Inequality in mortality between Black and White Americans by age, place, and cause and in comparison to Europe, 1990 to 2018

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Although there is a large gap between Black and White American life expectancies, the gap fell 48.9% between 1990 and 2018, mainly due to mortality declines among Black Americans. We examine age-specific mortality trends and racial gaps in life expectancy in high- and low-income US areas and with reference to six European countries. Inequalities in life expectancy are starker in the United States than in Europe. In 1990, White Americans and Europeans in high-income areas had similar overall life expectancy, while life expectancy for White Americans in low-income areas was lower. However, since then, even high-income White Americans have lost ground relative to Europeans. Meanwhile, the gap in life expectancy between Black Americans and Europeans decreased by 8.3%. Black American life expectancy increased more than White American life expectancy in all US areas, but improvements in lower-income areas had the greatest impact on the racial life expectancy gap. The causes that contributed the most to Black Americans' mortality reductions included cancer, homicide, HIV, and causes originating in the fetal or infant period. Life expectancy for both Black and White Americans plateaued or slightly declined after 2012, but this stalling was most evident among Black Americans even prior to the COVID-19 pandemic. If improvements had continued at the 1990 to 2012 rate, the racial gap in life expectancy would have closed by 2036. European life expectancy also stalled after 2014. Still, the comparison with Europe suggests that mortality rates of both Black and White Americans could fall much further across all ages and in both high-income and low-income areas.

life expectancy | racial divide | area-level socioeconomic status | international comparison | age-specific mortality

Recent events, notably the Black Lives Matter movement and the disproportionate impact of the COVID-19 pandemic on the Black population, have highlighted the persistent gap in life expectancy between Black Americans and other Americans (1, 2). In 2018, the gap in life expectancy between Black and White Americans was 3.6 y. However, there have also been tremendous improvements in life expectancy among Black Americans relative to White Americans over time and especially since 1990 (3–7). Much of the highly publicized recent research investigating changes in inequality in life expectancy and mortality in the United States over the past 30 y highlights inequalities in adult mortality across educational and income groups (8–23).

This paper discusses the evolution of inequalities in mortality between Black and White Americans from 1990 to 2018 through the lens of place. There are two innovations: First, following several recent studies (1, 6, 24–31), we examine the evolution of mortality rates among Black and White Americans by age and county poverty rates. This analysis allows us to see whether racial gaps have evolved differently in higher- and lower-income parts of the United States. Trends in age-specific mortality rates provide insights into whether changes in life expectancy are specific to certain age groups, for example, people over 65 who qualify for Medicare, which in turn may provide additional insight into possible mechanisms.

Second, we benchmark these developments against trends in mortality inequality across high- and low-income places in a set

Significance

From 1990 to 2018, the Black–White American life expectancy gap fell 48.9% and mortality inequality decreased, although progress stalled after 2012 as life expectancy plateaued. Had improvements continued at the 1990 to 2012 rate, the racial gap in life expectancy would have closed by 2036. Despite decreasing mortality inequality, income-based life expectancy gaps remain starker in the United States than in European countries. At the same time, European mortality improved strongly and even those U.S. populations with the longest life spans–White Americans living in the highest-income areas–experience higher mortality at all ages than Europeans in high-income areas in 2018. Hence, mortality rates of both Black and White Americans could fall much further in both high-income and low-income areas.

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The authors declare no competing interest.

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of six prosperous European countries. This comparison offers several potential insights, such as whether mortality in higher-income parts of the United States is more similar to that of European countries or whether both high- and low-income US places tend to lag behind. It also provides additional perspective on the gaps between Black and White Americans, allowing us to ask, for example, if only Black Americans fall short of a European benchmark or if the mechanisms driving lower life expectancy in the United States also affect White Americans.

Our analysis proceeds by first ranking counties by their poverty rate in each year and then grouping counties into clusters that each account for about 5% of the population (*Materials and Methods*). A key advantage of this approach is that we can examine all deaths, whereas information on income and completed education is not available for every person. We also avoid problems due to changes in the education distribution over time. For example, high school dropouts in the United States have become an increasingly small and more negatively selected group as high school completion and college attendance have become more normative (32–35). A limitation of our approach is that we cannot examine inequalities within small areas. Set against this limitation is evidence that low-income Americans live longer in high-income areas than in low-income ones (12), so that mortality across geographic areas is of independent interest. Our approach allows us to see whether changes in mortality occur in both high- and low-income areas or are driven largely by improvements in lower-income areas.

A second advantage of this geographical approach is that it can be easily adapted to examine mortality inequality in other countries using a similar framework. We examine trends in mortality inequality in six wealthy European countries using methods identical to the US analysis. Mortality inequality in these countries is of interest in its own right but also serves as a useful baseline for considering developments in the United States, contributing to a growing body of comparative literature on mortality differentials (6–39). Our main analysis focuses on six countries (England, France, Germany, the Netherlands, Norway, and Spain) for which consistent mortality data by geographic areas exist for the entire time period. All six are prosperous countries with well-developed health care and social welfare systems. The experience of these countries provides some insight into questions such as how low US mortality rates could fall given current medical standards; whether increasing gaps in life expectancy between the United States and Europe are driven only by lower-income areas or whether higher-income areas are also falling behind; and finally, whether mortality among Black Americans declined only relative to White Americans or whether it also declined relative to a European life expectancy benchmark.

Results

Our main results for age-specific mortality rates are shown in Figs. 1–4, representing the age groups 0 to 4, 5 to 19, 20 to 64, and 65 to 79. Each figure has three panels showing estimates for the years 1990, 2005, and 2018 and contains three heavy lines representing mortality rates for Black Americans, White Americans, and Europeans as defined in our study. Each marker on these figures represents a county group representing about 5% of a country's population. The lines drawn through the markers are simply least squares linear regression lines through the points. The data for each marker and the slopes of the regression lines are shown in *SI Appendix*, Tables S1–S4, along with P values for whether the slopes of the regression lines are equal to 0, whether the slopes for lines representing Black and White persons are equal, and whether the slopes of the White American and European lines are equal. The figures also show fainter gray lines corresponding to mortality rates in the individual European countries. Further details are provided in *Materials and Methods* and in *SI Appendix*.

The biggest takeaway from Fig. 1 is the huge gap in mortality between Black and White children aged 0 to 4 in 1990 and the equally stunning narrowing of the gap between Black and White child deaths over the subsequent decades. In 1990, 4.2 out of every 1,000 Black children aged 0 to 4 died compared to 1.82 per 1,000 White children. In 2018, the rates had fallen to 2.31 per 1,000 for young Black children and 1.13 per 1,000 for White children. Viewed as a percentage, the progress is less impressive—in 1990, 2.3 Black children died for every White child, while in 2018, 2.04 Black children died for every White child. However, the increase in the total number of lives saved was much greater for young Black children, resulting in much closer absolute mortality rates in 2018. Much of the improvement in Black child mortality rates happened between 1990 and 2005, with only slow progress from 2005 to 2018. Mortality rates for White children aged 0 to 4 also fell throughout the period, although at a slower rate.

Mortality improvements among young Black children occurred across the entire economic spectrum of US locations, although reductions were somewhat stronger in the highest-income areas, which led to an increase in mortality inequality for Black American children. Mortality inequality among White children decreased slightly. Hence, the strong reduction in overall inequality in mortality for young children aged 0 to 4 in high- and low-income areas that has been previously reported (6, 25–27) is due to the higher concentration of Black children in low-income areas combined with the large reduction in mortality rates among young Black children. Overall, despite strong improvements, mortality among young Black children remained substantially higher and more unequally distributed between high- and low-income places compared to White children.

Inequality in mortality among young children aged 0 to 4 in Europe was lower than in the United States in all years, and the European gradient between mortality rates and area poverty was almost entirely flat in 2018 (see *SI Appendix*, Table S1 for numerical values of the gradients). Fig. 1 shows that in 1990, the average US White mortality rate for the 0 to 4 age group was similar to the European rate, although deaths were more unequally distributed in the United States. Specifically, US death rates among White children aged 0 to 4 were lower than European rates in the highest-income areas and higher in the lowest-income areas in 1990. By 2005, mortality for White children aged 0 to 4 had pulled away from European levels and was uniformly higher than in Europe in both high- and low-income areas. This trend continued to 2018.

