
Ratios of Age-Standardized Death Rates, First/10th Decile, by Sex, 1982 vs. 2019

	Males		Females	
Age Group	**1982**	**2019**	**1982**	**2019**
0–19 years	1.5	1.8	1.4	1.9
20–44 years	1.9	2.1	1.5	2.5
45–64 years	1.4	2.4	1.2	2.4
65–84 years	1.1	1.5	1.1	1.5
85+ years	1.0	1.1	1.0	1.1
All ages	1.2	1.6	1.1	1.5

Mortality below age 20 declined regularly for all SIS deciles up to about 2010, when at least for males it appears to have reached a plateau (Figure 2). However, by contrast with the trends observed for the rates at all ages combined, the gap between the first and 10th deciles did not increase over time. In 1982, the age-standardized death rates per 100,000 for males younger than 20 ranged from 98 in the most affluent decile to 149 in the least affluent; for females, the corresponding rates were 67 and 94. In 2019, the corresponding figures were 41 and 75 for males and 28 and 54 for females. The absolute difference in the rates between the two extreme deciles was thus smaller in 2019 than it had been in 1982: 51 per 100,000 in 1982 and 34 in 2019 for males, and 27 and 25 for females. However, because of the continuous decline in mortality (at least until the 2000s), the relative difference increased: the rates in the bottom decile (least affluent) were higher than in those in the top decile by 52% (for males) and 40% (for females) in 1982, but these proportions rose to 83% and 93%, respectively, in 2019.

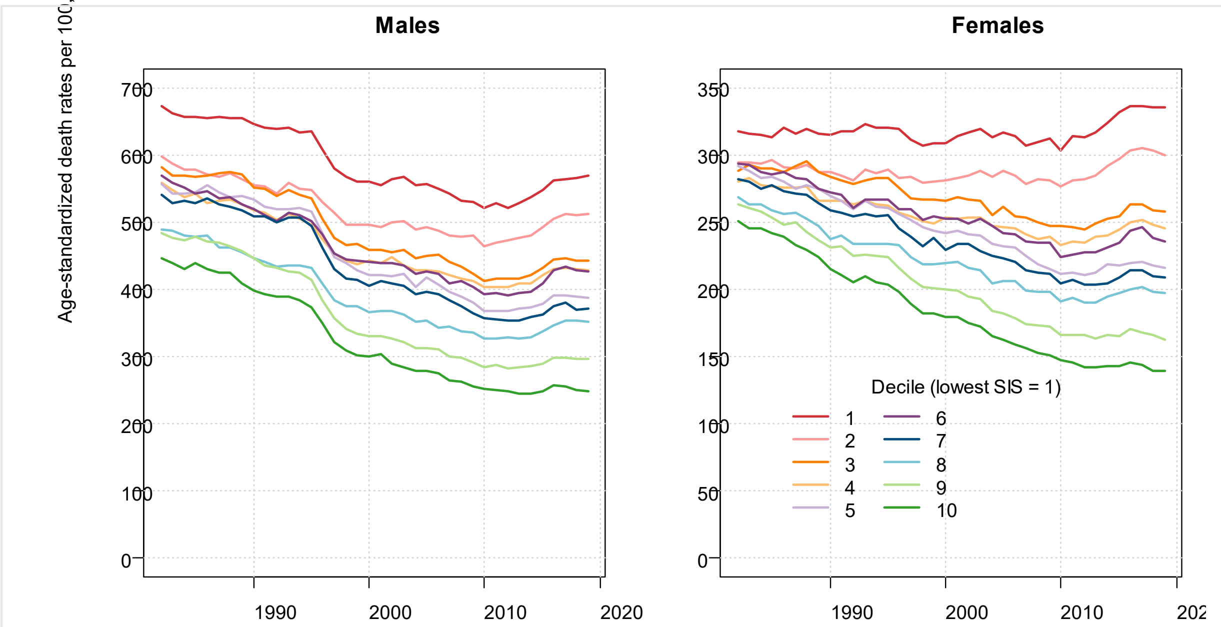
Figure 2
Age-Standardized Death Rates Below Age 20, by SIS Decile and Sex, 1982–2019



For adults aged 20 to 64 years, the gradient is much clearer than for the youngest age group, with a progressive increase in mortality from the bottom decile up to the top, except for the middle deciles, which were somewhat intertwined at the beginning of the study period (Figure 3). The 1982 age-standardized mortality rates per 100,000 range from 447 in the top (most affluent) decile to 674 in the bottom decile for males and from 251 to 318 for females, versus 2019 rates of 248 to 569 for males and 139 to 335 for females. Rates in 1982 were thus 50% (for males) and 27% (for females) higher in the least affluent decile than in the most affluent decile. In 2019, rates for the least affluent decile were more than twice as high: 2.3 times for males and 2.4 for females. Even more concerning is that the 20% of females in the bottom deciles showed virtually no progress in survival throughout the whole period (Figure 3). In fact, for these females, mortality rose after 2010 and was higher in 2019 than it had been in 1982. For both males and females, mortality increased during the late 2010s, with greater increases for the least affluent than for the most affluent deciles. However, all deciles except females in the top two deciles experienced higher mortality in 2019 than they did in 2013–14.

Figure 3

Age-Standardized Death Rates at Ages 20–64 Years, by SIS Decile and Sex, 1982–2019



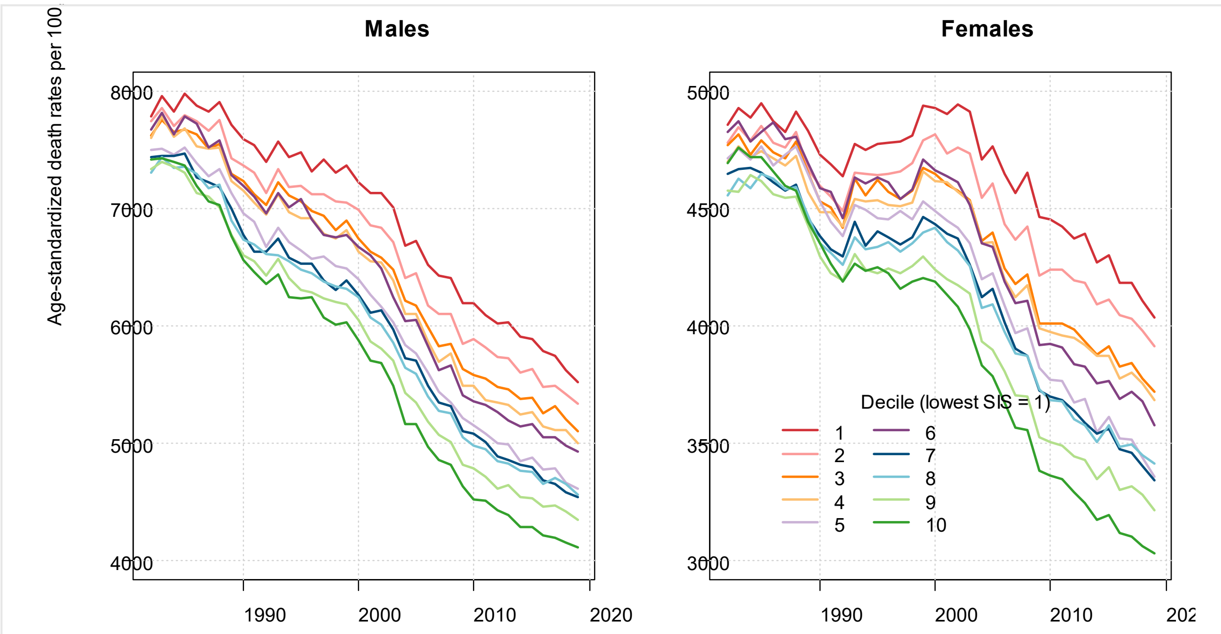
Analyses for finer age groups show some differences in trends below and above age 45 years. For males between the ages 20 and 44 years, mortality increased for all deciles during the 1980s and up to the mid-1990s due to the HIV/AIDS epidemic. It then declined suddenly during the second half of the 1990s, when highly active anti-retroviral (HART) therapy was successfully introduced. Afterward, for males aged 20-34 years, it remained fairly stable at a level slightly lower than pre-HIV epidemic level and for males aged 35-44 years, it continued declining, albeit more slowly, until about 2010. Mortality increased after 2010 for males 20–44 years of age in all deciles. Males aged 45–64 in the two top deciles experienced a continuous decline throughout the study period, but for those in the other deciles, the decline stopped around 2010—and then increased for those in the bottom two deciles.

Female mortality rates at ages 20–44 years exhibited a different pattern, with a divergence between the bottom and top deciles. Among females in the top deciles, those aged 20–44 experienced a continuous decline in mortality until the end of the 2000s, but those aged 45–64 experienced a decline in mortality throughout the entire study period. By contrast, those in the bottom deciles did not experience any progress in survival throughout the period at ages below 45 (with some fluctuations from one age group to the next). Trends until 2010 were much more positive for females older than 45. For all working-age females in the bottom deciles, however, the year 2010 (plus or minus a couple of years) marked a turning point in trends and was followed by an increase in mortality for those in the bottom four deciles or, at best, a plateau for those in deciles 5 to 8.

At ages 65 and over, trends were much more favorable throughout the period for all deciles (Figure 4). However, while the gap was relatively small at the beginning of the 1980s (with rates ranging from 7,423 to 7,783 for males and from 4,693 to 4,859 for females in 1982), it markedly increased by 2019 (with rates ranging from 4,115 to 5,521 for males and from 3,031 to 4,028 for females). While the rates in 1982 were only 5% (for males) and 4% (for females) higher in the bottom than in the top decile, they were 34% and 33%, respectively, higher in 2019.

Figure 4

Age-Standardized Death Rates at Ages 65 Years and Above, by SIS Decile and Sex, 1982–2019



Male mortality declined relatively quickly for all deciles after the mid-1980s and up to the last data point (2019). In the first decile, mortality was 29% lower in 2019 than in 1982, and for those in the 10th decile, it was 45% lower. For females, as previously mentioned, mortality dropped rapidly over a five-year period stretching from the end of the 1980s to the beginning of the 1990s, but it increased for all deciles between 1992 and 1993. The increase continued until about 2000 for all but the two most affluent deciles, which experienced a plateau, then the decline resumed for all deciles, continuing this favorable trend up to 2019. Throughout the study period, the rates declined by 17% for females in the first decile and by 35% for those in the 10th.

A more detailed analysis indicates that the pattern was very similar for all smaller age groups older than 65, except for a later and later onset of decline with age after an early plateau. While mortality started declining quickly in the early 1980s for males aged 65–79, the decline was delayed until the 1990s for older males with little differences in trends across the SIS deciles. Females experienced a similar pattern of mortality change but with some divergence across the SIS deciles throughout the period for those under 80 (with a faster decline among the most affluent) and after the 2000s for those above that age.

3.2 A CAUSE-OF-DEATH STRUCTURE VERY SIMILAR ACROSS SIS DECILES

For each of the 10 SIS deciles, Tables 3a and 3b show the percentage distribution of the age-standardized death rates attributable to each of the six broad cause-of-death categories in 1982. Tables 4a and 4b present the corresponding data for 2019.

Cardiovascular diseases were by far the leading cause of death for both males and females across all deciles in 1982, representing half (for males) or more (for females) of total mortality. The contribution of cardiovascular diseases to overall mortality was negligible at ages below 20 but increased throughout the working ages and was particularly large at 65 years and above. Cancer ranked second, representing 19%–23% of total age-adjusted mortality, from the lowest to highest decile, for males and 19%–24% for females. Other diseases (i.e., diseases other than cardiovascular diseases, cancer, and infectious and respiratory diseases) ranked third, with a slightly lower share for males (around 10%–11%) than for females (12%–13%). External causes were next, with a 10% share in the lowest decile down to

6% in the highest for males and fewer disparities for females—around 6%–7% throughout all SIS deciles. Infectious and respiratory diseases represented 9% of the total for all deciles for males and about half that amount (4%–5%) for females. The last category, ill-defined and unknown causes, represented a negligible proportion, at 1%, for all but the two lowest deciles (3% and 2%, respectively, for both males and females).

Table 3a

Proportional Distribution of Mortality by Broad Cause-of-Death Category, Males, 1982

	Decile										U.S.
Cause-of-Death Category	1	2	3	4	5	6	7	8	9	10	Total
Cardiovascular diseases	49%	50%	51%	50%	50%	51%	50%	50%	50%	51%	50%
Cancer	19%	20%	21%	21%	21%	22%	22%	22%	22%	23%	21%
Other diseases	10%	10%	10%	10%	10%	11%	11%	11%	11%	10%	11%
External causes	10%	8%	8%	8%	8%	7%	7%	7%	7%	6%	8%
Infectious/respiratory diseases	9%	9%	9%	9%	9%	9%	9%	9%	9%	9%	9%
Ill-defined/unknown causes	3%	2%	1%	1%	1%	1%	1%	1%	1%	1%	1%
All causes	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Age-standardized death rate per 100,000	1,408	1,353	1,327	1,310	1,296	1,326	1,278	1,228	1,226	1,215	1,302

Table 3b

Proportional Distribution of Mortality by Broad Cause-of-Death Category, Females, 1982

	Decile										U.S.
Cause-of-Death Category	1	2	3	4	5	6	7	8	9	10	Total
Cardiovascular diseases	53%	53%	55%	53%	53%	53%	52%	52%	51%	52%	53%
Cancer	19%	20%	21%	22%	22%	22%	22%	23%	23%	24%	22%
Other diseases	13%	13%	13%	13%	13%	13%	13%	13%	13%	12%	13%
External causes	7%	7%	6%	6%	7%	6%	7%	7%	7%	7%	7%
Infectious/respiratory diseases	5%	5%	4%	4%	5%	4%	4%	4%	4%	4%	4%
Ill-defined/unknown causes	3%	2%	1%	1%	1%	1%	1%	1%	1%	1%	1%
All causes	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Age-standardized death rate per 100,000	818	793	787	775	781	798	767	746	746	751	778

In 2019, again, the structure of mortality by cause (independently from its level) was remarkably similar across the SIS deciles. Overall, the share of cardiovascular diseases had declined considerably, from about half to about 30%, while that of cancer had remained stable at 21%–22%. By contrast, other diseases saw their contribution more than double, from 11%–13% for both sexes to 24% for males and 29% for females. The share of external causes remained stable at 7% for females but increased from 8% to 12% for males, while that of infectious and respiratory diseases increased only slightly for males (from 9% to 11%) while tripling for females (from 4% to 12%). As for the share of mortality from ill-defined or unknown causes, it became negligible, at 1% for each sex, the least affluent deciles converging to the low level previously recorded by the most affluent.