Fig. 2 tells a broadly similar story for children aged 5 to 19. The biggest difference is that even in 1990, White mortality rates for children aged 5 to 19 were higher than European rates in all but the highest-income US places. By 2005, the gap between European children and White American children had become wider than the gap between Black and White American children, which suggests that all American children in this age group suffered high levels of mortality relative to the lower potential mortality rates implied by the European baseline.

Fig. 3 shows trends in mortality for adults aged 20 to 64. (See *SI Appendix* for a further split into ages 20 to 49 and 50 to 64.) Focusing first on the US story, the three panels show that Black and White prime-age adult mortality (aged 20 to 64) converged sharply over time driven primarily by a rapid fall in Black mortality, especially in the lowest-income areas. In the highest-income areas of the United States, the gap in Black–White American death rates had fallen to 0.7 deaths per 1,000 by 2018, while in lower-income places it was still 1.47 (*SI Appendix*, Table S3). The comparison with Europe is striking. In 1990 and in 2005, White Americans in the highest-income area had mortality rates very similar to Europeans, while Black Americans suffered much higher mortality even in high-income areas. By 2018, European mortality rates were uniformly lower: the gap between Europeans and White Americans was generally larger than the gap between White and Black Americans. In large part this pattern is due to stagnation in US White mortality rates. The lower European mortality rates

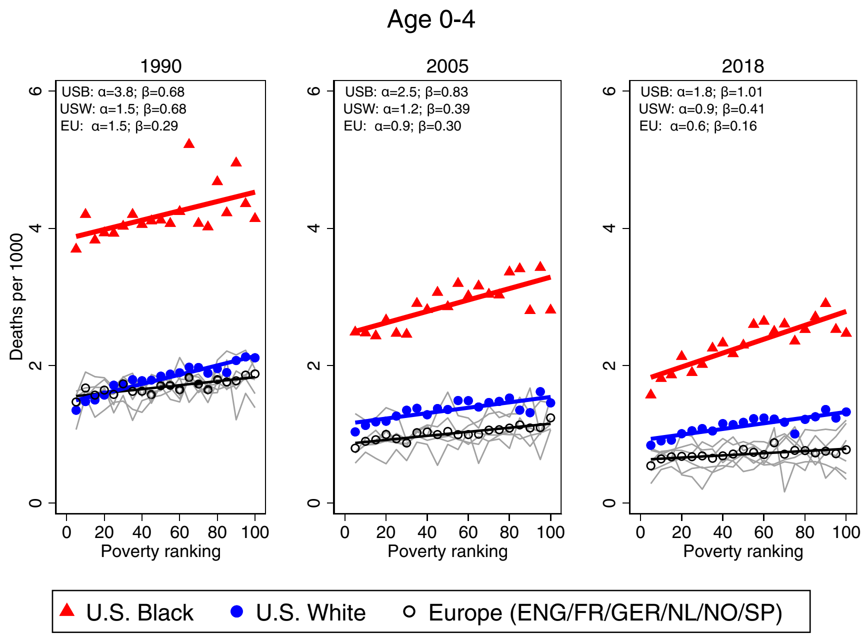

Fig. 1. One-year mortality for Black Americans, White Americans, and six European countries, ages 0 to 4, for (*Left*) 1990, (*Middle*) 2005, and (*Right*) 2018. Average 1-y mortality rates are plotted across poverty rate percentiles. For US Black (USB) and US White (USW) mortality, each bin represents a group of counties with about 5% of the overall population in the respective year. Black circles show population-weighted average mortality rates across England (ENG), France (FR), Germany (GER), the Netherlands (NL), Norway (NO), and Spain (SP), and each circle represents a group of municipalities or districts representing 5% of the overall population of each country in the respective year. Gray lines show mortality for each European country (see *SI Appendix*, Figs. S5–S9 for colorized figures with an extended set of European countries). Germany and Spain are included with 2016 data in *Right*. Straight lines provide linear fits. α and β refer to the fitted lines' intercepts and slopes, respectively. Additional numerical values are reported in *SI Appendix*, Table S1.

show the trajectory that might have been possible in a high-income country like the United States.

Fig. 4 shows trends for older adults (aged 65 to 79). This figure shows that mortality declined for both Black and White older adults in high- and low-income areas of the United States. Nevertheless, in the lowest-income areas, White American older adults went from having essentially the same mortality rates as Europeans in 1990 to having significantly higher rates in 2018: 27 per 1,000 in the United States compared to 20 per 1,000 in Europe. The mortality rate for Black American older adults aged 65 to 79 in low-income areas was even higher in 2018, at 32 per 1,000. We do not show mortality trends for adults older than age 80. For this group, we are lacking

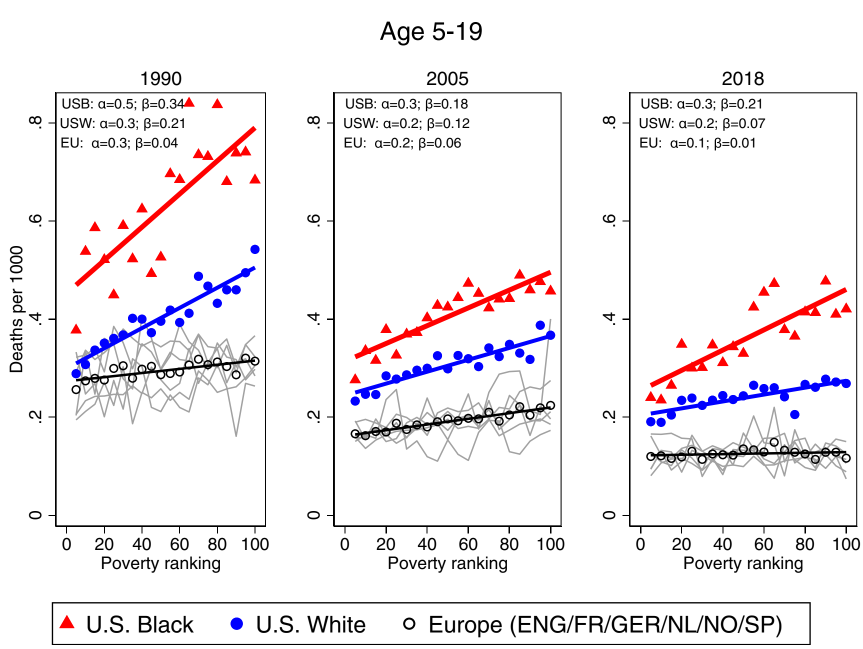

Fig. 2. One-year mortality for Black Americans, White Americans, and six European countries, ages 5 to 19, for (*Left*) 1990, (*Middle*) 2005, and (*Right*) 2018. Straight lines provide linear fits. α and β refer to the fitted lines' intercepts and slopes, respectively. For further notes, see Fig. 1. Numerical values and the slopes of fitted lines are reported in *SI Appendix*, Table S2.

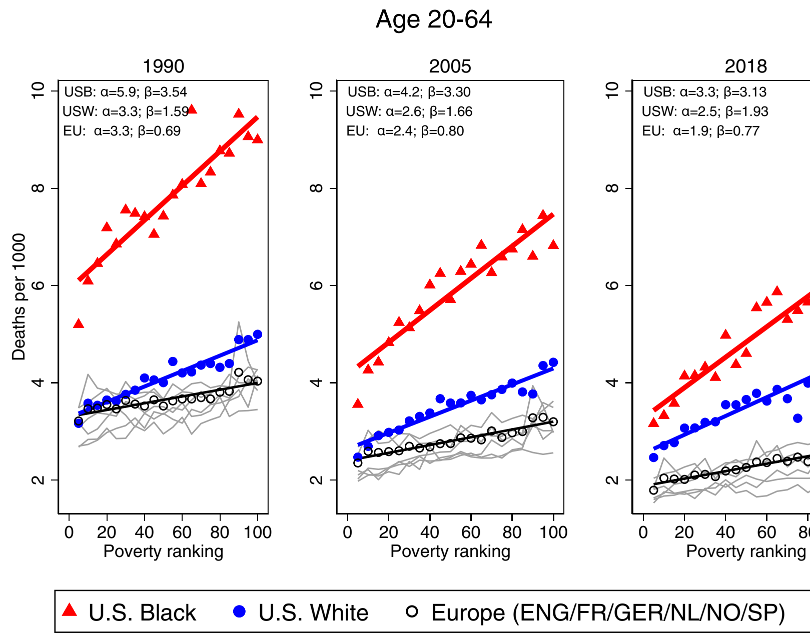

Fig. 3. One-year mortality for Black Americans, White Americans, and six European countries, ages 20 to 64, for (*Left*) 1990, (*Middle*) 2005, and (*Right*) 2018. Straight lines provide linear fits. α and β refer to the fitted lines' intercepts and slopes, respectively. For further notes, see Fig. 1. Numerical values and the slopes of fitted lines are reported in *SI Appendix*, Table S3.

the detailed data on death rates by single year of age to age-adjust the death rates, which is crucial to compare mortality across countries and over time.

Fig. 5 summarizes the trends in age-specific mortality by showing life expectancy at birth for Black and White persons for each year from 1990 to 2018. We have also drawn a trend line using data from 1990 through 2012. This figure highlights the strong convergence between Black and White American mortality rates between 1990 and 2012. Over this period, White American life expectancy continued to improve, but Black American life expectancy improved faster.

Fig. 5 shows that if mortality had continued to evolve at the same rate after 2012 as it did from 1990 to 2012, the gap in life expectancy between Black and White persons would have closed by 2036. However, improvements in life expectancy among both Black and White Americans faltered after about 2014. Both US White and Black American life expectancy plateaued and then fell between 2015 and 2018. Moreover, the decline in life expectancy

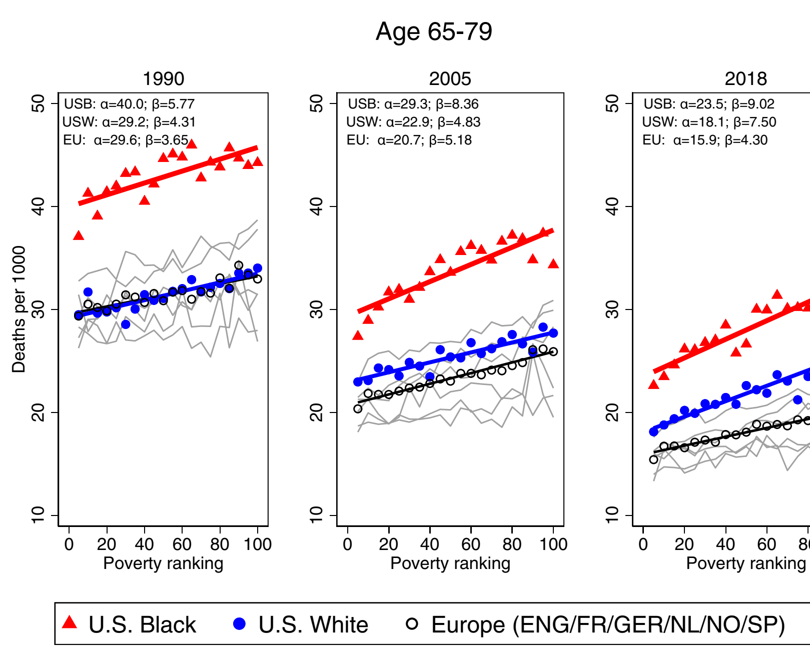

Fig. 4. One-year mortality for Black Americans, White Americans, and six European countries, ages 65 to 79, for (*Left*) 1990, (*Middle*) 2005, and (*Right*) 2018. Straight lines provide linear fits. α and β refer to the fitted lines' intercepts and slopes, respectively. For further notes, see Fig. 1. Numerical values and the slopes of fitted lines are reported in *SI Appendix*, Table S4.

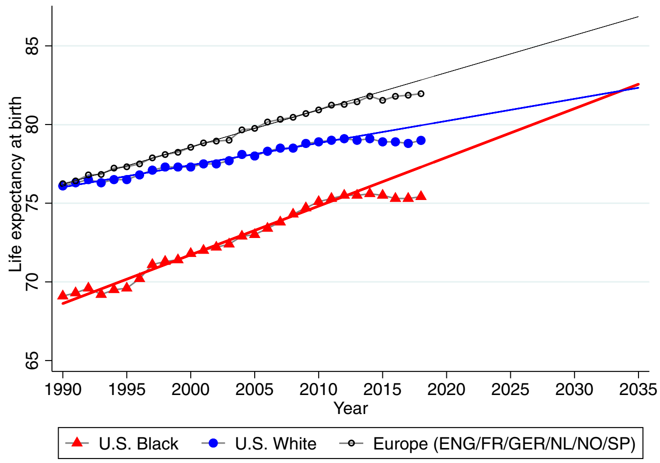

Fig. 5. Life expectancy for Black Americans, White Americans, and six European countries, extrapolated to 2035 fitting a linear trend through 1990 to 2012. Black American, White American, and European life expectancies are plotted over time and extrapolated to 2035 using a linear trend through 1990 to 2012. Black circles show the population weighted average life expectancy across England, France, Germany, the Netherlands, Norway, and Spain.

among Black Americans since 2015 appears to be even more severe than the decline among White Americans. Hence, although some observers have focused on the implications of the COVID-19 pandemic for Black/White American differences (40), even pre-pandemic, progress in improving the longevity of Black Americans and eliminating racial gaps in life expectancy had started to reverse.

A comparison with European mortality offers a useful perspective. In 1990, life expectancy among White Americans was the same as in the European benchmark countries. However, over the next 3 decades, White Americans increasingly fell behind Europeans. At the same time, life expectancy for Black Americans started far below both European and White American rates in 1990 but grew at a faster rate than European life expectancy.

Although European life expectancy remained above US life expectancy in 2018, European life expectancy also declined relative to the 1990 to 2012 trend after 2014, suggesting that there may be some element common to the United States and Europe that has moderated the growth of life expectancies in most high-income countries. It has been shown that the flattening of life expectancy in the United States was driven primarily by the plateauing of mortality improvements due to cardiovascular disease (41), and this may also be true in Europe.

Fig. 6 offers a closer look at the evolution of racial gaps in mortality by geographic area. As before, counties are sorted into population ventiles by overall poverty rate, but we focus on period life expectancy to summarize mortality rates across all ages. Each ventile represents approximately the same overall population, but race-specific populations are not balanced—in particular, Black people are overrepresented in the lower-income areas and underrepresented in the higher-income areas. This figure traces out the implications of that imbalance for the evolution of life expectancy. Fig. 6*A* shows the change in race-specific life expectancy between 1990 and 2018, calculated within each ventile. This panel confirms the evidence from Figs. 1–4 that between 1990 and 2018, Black American mortality declined faster than White mortality in all areas. The gap is larger in some ventiles than others but is sizeable in all but the highest-income 5% of counties. Fig. 6*B* confirms that Black people are overrepresented in lower-income counties and underrepresented in higher-income ones. Fig. 6*C* shows the contribution of each ventile group to overall life expectancy between 1990 and 2018 for Black and White Americans separately. In other words, Fig. 6*C* illustrates the impact on life expectancy if only mortality in a given ventile were allowed to change. Fig. 6*C* shows that improvements in the lowest-income counties made a disproportionate contribution to Black persons life expectancy gains.