Deciles differed only marginally in the distribution of mortality by cause. Most notable was the lower share of cancer in the first (least affluent) decile compared with the 10th decile. This was especially the case for females, for whom the proportion ranged from 20% to 24%. It was partly compensated by a reversed pattern for infectious and respiratory diseases, with a share declining from 12% to 10% for males across all SIS deciles and from 14% to 11% for females. External causes also contributed a larger share of mortality in the first decile for males (13%) compared with the 10th (10%) in 2019.

Table 4a

Proportional Distribution of Mortality by Broad Cause-of-Death Category, Males, 2019

Cause-of-Death Category	Decile 1	2	3	4	5	6	7	8	9	10	U.S. Total
Cardiovascular diseases	31%	31%	32%	31%	32%	30%	30%	30%	30%	31%	31%
Cancer	20%	20%	21%	21%	21%	21%	21%	22%	22%	22%	21%
Other diseases	23%	23%	23%	24%	23%	23%	24%	24%	25%	24%	24%
External causes	13%	13%	12%	13%	12%	13%	13%	13%	12%	11%	12%
Infectious/respiratory diseases	12%	12%	12%	11%	11%	11%	10%	11%	10%	10%	11%
Ill-defined/unknown causes	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%
All causes	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Age-standardized death rate per 100,000	1,043	986	914	893	819	882	801	789	728	670	850

Table 4b

Proportional Distribution of Mortality by Broad Cause-of-Death Category, Females, 2019

Cause-of-Death Category	Decile 1	2	3	4	5	6	7	8	9	10	U.S. Total
Cardiovascular diseases	29%	29%	30%	29%	30%	28%	29%	28%	28%	29%	29%
Cancer	20%	21%	21%	22%	23%	22%	22%	23%	23%	24%	22%
Other diseases	29%	28%	28%	29%	29%	29%	29%	29%	30%	29%	29%
External causes	7%	8%	7%	7%	7%	8%	8%	7%	7%	6%	7%
Infectious/respiratory diseases	14%	13%	13%	13%	12%	12%	12%	12%	11%	11%	12%
Ill-defined/unknown causes	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%
All causes	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Age-standardized death rate per 100,000	715	678	627	615	556	596	550	552	505	467	584

The same pattern holds for each age group, though the ranking of the broad cause-of-death categories varies. For those younger than 20, more than 85% of the mortality rate is attributable to diseases other than infectious, respiratory, cardiovascular disease and cancers (since this residual category includes all perinatal conditions, which affect very young children) and to external causes. Children surviving their first birthday and teenagers rarely die of diseases; most deaths are caused by accidents and injuries, which fall in the latter category. For all SIS deciles, “other diseases” has ranked before external causes throughout the study period, but more so for the most affluent than for the least affluent. Other diseases also contributed more to overall mortality for girls than for boys. For both sexes, their role tended to decline over the period as mortality from these other diseases fell faster than that from external causes.

For young adults (aged 20–44), external causes become prominent, as they contributed to more than half of the mortality rates for both males and females, and their contributions increased between 1982 and 2019. For males, they climbed from a range of 48%–56% of total mortality in 1982 to 58%–64% in 2019. For females, external causes rose from a range of 28%–32% in 1982 to 37%–44% in 2019, depending on the decile. In 1982, the second leading cause of death for males was cardiovascular disease, closely followed by other diseases and then by cancer. For females, it was cancer, with cardiovascular and other diseases competing for third place. While the cause-of-death structure remained relatively stable for males throughout the period (albeit with a slight increase in the share of mortality from other diseases, taking over the second place from cardiovascular diseases), it changed markedly for females: the share of cancer, which accounted for a quarter to a third of total mortality in 1982, declined to a range of 14%–20% in 2019), and that of other diseases increased.

In the next age group, 45–64 years, the share of mortality from external causes is much smaller, but it increased throughout the period, from a range of about 11%–12% in 1982 to 15%–20% in 2019 for males and from 5%–6% in 1982 to 10%–12% in 2019 for females. For males, cardiovascular diseases were by far the leading cause of death in 1982, with 4%3–44% of total mortality, declining to 27%–30% in 2019. Cancer came just behind, with around 30% of total mortality in 1982, down to 21%–25% in 2019 due to the increasing share of mortality from other diseases, from less than 10% in 1982 to 15%–20% in 2019. For females, the leading cause of death in this age group was cancer throughout the study period, its share representing 36%–48% of total mortality in 1982 and 29%–41% in 2019. While in 1982, the second leading cause of death for females was cardiovascular diseases, with 27%–35% of total mortality, their share declined to 19%–24% in 2019, while that of other diseases increased from 13%–14% in 1982 to 21%–23% in 2019.

After retirement age (65–84 years), the pattern is very similar for males, with cardiovascular diseases representing the leading cause of death, followed by cancer, and further behind by other diseases, with the latter share increasing throughout the period. For females, the main difference with the younger age group is that, as for males, cardiovascular mortality takes the lead, with 54%–58% of total mortality in 1982 and about 30% in 2019, while cancer progressively loses ground to “other diseases“ for second place between 1982 (when these two categories contributed about 20%–25% and 12%, respectively, to the overall death rate) and 2019 (when each contributed about a quarter of total mortality).

At older ages (85 years and above), the role of cardiovascular diseases is even more prominent, though it declined over the study period. In 1982, these diseases accounted for 60%–65% of total mortality for males and closer to 70% for females. In 2019, they accounted for a still-high 40% for both males and females. Cancer was the second leading cause in 1982 for males only, with “other diseases” overtaking cancer for females in both 1982 and 2019 and for males in 2019. However, the share of infectious and respiratory diseases increased significantly for this age group, from 10% in 1982 to 12% in 2019 for males and from 7% to 11% for females.

The contribution of each type of disease to socioeconomic differences in mortality does not systematically follow the same pattern. In section 3.3, we look into the role that specific causes of death play in the socioeconomic gradient in mortality and its increase between 1982 and 2019. We leave aside the ill-defined and unknown causes of mortality, as these contributed minimally to both the initial socioeconomic gradient in mortality across the deciles and its subsequent increase. In 1982, the age-standardized death rates for ill-defined and unknown causes ranged from 10 deaths per 100,000 population in the most affluent decile to 38 in the least affluent for males and from 6 to 20 per 100,000 for females. By 2019, the rates for this cause-of-death category declined to 7–11 per 100,000 for males and 5–8 for females. The pattern is very similar for all age groups, with ill-defined or unknown causes representing a higher proportion of deaths among those younger than 45 throughout the period, particularly at the lower end of the socioeconomic spectrum.

3.3 CAUSE-OF-DEATH CONTRIBUTIONS TO SOCIOECONOMIC DISPARITIES IN MORTALITY

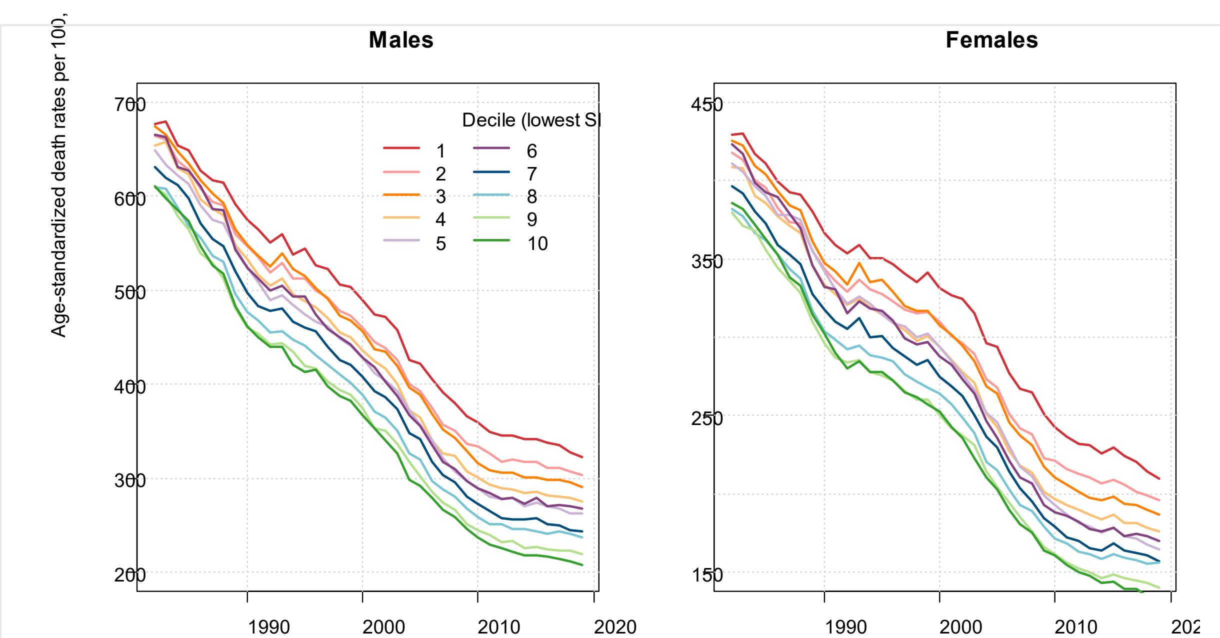
We next concentrate on the analysis of differentials and trends for each of the five broad cause-of-death categories: cardiovascular diseases, cancer, infectious and respiratory diseases, other diseases, and external causes. We will discuss how much each contributed to the gap in mortality across the SIS deciles as well as to the increase in this gap between 1982 and 2019.

3.3.1 CARDIOVASCULAR DISEASES

In 1982, cardiovascular diseases, the leading cause of death in the United States, contributed most to the gap in mortality between the least and most affluent deciles. For males, the difference between the two extreme deciles in the age-standardized death rates from these diseases reached 66 deaths per 100,000, representing just below one-third of the total difference (193 deaths per 100,000). For females, the difference was 44 deaths per 100,000, representing two-thirds of the much smaller total difference (68 per 100,000). By 2019, the gap between the first and 10th deciles due to cardiovascular diseases had increased to 115 deaths per 100,000 out of a total 374 deaths per 100,000 for all causes combined, and to 75 out of 248 deaths per 100,000 for females. So the absolute difference between deciles 1 and 10 in the mortality rates from the diseases of the circulatory system nearly doubled for both males and females between 1982 and 2019, even though the overall level of mortality from these diseases declined for all deciles (Figure 5). Cardiovascular diseases contributed more than a quarter of the overall increase in the difference in mortality between the two extreme deciles during the period 1982–2019 for males (49 out of 181 deaths per 100,000) and for one-sixth (31 out 181 deaths) for females. If all SIS deciles had experienced the same level of cardiovascular mortality as the top decile in 2019 (holding constant the differences from all other causes), the gap between the least and most affluent 10% of Americans would be smaller by 31% for males and 30% for females.

Figure 5

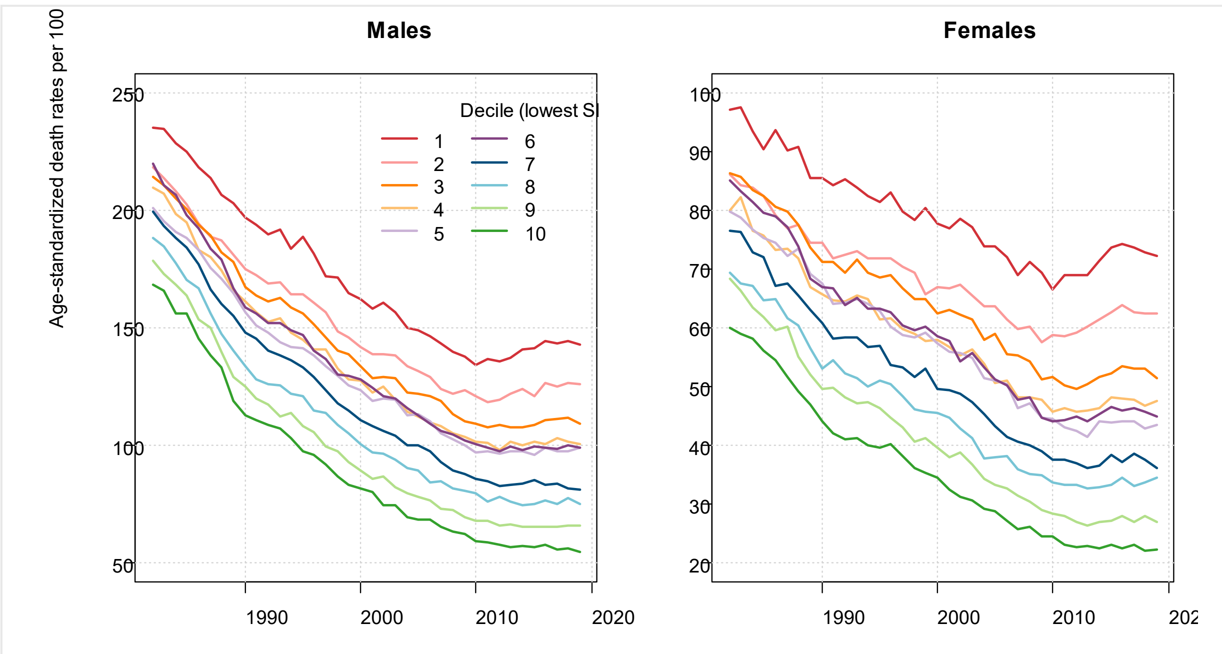
Age-Standardized Death Rates from Cardiovascular Diseases, by SIS Decile and Sex, All Ages Combined, 1982–2019



The overall pattern is particularly pronounced in absolute terms at ages 65 years and over. For that age group, the gap in cardiovascular mortality between the two extreme deciles more than doubled (increasing from 210 deaths per 100,000 in 1982 to 502 in 2019 for males and from 175 to 367 for females), even though the rates declined throughout the period. In relative terms, however, the socioeconomic gap increased considerably for younger (20–

44 years old) and especially for older (45–64 years old) working-age adults. The ratio of the age-standardized death rates from these diseases increased much more at these ages than at others, especially for females: from 1982 to 2019, the ratio increased from 1.7 to 2.6 for males and from 2.1 to 3.6 for females at ages 20–44, and it increased from 1.3 to 2.6 for males and from 1.5 to 3.2 for females at ages 45–64. The larger socioeconomic gap at the end of the study period is attributable to a worrying pattern of mortality from these diseases after 2010, when the rate stopped declining in the most advantaged segments of the population while it increased sharply for the most disadvantaged until about 2017 (Figure 6).