Fig. 6*D* shows the contribution of each ventile to the reduction of the racial mortality gap. Life expectancy in the highest-income counties increased the racial life expectancy gap, not because Black Americans living in these places experienced smaller life expectancy gains than White Americans but because White Americans were overrepresented in high-income areas. In other words, mortality

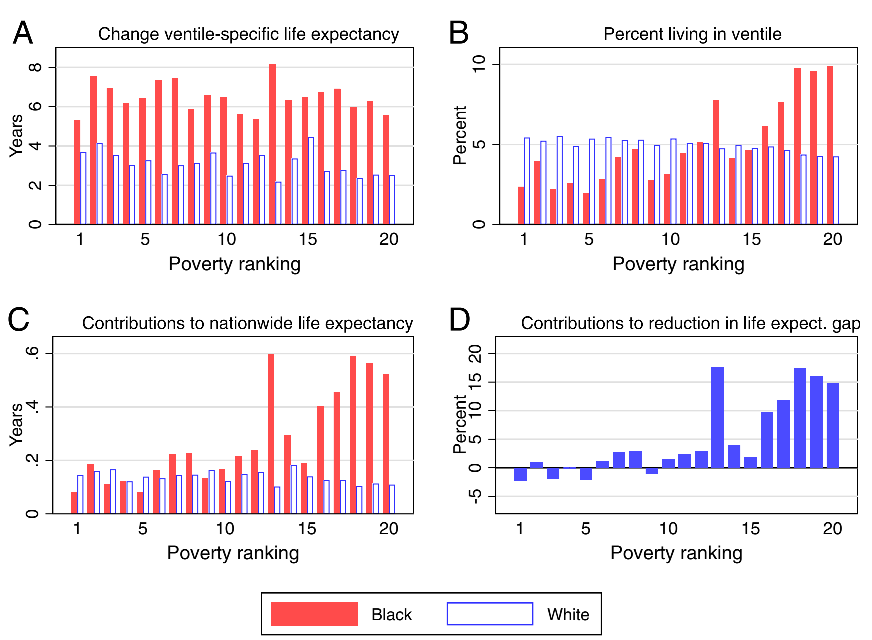

Fig. 6. Population distribution in 1990 and life expectancy contribution for 1990 to 2018, by ventile and race. (*A*) The change in race-specific life expectancy calculated within each ventile between 1990 and 2018. (*B*) The percent of the overall US Black and White population living in each ventile in 1990. (*C*) The contribution of the mortality changes in each ventile to the countrywide race-specific life expectancy. (*D*) The percent contribution of the mortality changes in each ventile to the reduction in the life expectancy gap between Black and White Americans.

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improvements among Black Americans living in the highest-income counties had relatively little impact on overall life expectancy of Black people because fewer Black people enjoyed them, while the opposite was the case for White Americans. The result is an increase in the racial life expectancy gap. Similarly, the lowest-income areas contributed the most to life expectancy gains among Black people and to the closing of the racial life expectancy gap because Black Americans are overrepresented in these areas. These results suggest that given continuing overrepresentation of Black Americans in low-income places, improving life expectancy in these places is key to further reductions in racial life expectancy gaps.

SI Appendix, Fig. S1 offers a breakdown of the causes of death that were most responsible for the reduction in the Black–White American mortality gap. These results are subject to the usual caveats about the limitations of cause of death data, particularly when making comparisons over time (42). *SI Appendix*, Fig. S1*A* breaks out some of the most important contributors to changes in life expectancy separately for Black and White Americans. One can immediately see that cardiovascular disease and cancer are the most important individual contributors for both groups.

SI Appendix, Fig. S1*B* shows the percent contribution of each cause to the reduction of the racial difference in life expectancy. *SI Appendix*, Table S5 shows the corresponding numerical values. *SI Appendix*, Fig. S1*B* shows that cardiovascular mortality had the smallest impact on the gap across all causes because reductions in deaths from cardiovascular disease benefitted White and Black persons fairly similarly over this time period. The causes that contributed most to reductions in the gap were, in order of importance, so called "deaths of despair" (43) (16.18%; this category includes suicide, overdoses, and cirrhosis), cancer (15.96%), homicide (12.51%), deaths from causes originating in the fetal or infant period (11.05%), and HIV (9.89%). The importance of overdose deaths (44), homicide, and HIV in explaining racial differences in life expectancy has been previously noted (3–5, 45–48). However, it is notable in light of previous work that over the period we analyze, changes in mortality due to cardiovascular disease explain relatively little of the changing gap. This finding indicates that the role of cardiovascular mortality in closing the inequality gap has declined in the 2010s. Faster reductions in cancer deaths among Black Americans also seem to have had a larger impact than they did before 2010 (3–5).

Since the opioid epidemic is one of the most important causes of recent declines in US life expectancy relative to other countries (44), *SI Appendix*, Fig. S2*A* compares actual life expectancy with a counterfactual life expectancy computed by assuming that the rate of deaths due to drug overdoses had remained at its 1990 value. *SI Appendix*, Fig. S2*B* is similar but assumes that the broader category of deaths of despair, that is, deaths from drug overdose, suicides, and chronic liver disease, had not changed since 1990. *SI Appendix*, Fig. S2 shows that without drug overdoses, there would still have been a slight downturn in life expectancy around 2015 and 2016 but that life expectancy may well have continued upward after that, albeit with the flattening trend noted above. Comparing *SI Appendix*, Fig. S2 *A* and *B* shows that suicides and chronic liver disease are also important for White Americans, but for Black Americans, only overdoses have had a large impact in terms of life expectancy, and then only since about 2014.

SI Appendix, Fig. S3 and Table S7 provide a similar breakdown of which age groups contributed the most to the decline in the life expectancy gap between Black and White Americans. Consistent with the analysis by cause, the age groups that contributed the most are 0- to 4-y-olds and 20- to 64-y-olds, although this pattern varies somewhat over time (*SI Appendix*, Table S6). For example, 0- to 4-y-olds contributed 19.6% of the reduction between 1990 and 2000 and 9.83% between 2000 and 2018. The decomposition shows that the single years of age that contributed most to the closing of the gap were in infancy and among prime-age adults (aged 20 to 64). For Black Americans, contributions to improvements in life expectancy rose from age 20 to about age 65 and then declined. As has been noted in the literature (9–11, 49), this is strikingly not the case for White Americans, who experienced small declines in life expectancy from about ages 25 to 40, followed by only small gains to age 60.

Following Macinko and Elo (50), we also provide a breakdown of differences between Black and White Americans in preventable causes of death below age 65 in *SI Appendix*, Fig. S4 and Table S8 (all deaths are classified as in ref. 50, reported in *SI Appendix*, Table S9). *SI Appendix*, Fig. S4 indicates that Black Americans made major gains to life expectancy in terms of reductions in deaths from causes amenable to medical care and, to a lesser extent, from deaths amenable to intervention. These results indicate a continuation of the trends reported up to 2005 by Macinko and Elo (50), with the exception of ischemic heart disease, which decreased in relevance.

Discussion

We focus on the evolution of mortality in the 3 decades leading up to the COVID-19 pandemic in order to take stock of the improvements and remaining inequalities that were present in the United States before the pandemic struck. We view racial disparities through the lens of place, comparing gaps in the highest-income parts of the country to those in the lowest-income areas, and we use European mortality rates as a benchmark for assessing mortality differences and trends in those differences.

In 1990, there were remarkable mortality differences between Black and White Americans. For most age groups, Black Americans living in the highest-income US areas had substantially higher mortality rates than White Americans in the country's lowest-income areas. The mortality disadvantage of Black Americans in 1990 was even more pronounced when compared to European countries, while mortality rates of White Americans were fairly similar to those in Europe.

Since 1990, Black Americans experienced large mortality improvements across all age ranges and in both higher- and lower-income areas, although because Black Americans are more likely to live in lower-income counties, gains in these counties played an outsized role in reducing the racial life expectancy gap. These reductions in mortality were strong enough to reduce the racial mortality gap by 48.9%, despite the fact that White Americans also experienced mortality improvements. Between 1990 and 2018, the US Black–White American life expectancy gap decreased from 7.0 to 3.6 y, while the gap between the six European countries and Black Americans decreased from 7.1 to 6.5 y.

Mortality improvements among Black Americans and the closing of the racial mortality gap stalled after 2012. Moreover, despite mortality improvements since 1990, White Americans have increasingly lost ground compared to Europeans, with substantial gaps in mortality rates opening between Europeans and White Americans. The gap between Black Americans and the six European countries included decreased by 19% between 1990 and 2012 but only by 8.3% in the overall period from 1990 and 2018. Hence, the convergence in the US Black–White American mortality gap reflects real progress among Black Americans even relative to a non-US benchmark, but this progress has reversed after 2012.

The diverging mortality experience between the United States and Europe is especially evident when analyzing a larger set of nine European countries, although some of these countries are missing data for 1990 (*SI Appendix*, Figs. S5–S9). Despite strong differences in social and economic starting points across these European countries, by 2018 their mortality gradients fall into a narrow band. Even countries like Portugal, which was much lower income than the European average in 1990, or the Czech Republic, which experienced the fall of the Soviet Union, were able to catch up to higher-income and more stable European countries in terms of mortality rates by 2018. European mortality rates in 2018 lie below US White American mortality rates for each country and across high- and low-income areas. This US health disadvantage even among economically advantaged groups in high-income US locations has also been shown for a broad set of health conditions (51, 52).

Another remarkable observation is how flat mortality gradients are at younger ages across all European countries. This pattern shows that health improvements among infants, children, and youth have been disseminated within European countries in a way that includes even the lowest-income areas. It suggests that there is great potential for disadvantaged infants, children, and youth living in lower-income US areas to catch up to European standards.

Focusing on the disparity between Black and White Americans, we show that improvements in Black Americans' relative to White Americans' life expectancy in the lowest-income counties had the greatest impact in narrowing the gap overall. In terms of mortality causes driving these improvements, greater reductions in Black relative to White American death rates due to cancer, homicide, HIV, and causes originating in the fetal or infant period had the largest impacts, while smaller increases in Black American compared to White American deaths of despair also closed the gap. Consistent with the importance of these causes, we find that rapid reductions in Black relative to White American deaths in early childhood and prime-aged adults (aged 20 to 64) accounted for the majority of the closure of the gap. Consistent once again with the importance of these causes (49), deaths due to causes amenable to medical care showed greater reductions for Black Americans relative to White Americans, greatly contributing to the closure of the gap in life expectancy. Reductions in causes amenable to intervention also played an important role, in line with prior research studying longitudinal racial disparities in more nuanced health indicators (53).

Many authors have commented on the role of systemic racism in shortening Black relative to White American life expectancies in the United States (54–56). Unpacking some of the dimensions of racism suggests that there are many possible reasons for these broad improvements in the health of Black Americans. The literature on the relationship between education and health suggests that improvements in the quantity and quality of education available to Black children and young adults over the past decades is one possible contributor to improved longevity and reduced gaps in life expectancy spread broadly over prime-aged adults (aged 20 to 64) (57, 58). Our results suggest that improvements in the availability of medical care are also likely to have been important in reducing racial disparities in mortality (59). Health care developments that may have been particularly important include expansions of the Medicaid program to cover pregnant women and children starting in the 1990s, which likely account for much of the improvement among infants (60), as well as improved access to treatment for cancer and HIV. Long-term health effects of access to Medicaid as well as other safety net programs such as food stamps and the Earned Income Tax Credit may also be an important contributor to mortality reductions (61). Reductions in pollution may have played a role given that Black Americans are more likely than White Americans to live in more-polluted areas (62–64).

Despite the strong mortality improvements among Black Americans over the past 3 decades, a dramatic gap remains, and this gap has increased again in recent years. It is important to understand which medical, social, and policy developments helped to increase the longevity of Black Americans through 2012 and how these positive changes can be reinforced over the coming decades with the ultimate goal of fully closing the racial longevity gap in the United States. Moreover, the comparisons with Europe suggest that mortality rates of both Black and White Americans could fall much further across all ages and across higher- and lower-income areas.

Materials and Methods

US Mortality. US Black and White American mortality rates are constructed by dividing death counts by population estimates for single years of age, county, and calendar year. Death counts come from the US Vital Statistics mortality files, while population estimates are provided by the National Center for Health Statistics (NCHS). The NCHS estimates are "bridged"; that is, they convert multiple race categories reported in the 2000 and 2010 Censuses back to single race categories comparable with those reported on the death certificates. Throughout the paper, "Black" populations include both non-Hispanic and Hispanic Black persons, while "White" populations include both non-Hispanic and Hispanic White persons. Neither race group includes American Indian and Alaska Native, Asian, or Native Hawaiian and Other Pacific Islander (the NCHS notes that these race categories "represent a social-political construct and are not anthropologically or biologically based") (65). Mortality rates spanning multiple years of age are age-adjusted using the 2015 US population. We age-adjust because in an age bracket such as ages 65 to 79, a group with more 79-y-olds would be expected to have higher mortality.

US Poverty Ranking. As in ref. 25, we rank counties by their poverty rate and place them into groups of fixed population size. This allows us to analyze trends in age-specific mortality across areas ranked by an area's poverty rate while taking into account population shifts across areas. We rank all US counties in 1990, 2005, and 2018 by their poverty level and then divide them into 20 groups, each representing roughly 5% of the overall US population. This way we can compare, for example, the 5% of the population living in the lowest-income counties in 1990 with the 5% of the population living in the highest-income counties in 1990 and analyze how the mortality differences between these groups change over time. We refer to the county groups with the highest (lowest) fractions of their populations in poverty as the lowest-income (highest-income) counties. Our approach reassigns county groups in 1990, 2005, and 2018 to adjust for changes in county ranking and population size. Poverty rates are taken from the 1990 and 2000 Censuses and the 2014 to 2018 American Community Survey 5-y sample and interpolated for intermediate years.

European Mortality. Data for nine European countries (Czech Republic, England, Finland, France, Germany, the Netherlands, Norway, Portugal, and Spain) come from the Institute for Fiscal Studies (IFS) project on Geographic Approaches to Inequalities in Mortality (66) and are treated similarly. Additional details on data sources are provided in *SI Appendix*.

Figs. 1–4 include the six European countries that provide consistent mortality data from 1990 onward (England, France, Germany, the Netherlands, Norway, and Spain). Figs. 1–4 include a mean Europe mortality rate, representing the population-weighted average of mortality rates across these countries in each ventile. *SI Appendix*, Figs. S5–S9 show analogous figures using all nine of the European countries in the IFS study. See *SI Appendix* for further information about these countries.

Mortality rates across all countries and years are age-adjusted using the 2015 US population, based on 5-y age groups. The following describes the respective area definitions, ranking measures, and available data years for each of the European countries included in Figs. 1–4: England, local authorities ranked by a deprivation index, for 1992 to 2017; France, départements ranked by poverty rate, for 1990 to 2018; Germany, districts ranked by per-capita income in 1990, 2005, and 2016 (1990 excludes East Germany because of the exceptionally high mortality in East Germany around the time of reunification); the Netherlands, municipalities ranked by poverty rate, 1995, 2005, and 2016; Norway, municipalities ranked by poverty rate, 1990 to 2018; and Spain, municipalities ranked by median income, 1990 to 2016. Further details on area definitions and the poverty or deprivation variables used for ranking areas can be found in ref. 51.

Life Expectancy Data. We construct US Black and White American life expectancy at birth based on 1-y mortality rates for the years 1990 to 2018. The Human Mortality Database (67) provides life expectancy estimates for the European countries in our study, while life expectancy estimates for England are provided by the United Kingdom Office for National Statistics.

Decompositions. We offer breakdowns of the contributions of location, age, and cause of death to Black and White American life expectancy and to the closing of the racial mortality gap. Each breakdown is based on asking how life expectancy would have changed if all other factors besides the one being considered had remained constant at their 1990 levels. For example, we ask how life expectancy would have changed between 1990 and 2018 if only the

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homicide rate had fallen while all other causes remained at their 1990 values. In all cases, this hypothetical exercise is conducted separately for Black and White Americans. Letting only one mortality rate change while keeping all other rates constant understates the one rate's overall contribution to life expectancy if other rates also improved. The reason is that the life expectancy formula interacts mortality rates at all ages. For example, a higher survival rate in old age makes improvements in infant mortality more valuable and vice versa. Our hypothetical life expectancy measure ignores interaction effects because they cannot be assigned to a specific age. Hence, our results should be interpreted as the partial effect of a given factor, which is sometimes referred to as the exclusive life expectancy impact of an age-specific effect (68). For further details, see *SI Appendix*.

Data Availability. All datasets used in this study are publicly available online or can be obtained from the National Vital Statistics offices. See *SI Appendix*, section C, for additional details and download links.