Figure 6
Age-Standardized Death Rates from Cardiovascular Diseases, by SIS Decile and Sex, Ages 20–64, 1982–2019



These general trends in cardiovascular mortality mask some differences by type of diseases. The increased SIS gradient more specifically characterized trends in heart diseases, with a faster continuous mortality decline throughout the period for the most affluent deciles than for the least affluent, resulting in an increasing disparity by the end of the 2010s. Because mortality from heart diseases represents more than 80% of mortality from all the diseases of the circulatory system for males and more than 75% for females, trends in the age-standardized death rates from these two categories are nearly identical.

By contrast, trends in mortality from cerebrovascular diseases were very similar across all SIS deciles for both males and females, and the initial gradient in mortality remained fairly stable from the early 1980s to the late 2010s (Figure 7). Furthermore, the trend exhibited some disruption during the early 1990s, when the rates seemed to have reached a plateau for both sexes and for all SIS deciles. Then the decline resumed at the end of the 1990s. This stalling in progress is mostly concentrated at ages over 65. Above age 85, there was an increase in mortality from cerebrovascular diseases for both males and females during the first half of the 1990s, immediately followed by a rapid fall, which lasted until about 2010. This disruption does not appear to be documented in the literature on historical trends in cardiovascular mortality, which typically insists on the extraordinary progress in survival from ischemic heart diseases, the leading cause of death. During the second decade of the 21st century, the death rates from cerebrovascular diseases have tended to plateau again or increased slightly for all SIS deciles. Mortality from all other diseases of the circulatory system (which are about one-tenth as deadly as heart diseases) shows very little difference in levels and trends across the SIS decile and exhibited a fairly steady decline throughout the study period (Figure 8). Overall, declines in mortality from all diseases of the circulatory system were strong for both sexes and all SIS deciles during most of the period.

Figure 7

Age-Standardized Death Rates from Cerebrovascular Diseases, by SIS Decile and Sex, 1982–2019

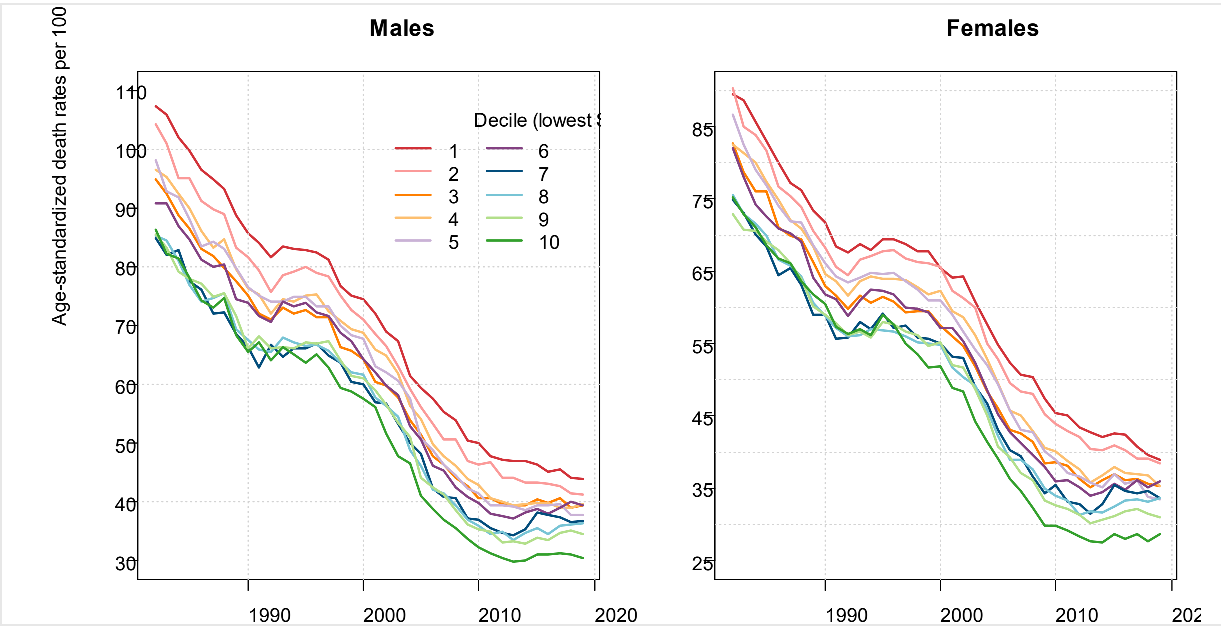
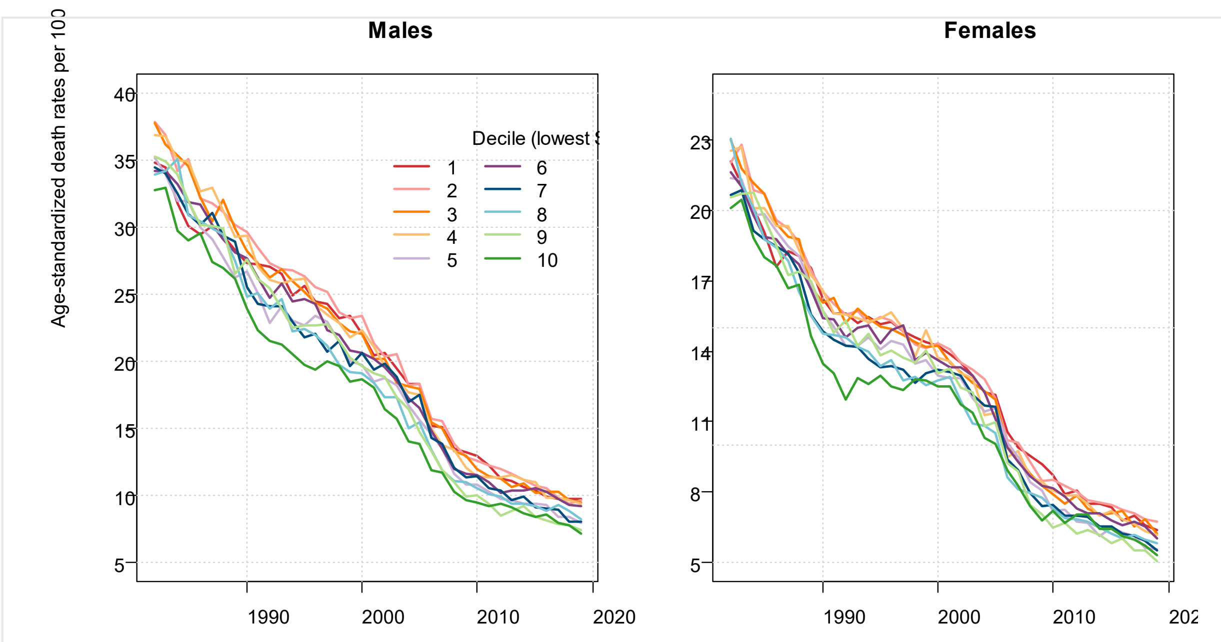


Figure 8

Age-Standardized Death Rates from the Other Diseases of the Circulatory System, by SIS Decile and Sex, 1982–2019



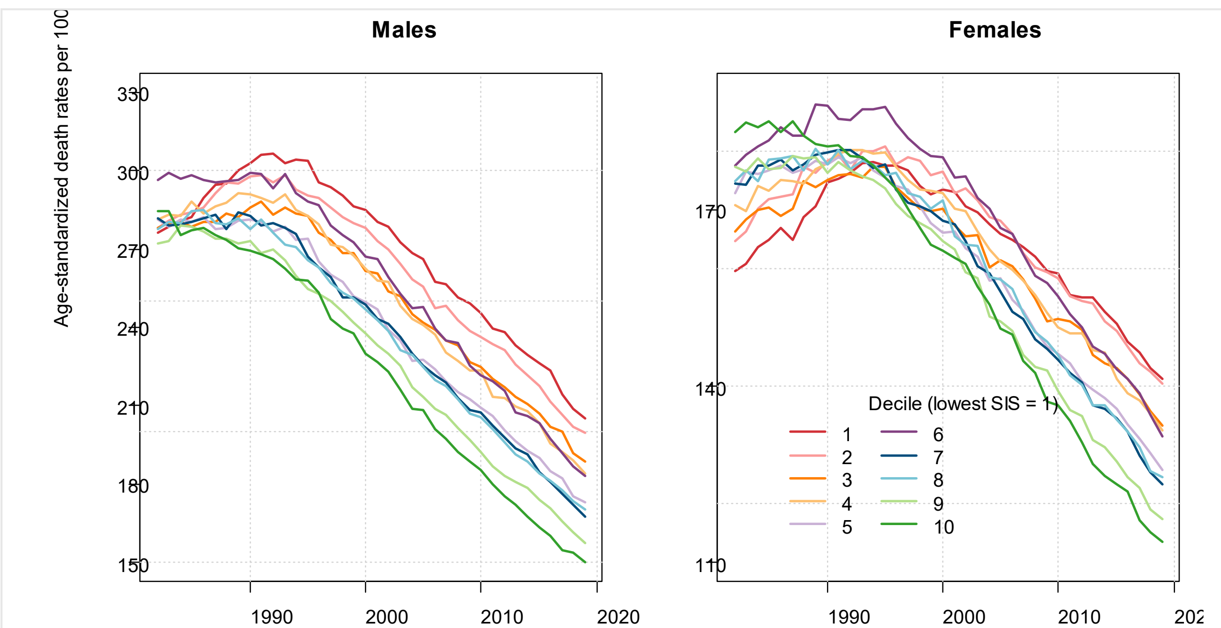
However, progress in mortality from all three groups of causes (heart diseases, cerebrovascular diseases, and all other cardiovascular diseases) and for all SIS deciles decelerated markedly during the 2010s, and as discussed above in this same section, the death rates from all cardiovascular diseases actually increased for working-age adults in the least affluent deciles (Figure 6).

3.3.2 CANCER

Of the data for 1982, cancer is the one broad cause-of-death category exhibiting a pattern of socioeconomic disparities in mortality that is completely different from the all-causes rate (Figure 9). For males, there were hardly any differences in mortality from cancer across the SIS deciles: the age-standardized death rates for this group of diseases were practically similar (around 275–285 deaths per 100,000) in all but the sixth decile, which hovered above the others, with a rate of 296 deaths per 100,000. For females, there was a relatively clear socioeconomic gradient in mortality from cancer but opposite to the all-causes gradient: the level of mortality rose with each successive SIS decile in a range from 160 to 183 deaths per 100,000. For both males and females, the pattern changed after cancer mortality reached its peak, in the 1990s. Because cancer mortality declined earlier for both sexes and faster for females in the most affluent deciles, the end of the study period exhibits the expected gradient with higher mortality for Americans in the least affluent decile and a progressive decline from one decile or every couple of deciles to the next. By 2019, the gap in the age-standardized death rates from cancer between deciles 1 and 10 grew to 55 per 100,000 for males and 28 per 100,000 for females, compared with −8 and −24 in 1982. If the gap had been 0 in 2019, holding constant the gaps for all other causes, the 2019 difference in the all-causes age-standardized death rate between the first and 10th decile would be smaller by 15% for males and 11% for females. Given these differential trends, cancer is a major contributor to the increasing gap in mortality from 1982 to 2019 between the extreme deciles, explaining 35% of the increase for males and 28% for females.

Figure 9

Age-Standardized Death Rates from Cancer, by SIS Decile and Sex, 1982–2019

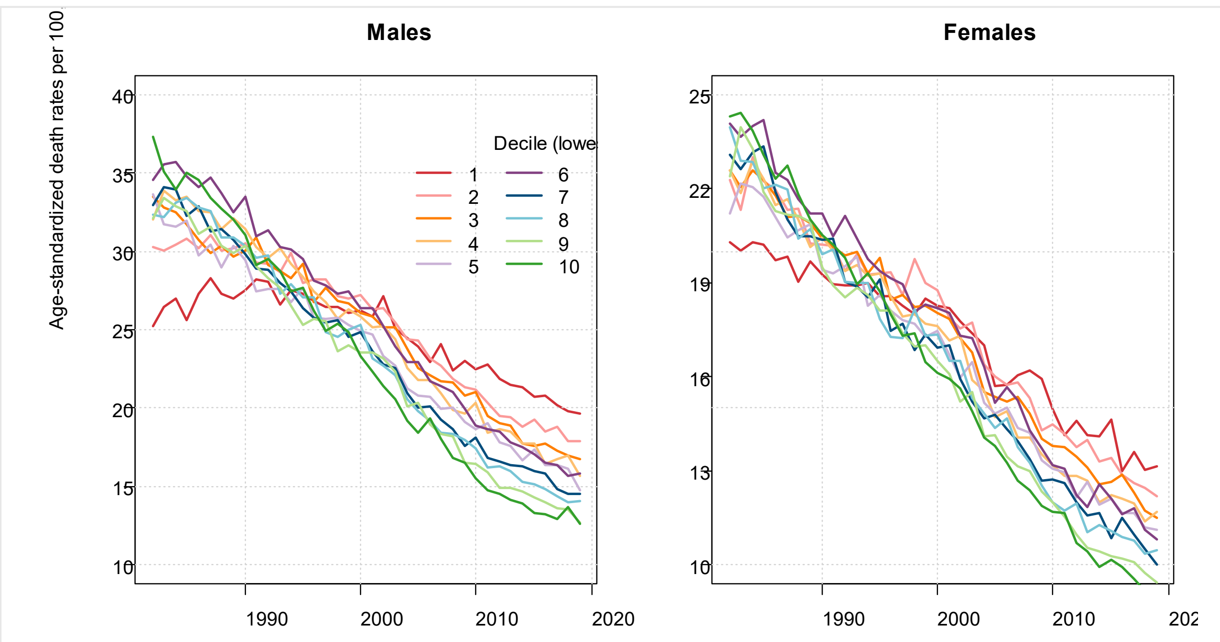


For males, trends and socioeconomic disparities in mortality from the cancers most closely associated with smoking (those of the lip, oral cavity, pharynx, esophagus, larynx, trachea, bronchus and lung) do not differ substantially from those attributable to other factors. The rates increased by 2% in the first two deciles but declined for all other deciles (by 23% in the top decile). For both males and females, however, the peak was later and higher for Americans in the least affluent deciles, leading to a reversal of the socioeconomic gradient. The overall trend is largely driven by cancers of the trachea, bronchus and lung, since the death rate for these cancers represented nearly 90% of the rate for all smoking-related cancers in 1982 and 80% in 2019, and it contributed for 30%–35% of the mortality for all cancers in 2019, versus 20%–25% in 2019. The pattern was also similar below and above age 65 but with an interesting difference, especially marked for females: the peak of smoking-related mortality was reached earlier for working-age adults (in the 1980s for males and around 1990 for females) than for older adults (in the 1990s for males and the 2000s for females), a clear cohort effect reflecting the aging of the generations with the highest smoking rates.

Two other leading cancers that are less closely related to smoking followed a different trend. The first is colorectal cancer. For this cancer, mortality at the beginning of the period was clearly much lower for Americans in the least affluent decile than for others, with an age-standardized death rate of 25 per 100,000 for those in the first decile, compared with 30–33 per 100,000 for those in deciles 2–9 and 37 per 100,000 for those in the most affluent decile. However, mortality from colorectal cancer started declining much later and at a much slower rate in the first SIS decile than in all others, so by the end of the study period, the age-standardized death rate in decile 1 was still at 20 per 100,000, compared with 13 per 100,000 in the most affluent decile, with a clear SIS gradient (Figure 10).

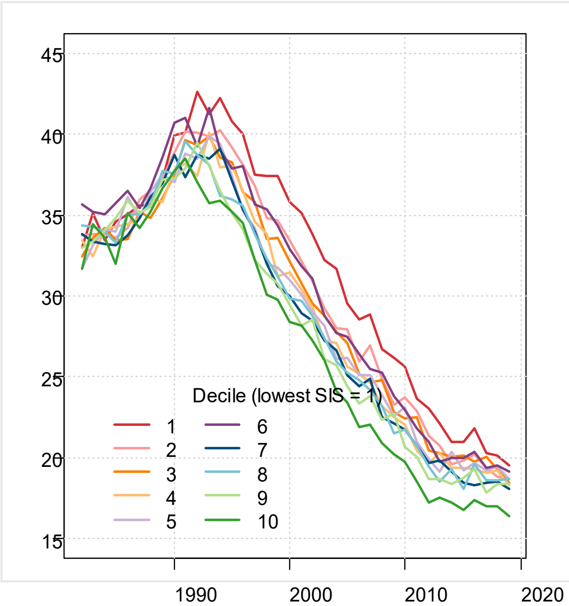
Figure 10

Age-Standardized Death Rates from Colon and Rectum Cancer, by SIS Decile and Sex, 1982–2019



The second type of cancer with a specific pattern is prostate cancer, for which all SIS deciles had a very similar level of mortality in 1982. Mortality increased for all by about one-third up to a peak in the mid-1990s and then underwent a general decline that was experienced a few years later by Americans in the least affluent deciles than by those in the most affluent deciles (Figure 11). By 2019, mortality from prostate cancer was lowest in the most affluent SIS decile (at 16 per 100,000), highest in the least affluent (at 20 per 100,000), and very similar (at 18–19 per 100,000) in all other deciles.

Figure 11
Age-Standardized Death Rates from Prostate Cancer, by SIS Decile, Males, 1982–2019



For females, the contrast between mortality from smoking-related cancers and mortality from other cancers is striking (Figures 12 and 13). Mortality from smoking-related cancers increased considerably for them between 1982 and up to the end of the 1990s in a similar way for all SIS deciles: in 1982, the rates were lowest for the least affluent deciles (ranging from 28 deaths per 100,000 in the first decile to 34 in the 10th). At the national level, the rate had increased by 50% at its peak, in 2002, from 31 to 45 deaths per 100,000 (declining from 101 to 88 deaths for males during the same period). The proportional increase ranged from 24% for American females in the 10th SIS decile to a high of 64% for those in the first (least affluent) decile. As for males, most of the trend in smoking-related cancer for females was driven by cancer of the trachea, bronchus and lung.

Figure 12

Age-Standardized Death Rates from Smoking-Related Cancers, by SIS Decile and Sex, 1982–2019

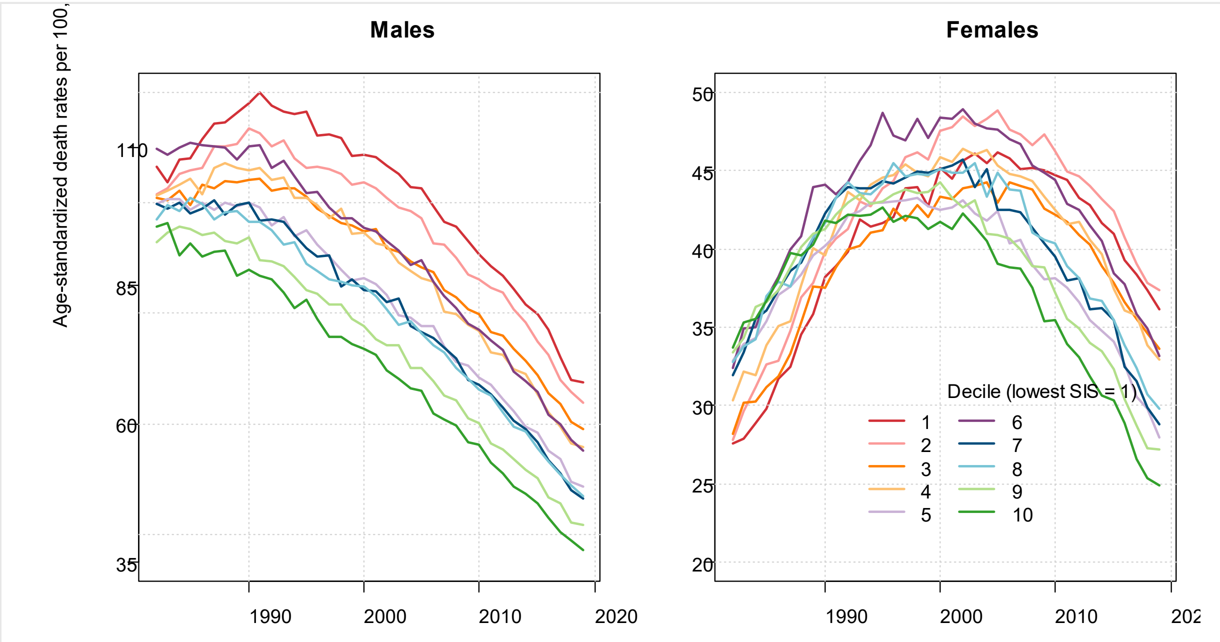
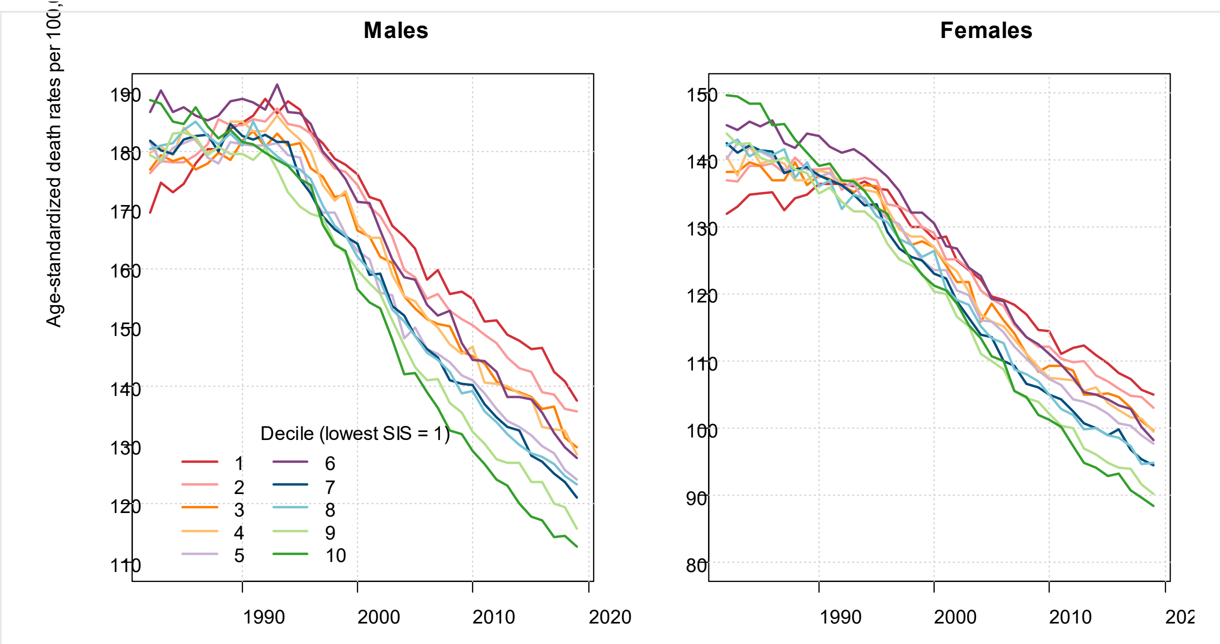


Figure 13

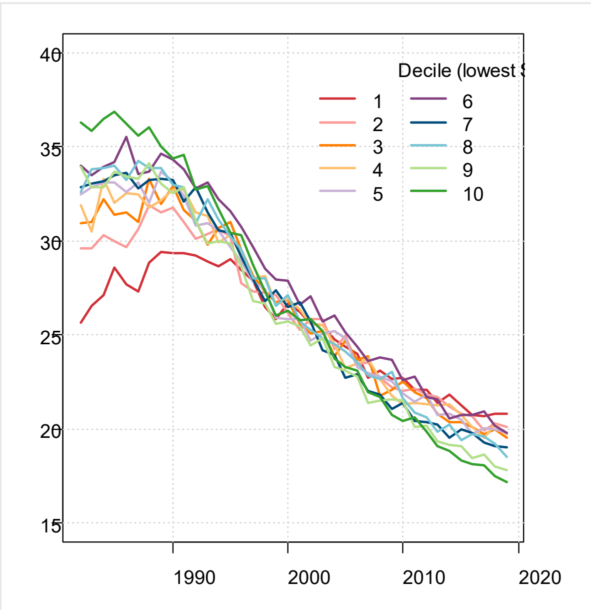
Age-Standardized Death Rates from Other Cancers, by SIS Decile and Sex, 1982–2019



Female mortality from colorectal cancer exhibited a different pattern, very similar to that of males, with a general decline for all but for Americans in the least affluent SIS decile. In that decile, mortality declined much more slowly than for Americans in all other deciles, resulting in a crossover and a fairly clear SIS gradient in mortality by 2019 (Figure 10).

Mortality from breast cancer followed a similar trend (Figure 14), except that in 1982 there was a reverse SIS gradient, which disappeared at the end of the 1990s and became barely visible in 2019, with rates ranging from 17 per 100,000 in the most affluent decile to 21 per 100,000 in the least affluent.

Figure 14
Age-Standardized Death Rates from Breast Cancer, by SIS Decile, Females, 1982–2019



The similarity, for males, in mortality trends for smoking-related cancers and other types of cancers might be related to smoking. Even though smoking is not identified as the one major single cause for these other cancers, it might play a more important role in males than in females. The rates increased during the 1980s and early 1990s for most SIS deciles but declined for all thereafter (Figures 13 and 14). For females, the period after 1982 showed some increase in mortality from these non-smoking-related cancers for ages 65 and over but a continuous decline for working-age adults. By 2019, the large difference in female mortality from these types of cancer across SIS deciles (which were favorable to Americans in the least affluent decile) reversed for both age groups—those below and above age 65—but became much more pronounced in relative terms for working-age females: 42 per 100,000 for those in the most affluent SIS decile and 63 for those in the least affluent. For females older than 65, the rates ranged from 508 per 100,000 for the 10th (most affluent) decile to 540 for the first decile.