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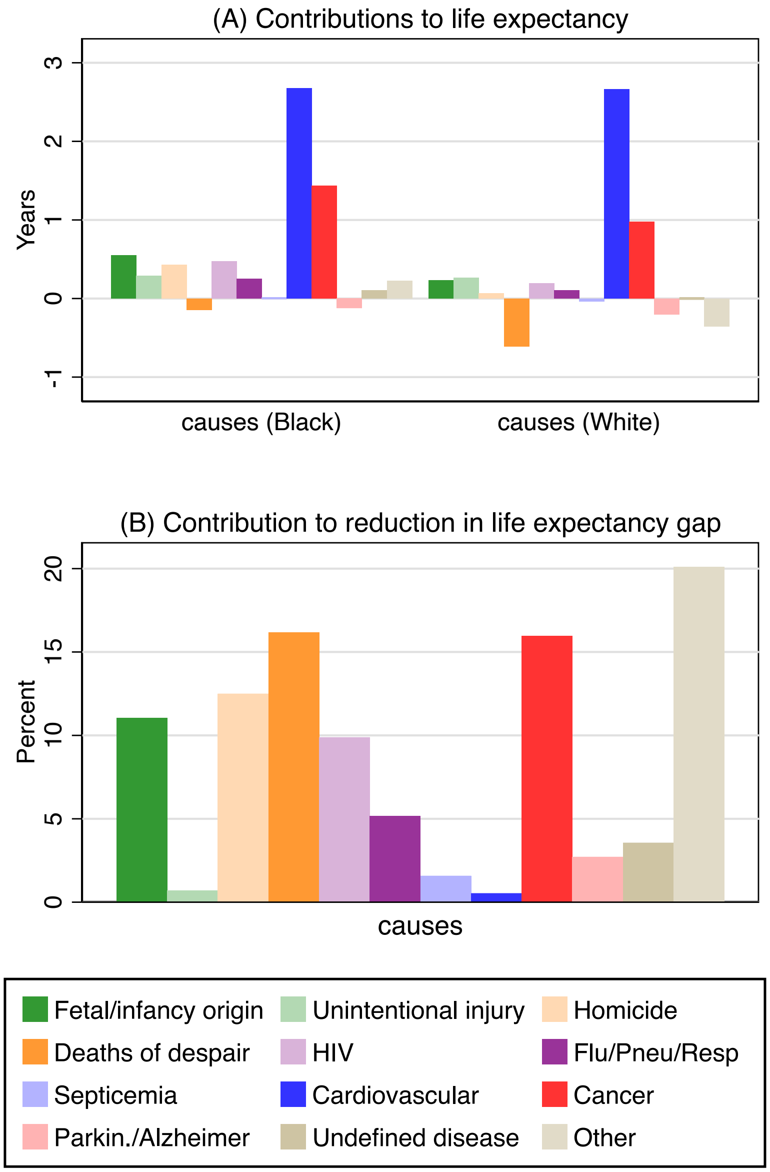
Supplementary information

Supplementary information for:

Schwandt, Hannes, Janet Currie, Marlies Bär, James Banks, Paola Bertoli, Aline Bütikofer, Sarah Cattan, Beatrice Zong-Ying Chao, Claudia Costa, Libertad González, Veronica Grembi, Kristiina Huttunen, René Karadakic, Lucy Kraftman, Sonya Krutikova, Stefano Lombardi, Peter Redler, Carlos Riumallo-Herl, Ana Rodríguez-González, Kjell Salvanes, Paula Santana, Josselin Thuilliez, Eddy van Doorslaer, Tom Van Ourti, Joachim Winter, Bram Wouterse, and Amelie Wuppermann.
"Inequality in Mortality between Black and White Americans by Age, Place, and Cause, and in Comparison to Europe, 1990--2018" (2021)

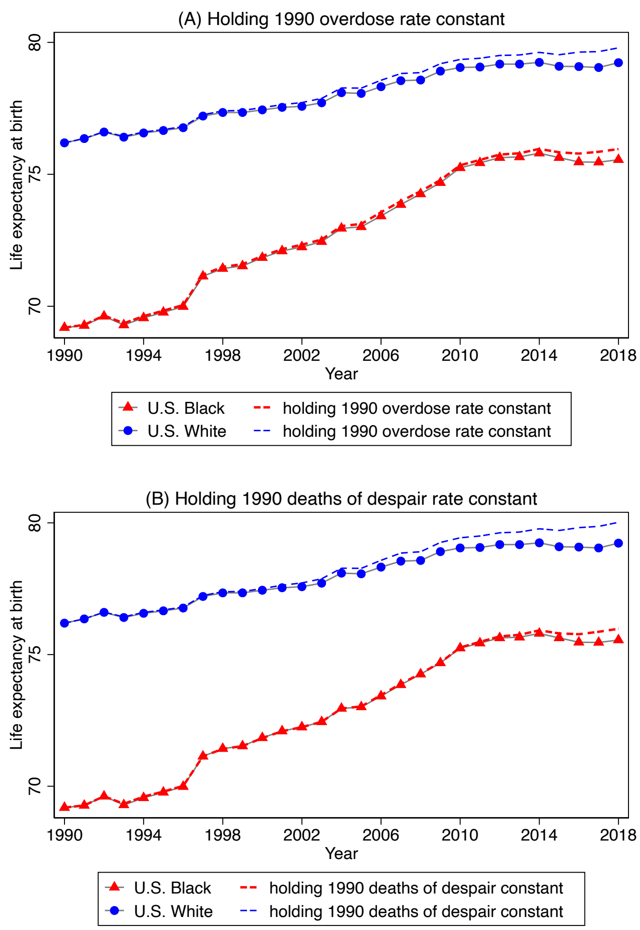
A Supplementary figures and tables

Figure S1: Cause-specific contributions to life expectancy gains and to the reduction of the Black-White life expectancy gap, 1990-2018



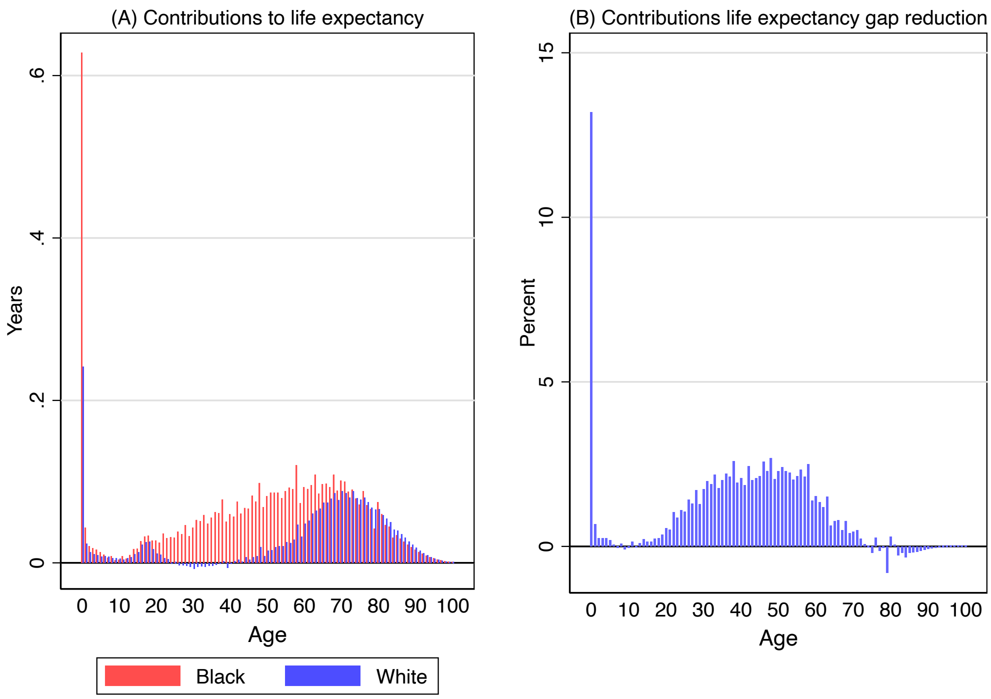
Notes: The top panel (A) shows the change in hypothetical race-specific life expectancy between 1990 and 2018 if only mortality from a given cause had changed between 1990 and 2018. The bottom panel (B) shows the percent contribution to the reduction in the Black-White life expectancy gap between 1990 and 2018. Numerical values and the list of included causes are provided in Appendix Tables S5 and S6.