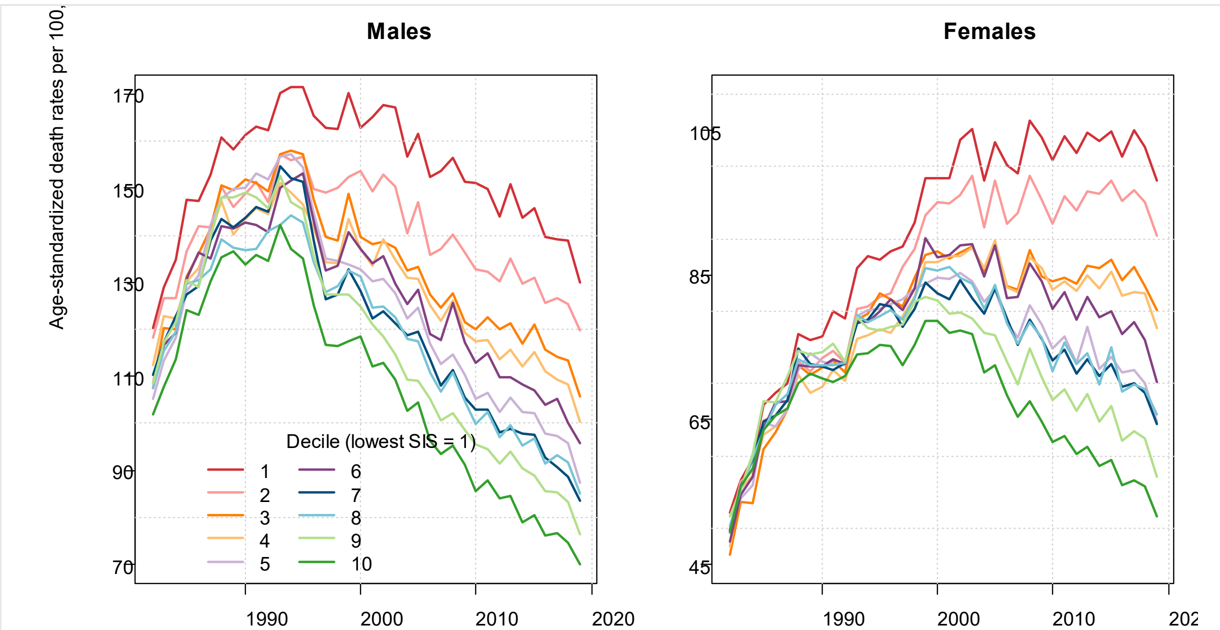
Trends in cancer mortality by SIS decile appear to be in part a reflection of the historical prevalence of and differentials in smoking across the U.S. population. For instance, data from the National Health Interview Survey show that, though Americans in all social classes smoked much less in 2019 than they did in the 1960s, the decline in smoking was considerably faster for the most educated than for the least educated. Smoking rates declined by 83% for American adults of both sexes with a university diploma between 1966 and 2015 but only by 39% for those who never finished high school. The most common cancers not strongly related to smoking (those of the colon and rectum, as well as prostate for males and breast for females) used to be more favorable for Americans in the lowest SIS decile. This decile reached its maximum level of cancer mortality later than Americans in the highest SIS deciles. The increase in prostate cancer for all groups up to the early 1990s was driven by improved diagnostics due to the discovery and progressive diffusion of prostate-specific antigen testing. Its following decline is attributable to better management of cases and improvements in treatment. Trends and disparities in mortality from prostate cancer are thus likely to have reflected at least in part differential access to diagnostics and screening, which would have been associated with an underestimation of mortality from these conditions compared to wealthier groups, as suggested by the scarce studies available for these early decades (Anderson and May 1995; Polednak 1993).

3.3.3 INFECTIOUS AND RESPIRATORY DISEASES

Mortality from infectious and respiratory diseases represented a small share of total mortality in 1982, with small differences by socioeconomic category (negligible for females). The age-standardized death rates per 100,000 for males ranged from 102 for the first decile to 120 for the 10th decile; for females, the rates ranged from 49 to 52 per 100,000. The rates increased for all deciles until the mid-1990s for males and the early 2000s for females, with a remarkable consistency across all deciles except for a delay of about five years in the turning point for females in the two least affluent deciles (Figure 15). The gap between the two extreme deciles in the age-adjusted death rates per 100,000 from all infectious and respiratory diseases increased from 19 in 1982 to 60 in 2019 for males. For females, the gap increased from 3 to 46. These increases contributed 23% to the increase in the all-causes gap for males and 24% to the all-causes gap for females.

Figure 15

Age-Standardized Death Rates from Respiratory and Other Infectious Diseases, by SIS Decile and Sex, 1982–2019

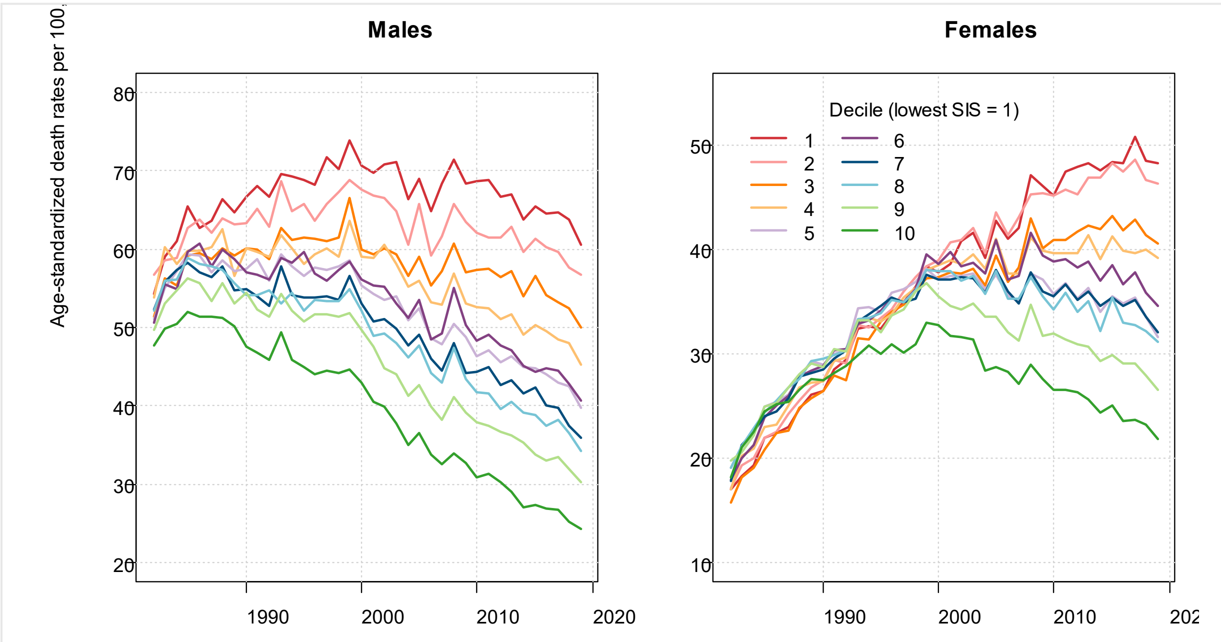


The increase in the rates of mortality from this group of causes is mostly attributable to HIV/AIDS, especially for males, and to chronic obstructive pulmonary diseases (COPD), especially for females. However, for HIV/AIDS the increase in deaths per 100,000 did not follow a clear gradient for males: it was smallest for the second decile, rising from 1 in 1982 to 19 at its peak in 1994, and largest for the fifth decile, increasing from 1 in 1982 to a peak of 37 in 1995.

For COPD, the increase in deaths per 100,000 did follow the typical SIS gradient (Figure 16). For males in the least affluent decile, rates rose from 64 in 1982 to a maximum of 74 in 1999, and for females, rates rose from 17 in 1982 to a high of 51 in 2017. For those in the most affluent decile, rates rose from 48 to 52 in 1985 for males and from 18 to 33 in 2005 for females. Thus, mortality from COPD rose higher and longer for the most disadvantaged than for the most advantaged deciles. For males in all SIS deciles, the rates declined regularly after reaching their peaks. For females, however, the five top deciles experienced similar declines. The third to fifth deciles plateaued after reaching their highest level, while the first and second deciles continued to increase, explaining the rapid divergence across deciles in the first two decades of the 21st century. These trends are most obvious for females at ages 65 years and above and for males at ages 85 years and above. The rates for COPD mortality are negligible below age 45. Between the ages of 45 and 84 years for males and between 45 and 64 years for females, rates increased only slightly for those in the bottom deciles while declining for those in the top deciles. These trends were partly offset by large declines for both sexes at all ages (but particularly at higher ages) in the mortality rates from pneumonia, which represented by far the leading respiratory and infectious cause of death after age 85 years in 1982.

Figure 16

Age-Standardized Death Rates from Chronic Obstructive Pulmonary Diseases, by SIS Decile and Sex, 1982–2019

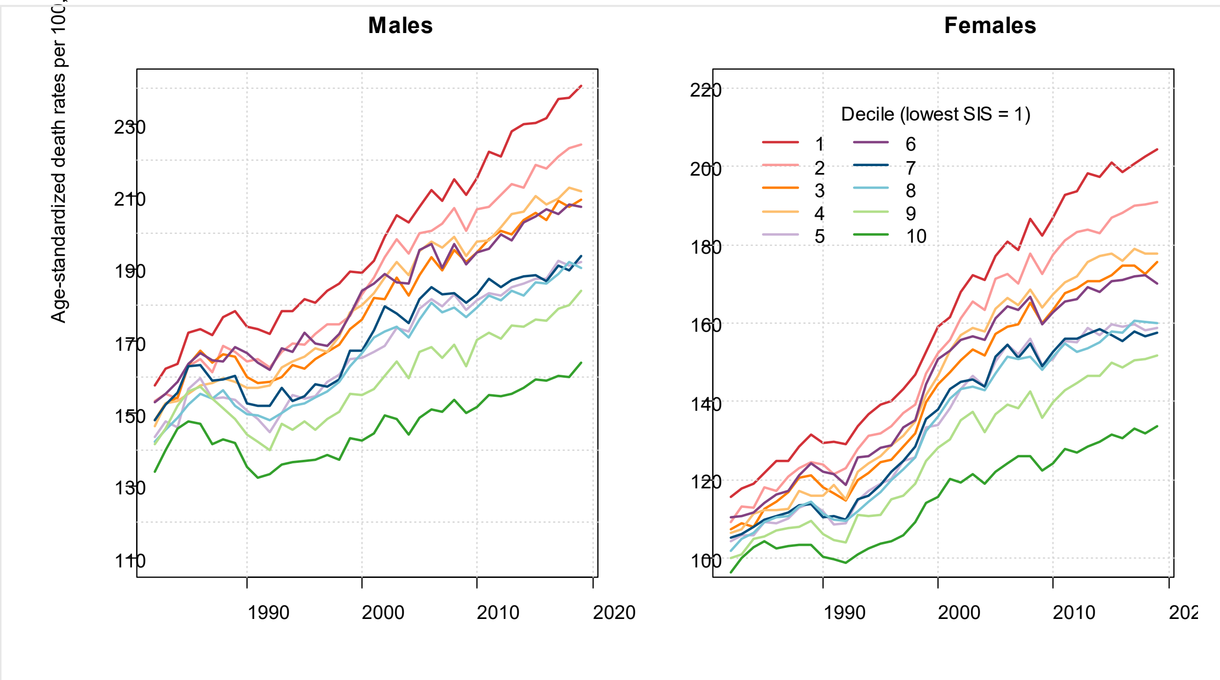


3.3.4 OTHER DISEASES

Other diseases—i.e., diseases other than cancer and those of the infectious, respiratory and circulatory systems—represented the fourth main cause of death in 1982, with a relatively clear socioeconomic gradient (albeit with some interweaving for the middle deciles) and age-standardized death rates ranging from 134 to 158 per 100,000 for males and from 96 to 116 per 100,000 for females. However, mortality rates from these diseases increased continuously starting in the early 1990s after a short period of decline, so they ranked at the top in 2019, behind cardiovascular diseases for males and right at the same level as mortality from these diseases for females. At the end of the study period, the rates ranged from 164 to 241 per 100,000 for males and from 134 to 204 per 100,000 for females (Figure 17). For males and females, this group of diseases contributed to 29% of the increasing gap in mortality between the first and 10th deciles over the study period.

Figure 17

Age-Standardized Death Rates from Other Diseases, by SIS Decile and Sex, 1982–2019



These diseases are a heterogeneous composite. They include conditions as diverse as blood diseases, skin diseases, endocrine and metabolic diseases, mental disorders, diseases of the nervous system such as multiple sclerosis, Alzheimer's, Parkinson's and others, diseases of the digestive system, of the genitourinary system, musculoskeletal diseases, complications of pregnancy or childbirth and congenital malformations, and certain conditions originating in the perinatal period. Understanding the observed trends thus requires digging into more details.

In 1982, the age-standardized death rate per 100,000 at the national level for this group of diseases was 147 for males and 106 for females. Mortality was mainly attributable to digestive diseases (with a national rate of 46 and 28 deaths per 100,000, respectively, for males and females), endocrine and metabolic disorders (25 and 23), diseases of the genitourinary system (23 and 14), and diseases of the nervous system (16 and 11). By 2019, this last type of diseases had soared to 58 and 56 deaths per 100,000, with mortality rates multiplied by 3.6 for males and 5.1 for females. Thus, diseases of the nervous system alone explain three-quarters of the increase in mortality from all other diseases between 1982 and 2019.

The rest is mostly due to endocrine and metabolic diseases and for males is partly driven by increases in mortality from diabetes mellitus, for which deaths per 100,000 rose from 19 to 27 while the rate for other metabolic diseases rose from 7 to 15. For females, the corresponding values stood at 18 and 17 for diabetes mellitus and at 5 and 11 for other metabolic diseases. The increase in mortality from this type of disease could be associated with the rise in the prevalence of obesity in the population. However, while the rate of obesity has increased at all income and education levels, the most underprivileged American males are not more likely to be obese than males in more affluent categories. In contrast, American females, increased affluence appears to be associated with a reduced risk of obesity (Ogden et al. 2010).

All four of the main conditions in the "other diseases" category contributed to the increasing gap in mortality across the SIS deciles. For males, endocrine and metabolic diseases contributed most, increasing the difference between the first and 10th decile by 23 deaths per 100,000 out of a total increase for "other diseases" of 53 deaths per

100,000 between 1982 and 2019. For females, diseases of the nervous systems contributed most, increasing the difference by 18 deaths out of a total increase of 52 deaths per 100,000. In addition, there are important differences between age groups in the ranking and differentials by cause.

For children and adolescents, the most lethal “other” diseases are those most likely to kill infants and very young children. One such category consists of certain conditions originating in the perinatal period and congenital malformations, and the other is accidents, especially transport accidents. Below age 20, these two broad groups of conditions accounted for 70%–75% of the age-standardized death rate for all causes combined in 1982 and 60%–65% in 2019. Though the mortality rates for these conditions fell consistently across all SIS deciles throughout the study period, the rate of decline increases from one decile to the next. For instance, in the bottom SIS decile, mortality per 100,000 declined by 57% for boys (from 106 to 45) and 47% for girls (from 67 to 35); in the top decile, mortality per 100,000 declined by 66% for boys (from 71 to 24) and 65% for girls (from 49 to 17). As previously mentioned, the under-20 age group is the only one for which differences in mortality from all causes across SIS deciles did not increase between 1982 and 2019. Socioeconomic differences in mortality from these “other diseases” followed a similar pattern, with very little change in the difference between the least and most affluent deciles over time.

For working-age adults, the leading cause of death in the “other diseases” category is diseases of the digestive system. In 1982, mortality from these diseases contributed about one-quarter of the rate for all “other” diseases for females and a bit more for males; in 2019, they contributed one-sixth at ages 20–44 for both sexes. Their share was higher at ages 45–64: for males, 45%–50% in 1982 and 30%–45% in 2019, and for females, 30%–35% in 1982 and around 30% in 2019. Trends in mortality from diseases of the digestive system—mostly driven by liver diseases—are striking across the SIS spectrum at ages 45–64. The corresponding rate increased over time for the bottom deciles (18% and 12% for males in the first and second deciles and 51%, 49%, 8% and 5% for females in the first to fourth deciles) and declined for the top deciles (ranging from −11% to −48% for males in the third to 10th deciles and from −14% to −47% for females in the fifth to 10th deciles). For younger working-age adults (ages 20–44), the trend was favorable for males in all deciles, though more so for the most affluent (from −13% in the first decile to −42% in the 10th) but similar for females in this age group as for those aged 45-64 years (with an increase of 18% in the first decile and 37% in the second but a decline of 20% in the ninth and 34% in the 10th), but for females in all SIS deciles but the 10th, the rates were much lower than for males.

The second leading “other” disease for working-age adults is diabetes mellitus. Between 1982 and 2019, the rates of associated deaths exploded for males and, to a lower extent, for females at ages 45–64, especially in the lower SIS deciles. The age-standardized death rate from diabetes mellitus doubled or more than doubled for deciles 1–5 for males and increased by 70% in deciles 6 and 7, 50% in decile 8, 35% in decile 9, and 20% in decile 10. For females, the increase was also higher at the lower end of the SIS distribution, with a ratio of the rate in 2019 to 1982 ranging from 1.5 (decile 1) to 0.8 (decile 10). A similar though much more muted trend was experienced by adults aged 20 to 44 years.

At older ages, the most worrying trends are those exhibited by three very different groups of diseases—namely, endocrine and metabolic diseases (including but not limited to diabetes mellitus), mental disorders, and the diseases of the nervous system. For these last two groups of diseases between 1982 and 2019, mortality per 100,000 increased for all SIS deciles, for both males and females at ages 65–84 years and at 85 years and above but especially so in the higher age group . For instance, the age-standardized mortality rates from mental disorders (excluding alcohol and drug abuse) skyrocketed from 197 to 881 for males aged 85 and above in the least affluent decile and from 209 to 1,097 for those in the most affluent decile. For females, the respective figures are 187 and 1,052 for those in the first decile and 202 and 1,213 for those in the 10th. It is, however, difficult to determine how much of this increase is real and how much is due to rising awareness of this type of medical problems. Even more striking have been the increases in mortality from the diseases of the nervous system: for males, the rate increased from 153 to 1,738 in the first decile and from 208 to 1,560 in the 10th decile in this age group, and for females, the increases were from 110 to 2,023 and from 141 to 1,549.

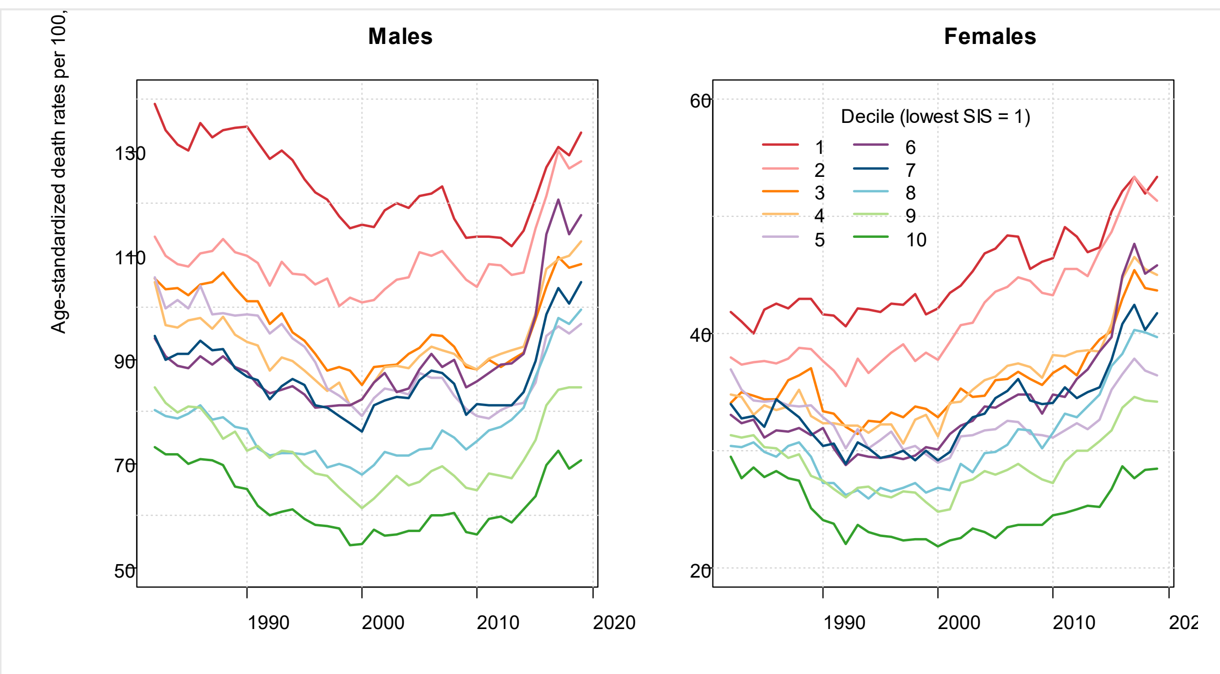
However, because mortality from mental disorders increased faster for Americans in the most affluent deciles than for those in the least affluent, this group of diseases has contributed to closing the gap in mortality across the SIS spectrum. By contrast, the increase in mortality from the diseases of the nervous system has affected the least affluent much more than the most affluent and consequently contributed considerably to the increasing gap in survival between Americans in the two extreme SIS deciles. Without the divergence, the difference in the age-standardized mortality rates from all causes would be 23% smaller for males and an extraordinary 45% for females at ages 85 and above—and 5% and 10% smaller, respectively, at ages 65–84—assuming the rates of mortality from all other diseases had been as observed.

3.3.5 EXTERNAL CAUSES

For males in 1982, mortality from external causes and cardiovascular diseases contributed most to the gap between the two extreme SIS deciles (for 66 deaths out of the difference of 193 deaths per 100,000). For females, the difference in the rates between the first and 10th deciles for external causes was only 12 out of a total difference of 68 deaths per 100,000. Over the study period , the gap in mortality from external causes between the two extreme deciles declined slightly for males, to 63 deaths per 100,000, but doubled for females, to 25 per 100,000. Nevertheless, the difference remained low enough to contribute little (for females) or not at all (for males) to the overall increase in the socioeconomic gradient in mortality from 1982 to 2019 (Figure 18). However, the long view masks some more concerning trends: while the age-standardized death rates from external causes declined for males and remained fairly stable for females until about 2000, they then increased for all SIS deciles, with a marked acceleration after 2010—a trend that is essentially driven by the so-called diseases of despair.

Figure 18

Age-Standardized Death Rates from External Causes, by SIS Decile and Sex, 1982–2019



The term “diseases of despair” was coined by Anne Case and Angus Deaton in a memorable article demonstrating for the first time an increase in mortality among low-educated white males in the United States (Case and Deaton 2015). Later, they and other scholars showed that their finding also applied to females and to other racial groups

(Case and Deaton 2017; Case and Deaton 2020; Alexander et al. 2018; Brignone et al. 2020). Diseases of despair combine three different types of causes of death: suicide, drug overdoses and alcohol-related disorders. These conditions are responsible for the lack of progress in survival at the national level between 2010 and 2014 and for the increase in mortality observed between 2014 and 2017. While suicides and drug overdoses are included in external causes, some types of alcohol-related conditions are also part of other chapters of the International Classification of Diseases, most of which are included in the "other diseases" categories in this report. In this section, we separate out suicides, drug overdoses and alcohol abuse from all other causes of death to measure their specific contribution to socioeconomic disparities in mortality between 1982 and 2019.

Figure 19, which represents the trends in the age-standardized death rates from all three diseases of despair combined for each SIS decile and sex between 1982 and 2019, shows a relatively stable level of mortality until about 2000 and a general increase for all deciles and both sexes thereafter. Before 2000, the socioeconomic gradient is mostly visible for males and not so much for females. For males, the mortality per 100,000 ranged from 25 in the first (least affluent) decile to 44 in the 10th decile in 2000 and from 45 to 72 in 2019, a considerable increase over a short decade, representing a doubling of the initial rates on average (Table 5a). Females experienced a similar increase in mortality from the diseases of despair but starting at a lower level, with mortality per 100,000 ranging from 6 (decile 1) to 10 (decile 10) in 2000, increasing to 15–26 in 2019 (Table 5b).

Figure 19

Age-Standardized Death Rates from Diseases of Despair, by SIS Decile and Sex, 1982–2019

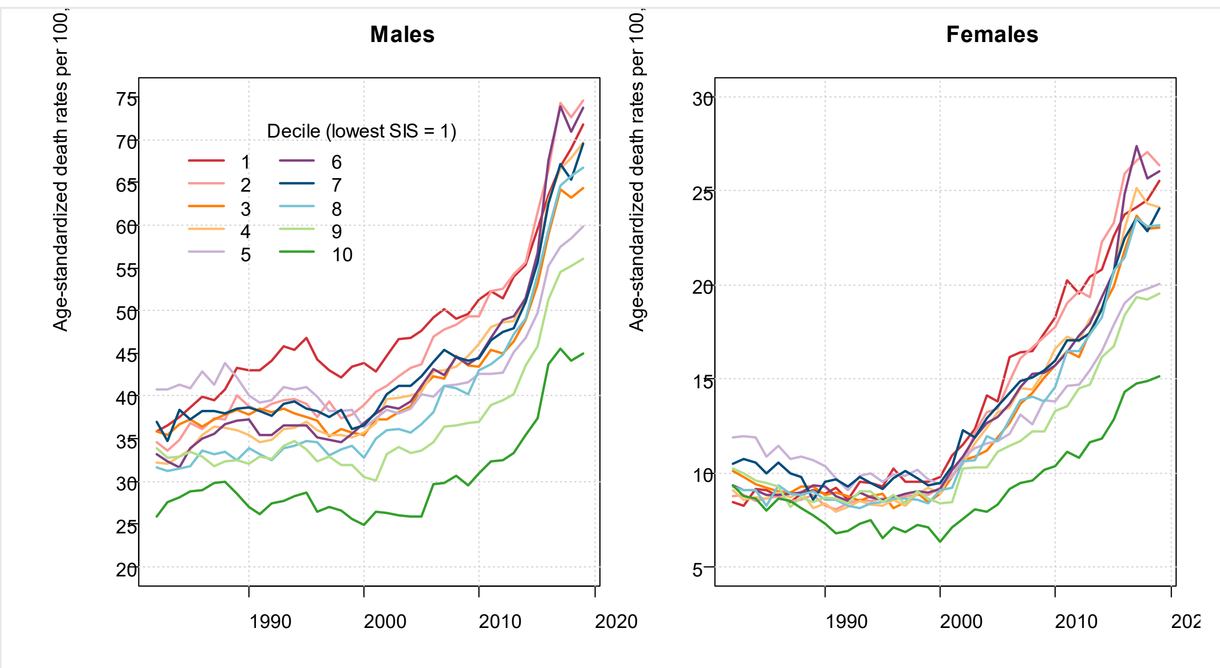


Table 5a

Age-Standardized Death Rates (All Ages Combined) from Diseases of Despair, Males, 1982–2019