Figure S2: Black Americans and White Americans actual and counterfactual life expectancy, holding drug overdose deaths and deaths of despair constant



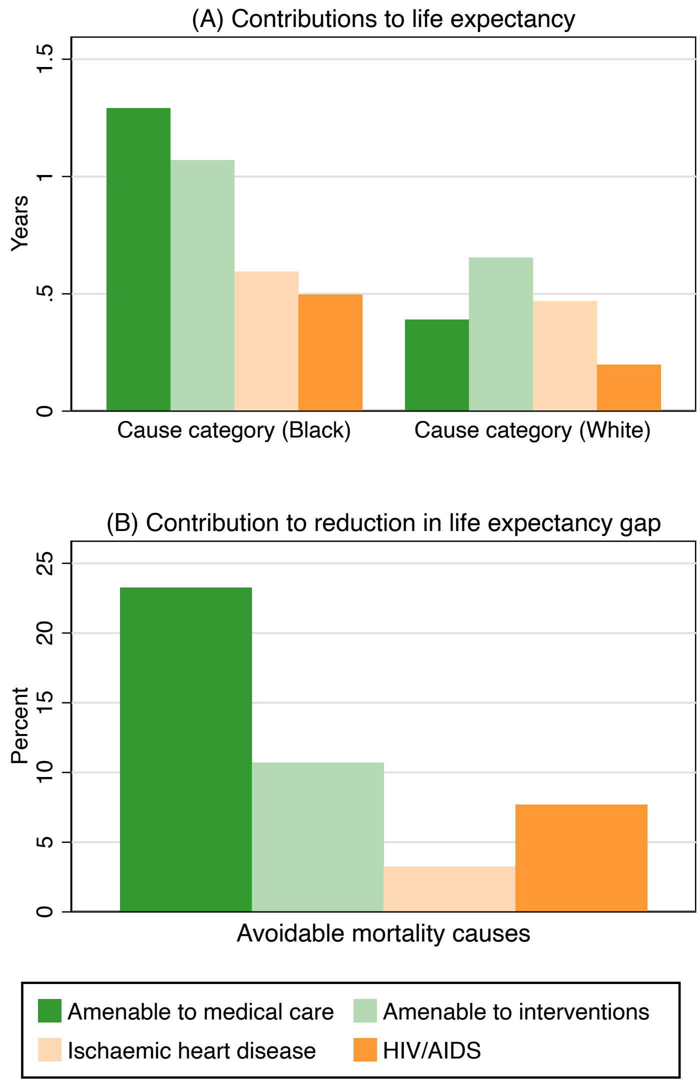
Notes: The red triangles and blue circles show actual life expectancy for Black Americans and White persons, respectively, over time. The dashed lines show counterfactual life expectancy estimates assuming constant death rates for drug overdose deaths (top panel) and constant death rates for deaths of despair (bottom panel), respectively, at their 1990 level. Source: Authors' calculations based on Vital Statistics mortality data.

Figure S3: Age-specific contributions to life expectancy gains and to the reduction of the Black-White life expectancy gap, 1990-2018



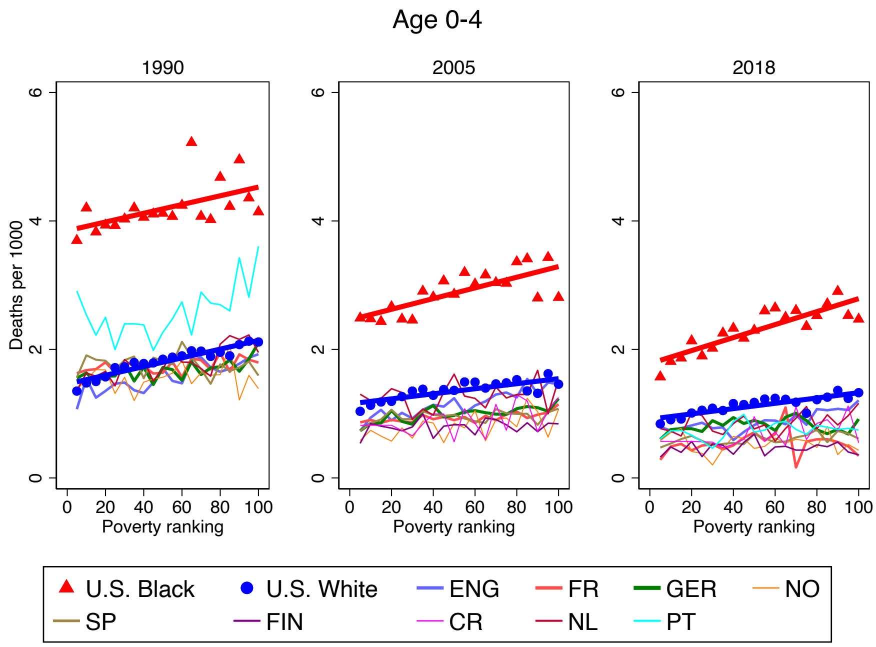
Notes: The top panel (A) shows the change in hypothetical race-specific life expectancy between 1990 and 2018 if only mortality at a given age had changed between 1990 and 2018. The bottom panel (B) shows the percent contribution to the reduction in the Black-White life expectancy gap between 1990 and 2018. Numerical values and contributions by subperiod are provided in Appendix Tables S7.

Figure S4: Contributions of avoidable mortality below age 65 (defined following Macinko and Elo (2009)) to life expectancy gains and to the reduction of the Black--White life expectancy gap, 1990-2018



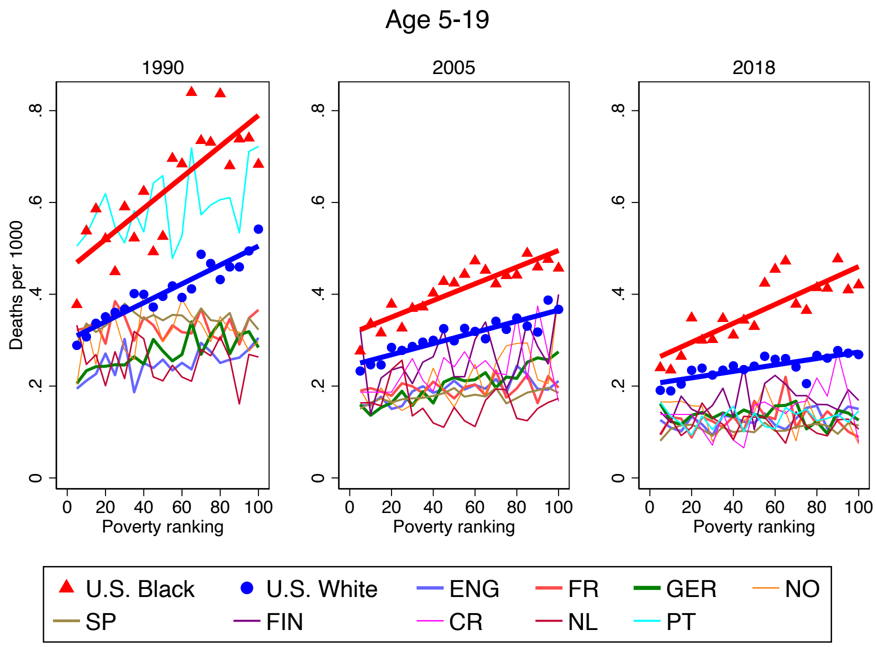
Notes: The top panel (A) shows the change in hypothetical race-specific life expectancy between 1990 and 2018 if only mortality in a given cause category, and below age 65, had changed between 1990 and 2018. The bottom panel (B) shows the percent contribution to the reduction in the Black-White life expectancy gap between 1990 and 2018. Mortality categories and age restrictions are defined following Macinko and Elo (2009), and causes in each category are listed in Table S8.

Figure S5: 1-year mortality for Black Americans, White Americans, and nine European countries, age 0-4.