SIS decile	Suicide			Drug Overdoses			Alcohol Abuse			All		
	1982	2000	2019	1982	2000	2019	1982	2000	2019	1982	2000	2019
1	20.0	21.0	25.7	2.0	8.2	27.6	13.9	14.6	18.6	35.9	43.9	71.8
2	20.9	21.1	27.6	2.0	6.7	30.4	11.6	11.2	16.6	34.5	39.0	74.6
3	20.1	17.9	22.7	1.7	5.9	26.3	14.2	11.6	15.4	35.9	35.5	64.4
4	20.6	17.6	22.5	1.6	6.8	31.4	10.0	11.4	15.8	32.2	35.8	69.7
5	20.7	16.1	20.2	3.6	7.0	23.6	16.5	13.2	16.1	40.8	36.3	59.9
6	19.0	16.6	21.6	2.4	9.4	37.4	11.9	10.8	14.8	33.2	36.8	73.7
7	21.2	16.3	21.0	1.7	8.1	31.2	14.0	12.2	17.3	36.9	36.6	69.5
8	18.9	15.3	20.8	1.6	7.4	31.1	11.2	10.1	14.8	31.7	32.8	66.7
9	18.3	13.8	17.7	2.5	6.8	25.3	13.1	10.0	13.1	33.9	30.6	56.1
10	14.9	11.1	13.7	2.1	6.1	21.7	8.8	7.7	9.6	25.9	24.9	45.0
All	19.5	16.7	21.2	2.1	7.2	28.5	12.5	11.2	15.1	34.1	35.1	64.8

Table 5b

Age-Standardized Death Rates (All Ages Combined) from Diseases of Despair, Females, 1982–2019

SIS decile	Suicide			Drug Overdoses			Alcohol Abuse			All		
	1982	2000	2019	1982	2000	2019	1982	2000	2019	1982	2000	2019
1	3.9	2.8	4.9	1.2	3.6	14.3	3.4	3.5	6.3	8.4	9.8	25.5
2	4.2	3.0	5.5	1.3	3.2	14.6	3.3	3.0	6.3	8.8	9.2	26.4
3	4.5	2.7	4.7	1.2	2.8	12.7	4.4	3.4	5.7	10.1	8.9	23.0
4	4.7	2.9	4.8	1.0	3.0	13.3	3.4	3.0	6.0	9.1	8.9	24.1
5	4.6	2.8	4.2	1.9	3.0	10.3	5.4	3.7	5.6	11.9	9.4	20.1
6	4.5	2.8	4.5	1.3	3.3	15.5	3.6	3.1	6.1	9.3	9.2	26.1
7	4.8	3.0	4.5	1.2	2.9	12.5	4.6	3.5	7.1	10.5	9.5	24.1
8	4.2	2.9	4.4	1.1	2.9	12.9	4.0	3.4	5.8	9.3	9.1	23.2
9	4.3	2.8	3.9	1.2	2.6	9.8	4.8	3.0	5.8	10.2	8.4	19.5
10	4.1	2.1	3.5	1.3	2.0	7.7	4.0	2.3	4.0	9.3	6.3	15.1
All	4.4	2.8	4.4	1.3	2.9	12.2	4.0	3.2	5.8	9.6	8.8	22.5

These overall trends have been mostly driven by what happened to working-age males and females, who experienced the largest increases in mortality from the diseases of despair, with a doubling of the age-standardized death rates for both sexes between 1982 and 2019. While the rates were lower in this age group than for those at least 65 years old at the beginning of the study period, they were considerably higher in 2019 (by 25% to 50%, depending on the decile). While Americans in the bottom SIS deciles experienced higher rates and a faster increase than those in the top SIS deciles, the relationship is not linear: males and females in the deciles 6 (at ages 20–64) and 7 (at ages 65 and over) experienced the highest level of mortality and (for males) the fastest increase.

The impact of the differential increase in mortality from the diseases of despair on the growing divergence in the death rate across the SIS decile is significant only for working-age adults, particularly for adults aged 45–64. At these ages, diseases of despair contributed 15% of the increasing SIS gradient between 1982 and 2019 for males and 9% for females.

The trends varied depending on the type of condition and were similar across age groups. Between 1982 and 2000, mortality from suicide declined for females in all deciles and for males in all but the two lowest SIS deciles, but between 2000 and 2019, it rose for both males and females in all deciles. The increase in deaths per 100,000 was larger for males than for females. Alcohol-related deaths followed a similar trend, with a general decline before 2000 (except in the first and, for males only, fourth deciles, where rates remained fairly stable) and an increase thereafter. Increases in mortality from alcohol-related causes during this decade were on the order of 2–5 deaths per 100,000—lower rates than those from suicide for males (with rates increasing by 3–7 per 100,000 depending on the SIS decile) but larger for females. By contrast, mortality from drug overdoses increased continuously throughout the period, albeit considerably faster after 2000 than before: for males, the average annual increase in the mortality rate ranged from 4% to 9% between 1982 and 2000 and from 14% and 17% between 2000 and 2019; for females, the rate increase ranged from 2% to 6% in the first period and from 14% to 17% in the second.

Section 4: Conclusions

In 1982, there was a clear relationship between a community's degree of affluence and its residents' level of mortality. The ratio of the age-standardized death rate in the least affluent decile of counties to that in the most affluent was 1.16 for males and 1.09 for females. Over the next four decades or so, the mortality rate declined for all SIS categories, but it did so later and more slowly for Americans in the bottom deciles than for those in the top deciles. The result was an increasing divergence in the level of mortality over all 10 SIS deciles. By 2019, the ratio of the rates for the two extreme deciles (first and 10th) surpassed 1.5 for both males (at 1.56) and females (1.53). Mortality diverged for all age groups, but the divergence was particularly pronounced at ages 45–64. For this age group, the ratios increased from 1.39 and 1.21 for males and females, respectively, in 1982 to 2.38 and 2.40 in 2019. In general, the divergence was more marked for females than for males, especially at ages below 65 years.

The cause-of-death analysis presented in this report indicates that no specific disease or type of disorders can be singled out to explain the increasing divergence in mortality across SIS deciles. It appears as if all broad disease categories contributed to the growing gap in mortality by socioeconomic category, with lower contributions from external causes (except for children and young adults) and for ill-defined and unknown causes. The results of our study are summarized in Tables 6a and 6b and in Figure 20 for the six broad cause-of-death categories and for each sex, concentrating on the differences between the two extreme deciles (decile 1, the least affluent, and decile 10, the most affluent). The ranking of the causes in terms of their contribution to the increasing socioeconomic gradient in mortality between 1982 and 2019 is different for males and for females. For males, cancer contributed 35% of the increasing gap, "other diseases" for 29%, cardiovascular diseases for 27%, and infectious and respiratory diseases for 23%, while external causes (−2%) and ill-defined and unknown causes (−13%) contributed to narrowing the gap. For females, "other diseases" contributed most (29%), though cancer came close behind (28%), followed by infectious and respiratory diseases (24%), cardiovascular diseases (17%), and external causes (7%); again, ill-defined and unknown causes contributed positively (shrinking the gap by 6%).

Table 6a

Trends and Differentials in the Age-Standardized Death Rates for Deciles 1 and 10, Males, 1982 vs. 2019

	Age-Standardized Death Rates, 1982		Age-Standardized Death Rates, 2019		Difference (D1 – D10)		% Contribution to Difference		Change in Difference, 1982–2019	
Cause-of-Death Category	Decile 1	Decile 10	Decile 1	Decile 10	1982	2019	1982	2019	Absolute	%
Cardiovascular diseases	677	611	323	208	66	115	34	31	−49	27
Cancer	276	285	205	150	-8	55	−4	15	−64	35
Infectious/respiratory diseases	120	102	130	70	19	60	10	16	−41	23
Other diseases	158	134	241	164	24	77	12	21	−53	29
External causes	139	73	134	71	66	63	34	17	3	−2
Ill-defined/unknown causes	38	10	11	7	27	4	14	1	23	−13
All causes	1,408	1,215	1,043	670	193	374	100	100	−181	100

Table 6b

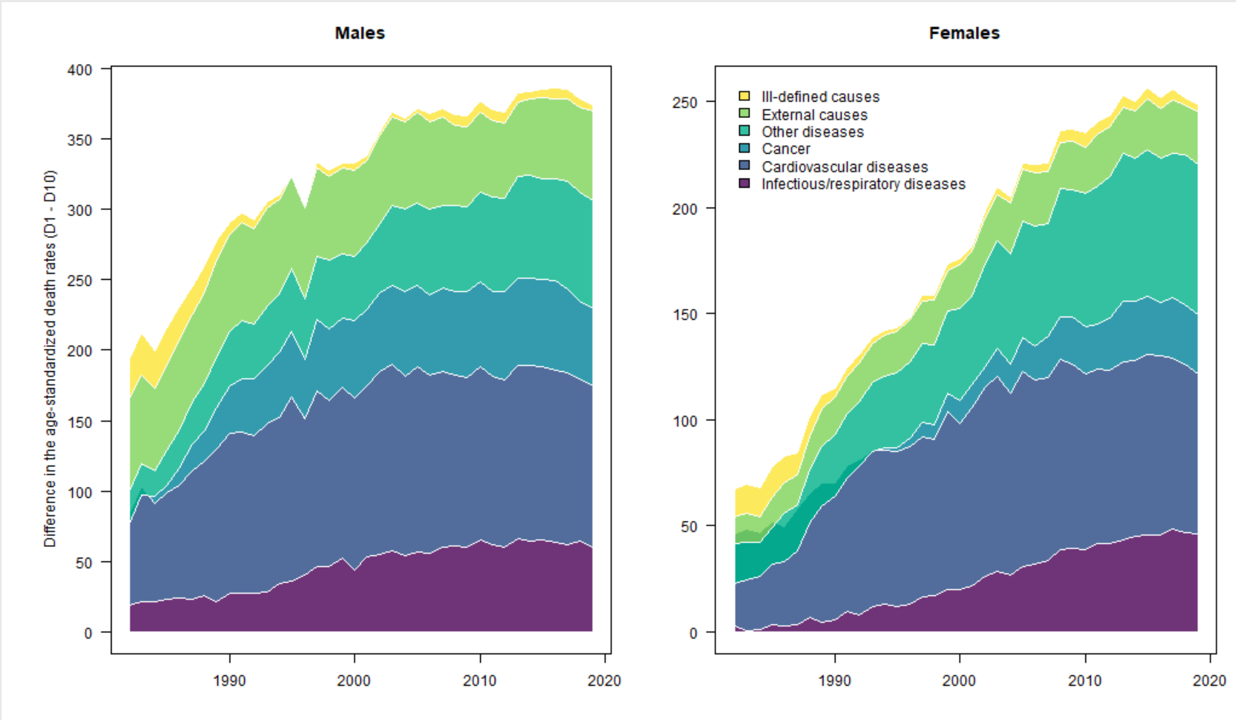
Trends and Differentials in the Age-Standardized Death Rates for Deciles 1 and 10, Females, 1982 vs. 2019

	Age-Standardized Death Rates, 1982		Age-Standardized Death Rates, 2019		Difference (D1 – D10)		% Contribution to Difference		Change in Difference, 1982–2019	
Cause-of-Death Category	Decile 1	Decile 10	Decile 1	Decile 10	1982	2019	1982	2019	Absolute	%
Cardiovascular diseases	430	386	210	135	44	75	65	30	−31	17
Cancer	160	183	141	113	−24	28	−35	11	−51	28
Infectious/respiratory diseases	52	49	98	52	3	46	4	19	−44	24
Other diseases	116	96	204	134	19	71	28	28	−52	29
External causes	42	30	53	29	12	25	18	10	−12	7
Ill-defined/unknown causes	20	6	8	5	13	3	20	1	10	−6
All causes	818	751	715	467	68	248	100	100	−181	100

Note: Age-standardized death rates (ASDR) in 1982 and 2019 are for 1st and 10th deciles per 100,000. Difference in ASDR between 1st and 10th deciles in 1982 and 2019 expressed in absolute terms (deaths per 100,000) and in relative terms (as % contribution to difference for all causes). Change in the difference between 1st and 10th deciles given in absolute and relative (%) terms.

Figure 20

Cause-of-Death Categories' Contributions to the Difference in the Age-Standardized Death Rate Between Deciles 1 and 10, by Sex, 1982–2019



Very few favorable trends were identified for the socioeconomic differential in mortality. The only broad cause-of-death category that systematically—across all age groups and for both sexes—contributed to closing the gap is that of the ill-defined and unknown causes as the comparatively large rates of 1982 for the lowest SIS deciles declined to reach the very low level of the highest deciles by 2019. The one exception to this general rule is a reduced gap in mortality from cancer for females below age 20, but cancer mortality at these ages is so small that the trend had little impact on the overall SIS gradient. Even when we examined mortality trends across SIS deciles for 57 finer cause-specific categories, the only positive trend identified is the general fall in the rate from cerebrovascular diseases and an associated decline—albeit very small—in the gap across SIS deciles. The other causes of death for which the mortality differences between the least and most affluent deciles became smaller also had a minimal impact. One was mental disorders, but this decline in the difference resulted from a very large increase in mortality across all deciles: a tripling of the rate for males and a quadrupling for females between 1982 and 2019. Likewise, for females only, a decline in the gap in mortality from non-transport accidents accompanied an undifferentiated increase in mortality throughout the period. We did measure a significant decline in homicides affecting females.

The fact that nearly all cause-of-death categories contributed to either maintaining the initial gap in mortality across the SIS deciles or increasing it suggests that multiple underlying factors are responsible for the large socioeconomic differentials in mortality identified at the area level. They have to do with compositional effects of the population, as the least affluent SIS deciles include, by definition, a higher proportion of individuals with low social and economic status. A large body of literature has demonstrated the link between these characteristics and detrimental behavior (smoking, drinking, unhealthy eating, and lack of physical activity) and higher risks for chronic diseases due to stress (in part due to structural racism, since the share of people of color is higher in the lower than in the higher SIS deciles) and to the biological vulnerability associated with early childhood infections. The factors responsible for the observed differentials are also likely related to the biological environment (higher pollution and higher risks of natural disasters in poorer areas) and to the human context (neighborhood factors such as the level of crime, availability and quality of health care, and access to fresh food), as well as to higher-level policy interventions. The mechanisms are likely to vary from place to place and from disease to disease.

The socioeconomic gradient in mortality is growing and has been shown to be much higher in the United States than in other high-income countries (Wilmoth et al. 2011; Banks et al. 2006; Banks et al. 2010; Baker et al. 2021). For the sake of equity, this gradient needs to be better understood. Failure to address the particularly high level of mortality experienced by the most disadvantaged segments of the U.S. population will perpetuate the country's international disadvantage in life expectancy and perhaps allow it to worsen.

Section 5: Acknowledgments

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Appendix A: Exhaustive Cause-of-Death Categories and Associated ICD-10 Codes

Note: These 57 cause-of-death categories are consistent with those used for the Human Mortality Database.

Number	Title	Category Codes According to ICD-10
1	Intestinal infectious diseases	A00–A09
2	Tuberculosis	A15–A19, B90
3	Septicemia	A40–A41
4	Other and unspecified infectious and parasitic diseases	A20–A39 A42–A99, B00–B09, B25–B89, B91–B99
5	HIV disease	B20–B24
6	Viral hepatitis	B15–B19
7	Malignant neoplasms of lip, oral cavity and pharynx	C00–C14
8	Malignant neoplasm of esophagus	C15
9	Malignant neoplasm of stomach	C16
10	Malignant neoplasm of colon, rectum and anus	C18–C21
11	Malignant neoplasm of pancreas	C25
12	Other malignant neoplasm of digestive system	C17, C22–C24, C26
13	Malignant neoplasm of larynx, trachea, bronchus and lung	C32–C34
14	Malignant neoplasm of skin	C43–C44
15	Malignant neoplasm of breast	C50
16	Malignant neoplasm of uterus	C53–C55
17	Malignant neoplasm of ovary	C56
18	Malignant neoplasm of prostate	C61
19	Malignant neoplasm of other genital organs	C51–C52, C57–C60, C62, C63
20	Malignant neoplasm of bladder	C67
21	Malignant neoplasms of kidney and other urinary organs	C64–C66, C68
22	Leukemia	C91–C95
23	Other cancer, including in situ neoplasms, benign neoplasms and neoplasms of uncertain or unknown behavior	C30–C31, C37–C41, C45–C49, C69–C90, C96–C97, D00–D48
24	Blood diseases	D50–D89
25	Diabetes mellitus	E10–E14
26	Other endocrinologic and metabolic diseases	E00–E07, E15–E90
27	Alcohol abuse	F10
28	Drug abuse	F11–F19
29	Other mental disorders	F00–F09, F20–F99, G30–G31
30	Other diseases of nervous system	G00–G26, G32–G44, G46–G99, H00–H95
31	Rheumatic heart diseases	I00–I09

32	Hypertensive disease	I10–I15
33	Other ischemic heart diseases	I20–I25
34	Other heart diseases	I26–I52
35	Cerebrovascular diseases	I60–I69, G45
36	Other circulatory diseases	I70–I99
37	Influenza	J09–J11
38	Pneumonia	J12–J18
39	Other acute respiratory infections	J00–J06, J20–J22, U04
40	Other chronic obstructive pulmonary disease	J40–J47
41	Other diseases of the respiratory system	J30–J39, J60–J99
42	Gastric and duodenal ulcer	K25–K28
43	Liver diseases	K70–K77
44	Other digestive diseases	K00–K23, K29–K67, K80–K93
45	Diseases of skin and subcutaneous tissue	L00–L99
46	Diseases of the musculoskeletal system and connective tissue	M00–M99
47	Diseases of genitourinary system	N00–N99
48	Complications of pregnancy, childbirth and puerperium	O00–O99
49	Certain conditions originating in the perinatal period	P00–P96
50	Congenital malformations and chromosomal abnormalities	Q00–Q99
51	Transport accidents	V01–V99
52	Other accidents	W00–W99, X00–X59, Y40–Y98
53	Suicide and self-inflicted injury	X60–X84
54	Assault	X85–Y09, Y35, Y36
55	Event of undetermined intent	Y10–Y34
56	Senility	R54
57	Other ill-defined and unspecified causes of death	R00–R53, R55–R99

Appendix B: Using the NCHS 1996 Bridge-Coding Study to Create Consistent Cause-of-Death Data Series for the United States

As mentioned in the main text, a redistribution of deaths coded to the 9th revision of the ICD into ICD-10 categories is necessary to avoid disruptions in the mortality estimate series resulting from the change from one classification to the other. This redistribution was carried out by applying transition coefficients from the 1996 bridge coding study. The 1996 bridge coding study was conducted by the NCHS to understand the impact of the transition from the 9th to the 10th revision of the International Classification of Disease (ICD-9 and ICD-10) in the United States (Anderson et al. 2001). In the NCHS bridge coding study, all deaths occurring in 1996 were coded to both ICDs, and the data are publicly available at the individual level. We used the NCHS data to compute sex-specific redistribution coefficients by age and applied these coefficients to the ICD-9 deaths (i.e., deaths from 1982 to 1998) for the 57 cause-of-death categories in the study.

As an illustration of the results, Figures B.1 and B.2 show how this procedure eliminates the previous distortions in the data for two broad cause-of-death categories—namely, cerebrovascular diseases and neoplasms. In each figure, the height of the red markers on the plots indicates the size of the confidence interval based on the variability in the death counts for both ICD periods (mean plus or minus the root mean square error) centered halfway between the ends of the robust smooths.

Figure B.1

Age-Standardized Death Rates from Cerebrovascular Diseases, Unadjusted and Adjusted for ICD Change, 1982–2019

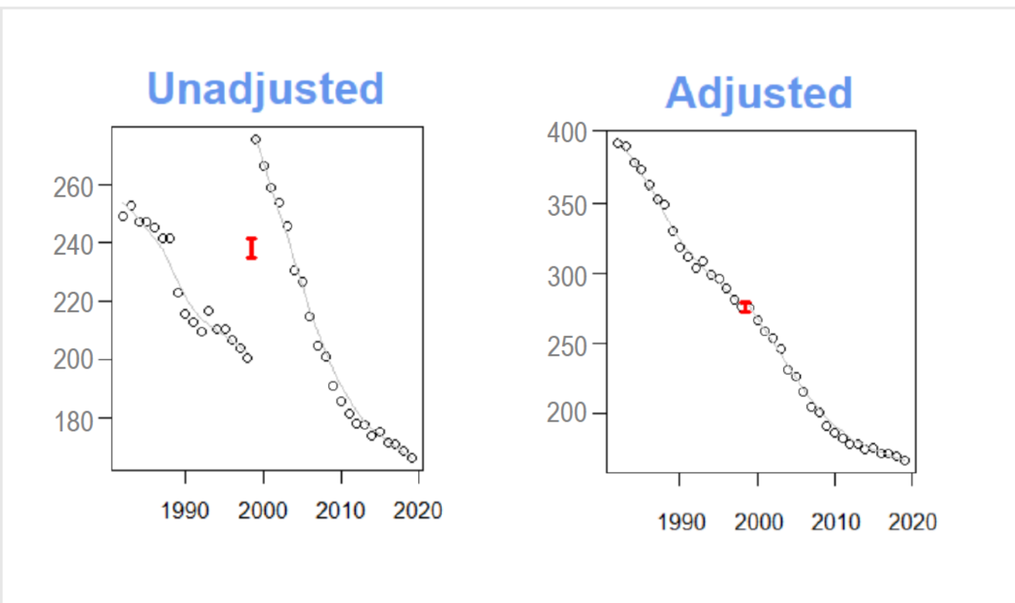
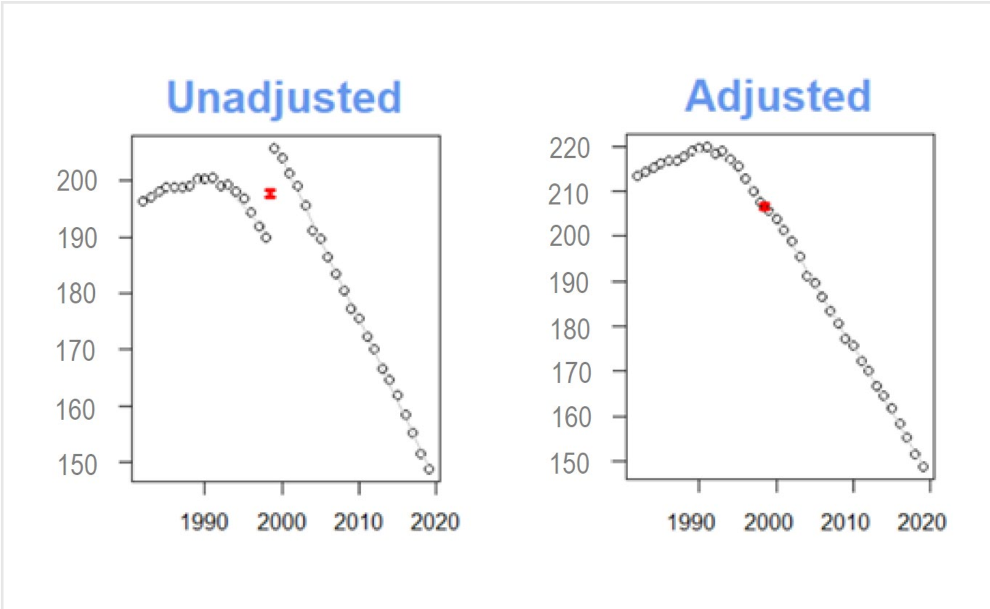


Figure B.2

Age-Standardized Death Rates from Neoplasms, Unadjusted and Adjusted for ICD Change, 1982–2019



References

Adler, N. E., and K. Newman. 2002. Socioeconomic Disparities in Health: Pathways and Policies. *Health Affairs* 21(2): 60–76.

Alexander, M. J., M. V. Kiang and M. Barbieri. 2018. Trends in Black and White Opioid Mortality in the United States, 1979–2015. *Epidemiology (Cambridge, Mass.)* 29(5): 707.

Anderson, L. M., and D. S. May. 1995. Has the Use of Cervical, Breast, and Colorectal Cancer Screening Increased in the United States? *American Journal of Public Health* 85(6): 840–842.

Anderson, R. N., A. M. Miniño, D. L. Hoyert and H. M. Rosenberg. 2001. Comparability of Cause of Death Between ICD-9 and ICD-10: Preliminary Estimates. *National Vital Statistics Reports* 49(2): 1–32.

Baker, M., J. Currie, B. Miloucheva, H. Schwandt and J. Thuilliez. 2021. Inequality in Mortality: Updated Estimates for the United States, Canada and France. *Fiscal Studies* 42(1): 25–46.

Banks, J., M. Marmot, Z. Oldfield and J. P. Smith. 2006. Disease and Disadvantage in the United States and in England. *JAMA* 295(17): 2037–2045.

Banks, J., A. Muriel and J. P. Smith. 2010. Disease Prevalence, Disease Incidence, and Mortality in the United States and in England. *Demography* 47(1): S211–S231.

Barbieri, M. 2020. *Mortality by Socioeconomic Category in the United States.* Society of Actuaries Research Institute, *https://www.soa.org/resources/research-reports/2020/us-mort-rate-socioeconomic/.*

Brignone, E., D. R. George, L. Sinoway, C. Katz, C. Sauder, A. Murray et al. 2020. Trends in the Diagnosis of Diseases of Despair in the United States, 2009–2018: A Retrospective Cohort Study. *BMJ Open* 10(10): e037679.

Case, A., and A. Deaton. 2015. Rising Morbidity and Mortality in Midlife Among White Non-Hispanic Americans in the 21st Century. *Proceedings of the National Academy of Sciences* 112(49): 15,078–15,083.

———. 2017. Mortality and Morbidity in the 21st Century. *Brookings Papers on Economic Activity* (Spring): 397–476.

———. 2020. *Deaths of Despair and the Future of Capitalism*. Princeton, NJ: Princeton University Press.

Gomes, T., M. Tadrous, M. M. Mamdani, J. M. Paterson and D. N. Juurlink. 2018. The Burden of Opioid-Related Mortality in the United States. *JAMA Network Open* 1(2): e180,217.

Jdanov, D. A., V. M. Shkolnikov, A. A. van Raalte and E. M. Andreev. 2017. Decomposing Current Mortality Differences into Initial Differences and Differences in Trends: The Contour Decomposition Method. *Demography* 54(4): 1579–1602.

Ogden, C. L., M. M. Lamb, M. D. Carroll and K. M. Flegal. 2010. Obesity and Socioeconomic Status in Adults: United States, 2005–2008. *NCHS Data Brief* 50 (Dec.): 1–8.

Penman-Aguilar, A., K. Bouye, L. C. Liburd, D. Satterfield, L. DeBruyn, M. Santos et al. 2016. *Strategies for Reducing Health Disparities—Selected CDC-Sponsored Interventions, United States, 2016.* Supplement 1 of *Morbidity and Mortality Weekly Report* 65.

Polednak, A. P. 1993. Geographic Variation in the Treatment of Prostate Cancer in Connecticut. *International Journal of Technology Assessment in Health Care* 9(2): 304–310.

Singh, G. K. 2003. Area Deprivation and Widening Inequalities in US Mortality, 1969–1998. *American Journal of Public Health* 93(7): 1137–1143.

Singh, G. K., and M. Siahpush. 2006. Widening Socioeconomic Inequalities in US Life Expectancy, 1980–2000. *International Journal of Epidemiology* 35(4): 969–979.

Wilmoth, J. R., C. Boe, M. Barbieri. 2011. Geographic Differences in Life Expectancy at Age 50 in the United States Compared with Other High-Income Countries. Pages 333–366 in *International Differences in Mortality at Older Ages: Dimensions and Sources*, edited by E. M. Crimmins, S. H. Preston and B Cohen. Washington, DC: National Academies Press.

Wilmoth, J. R., et al. 2021. Methods Protocol for the Human Mortality Database. Revised Jan. 26, 2021, for version 6. Human Mortality Database, *https://www.mortality.org/Public/Docs/MethodsProtocol.pdf*.

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