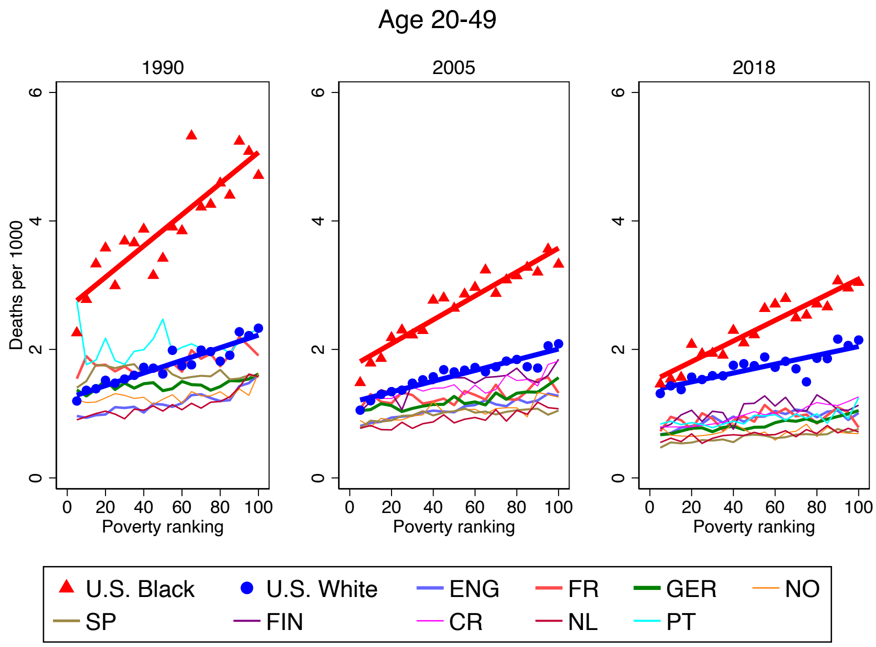
Notes: Average 1-year mortality rates are plotted across poverty rate percentiles for Black Americans, White Americans, Finland, France, the Netherlands, and Norway; across median income percentiles (higher percentiles refers to lower income) for Czech Republic, Germany, and Spain; across deprivation percentiles for England and Portugal. Each bin represents a group of counties, districts, or municipalities with about 5% of the overall population in the respective year. Germany excludes East Germany in 1990. The 2018 subpanel shows 2018 rates for the U.S., France, Norway, and Portugal; 2017 rates for England; 2016 rates for Czech Republic, Germany, Netherlands, and Spain; 2015 rates for Finland. More details provided in the Materials and Methods Section. Straight lines provide linear fits for Black Americans and White Americans mortality.

Figure S6: 1-year mortality for Black Americans, White Americans, and nine European countries, age 5-19.



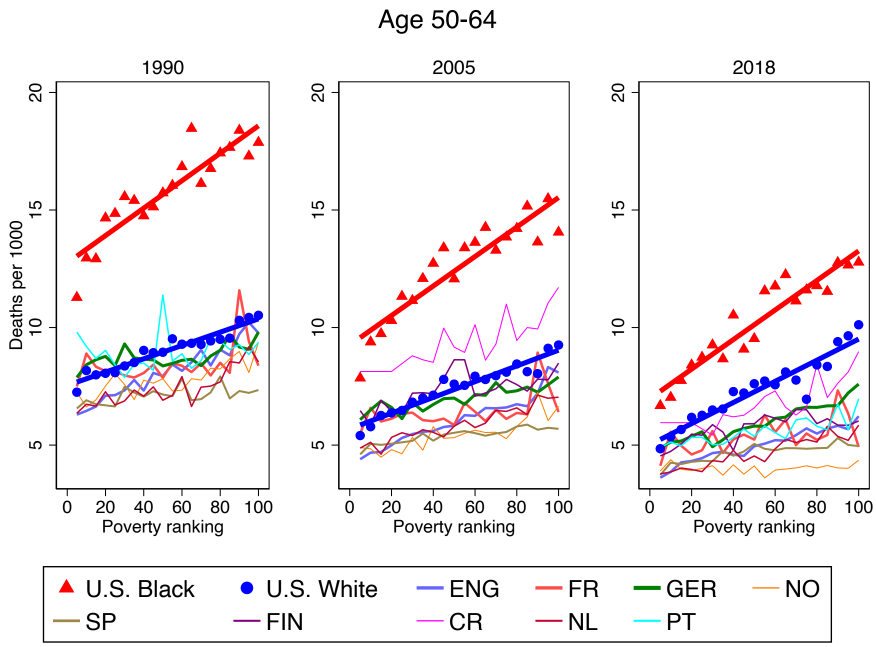
Notes: Average 1-year mortality rates are plotted across poverty rate percentiles for Black Americans, White Americans, Finland, France, the Netherlands, and Norway; across median income percentiles (higher percentiles refers to lower income) for Czech Republic, Germany, and Spain; across deprivation percentiles for England and Portugal. Each bin represents a group of counties, districts, or municipalities with about 5% of the overall population in the respective year. Germany excludes East Germany in 1990. The 2018 subpanel shows 2018 rates for the U.S., France, Norway, and Portugal; 2017 rates for England; 2016 rates for Czech Republic, Germany, Netherlands, and Spain; 2015 rates for Finland. More details provided in the Materials and Methods Section. Straight lines provide linear fits for Black Americans and White Americans mortality.

Figure S7: 1-year mortality for Black Americans, White Americans, and nine European countries, age 20-49.



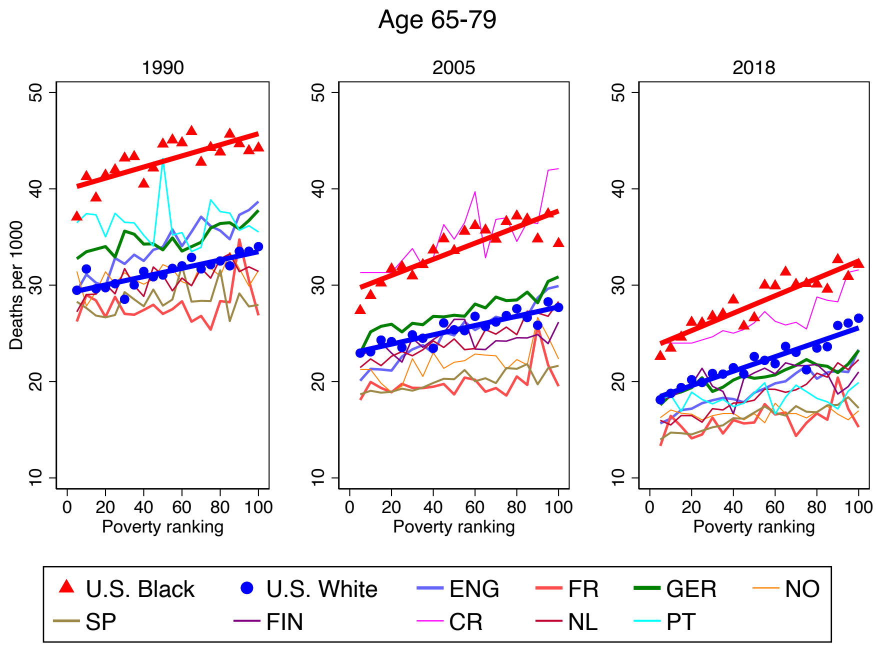
Notes: Average 1-year mortality rates are plotted across poverty rate percentiles for Black Americans, White Americans, Finland, France, the Netherlands, and Norway; across median income percentiles (higher percentiles refers to lower income) for Czech Republic, Germany, and Spain; across deprivation percentiles for England and Portugal. Each bin represents a group of counties, districts, or municipalities with about 5% of the overall population in the respective year. Germany excludes East Germany in 1990. The 2018 subpanel shows 2018 rates for the U.S., France, Norway, and Portugal; 2017 rates for England; 2016 rates for Czech Republic, Germany, Netherlands, and Spain; 2015 rates for Finland. More details provided in the Materials and Methods Section. Straight lines provide linear fits for Black Americans and White Americans mortality.

Figure S8: 1-year mortality for Black Americans, White Americans, and nine European countries, age 50-64.



Notes: Average 1-year mortality rates are plotted across poverty rate percentiles for Black Americans, White Americans, Finland, France, the Netherlands, and Norway; across median income percentiles (higher percentiles refers to lower income) for Czech Republic, Germany, and Spain; across deprivation percentiles for England and Portugal. Each bin represents a group of counties, districts, or municipalities with about 5% of the overall population in the respective year. Germany excludes East Germany in 1990. The 2018 subpanel shows 2018 rates for the U.S., France, Norway, and Portugal; 2017 rates for England; 2016 rates for Czech Republic, Germany, Netherlands, and Spain; 2015 rates for Finland. More details provided in the Materials and Methods Section. Straight lines provide linear fits for Black Americans and White Americans mortality.

Figure S9: 1-year mortality for Black Americans, White Americans, and nine European countries, age 65-79.



Notes: Average 1-year mortality rates are plotted across poverty rate percentiles for Black Americans, White Americans, Finland, France, the Netherlands, and Norway; across median income percentiles (higher percentiles refers to lower income) for Czech Republic, Germany, and Spain; across deprivation percentiles for England and Portugal. Each bin represents a group of counties, districts, or municipalities with about 5% of the overall population in the respective year. Germany excludes East Germany in 1990. The 2018 subpanel shows 2018 rates for the U.S., France, Norway, and Portugal; 2017 rates for England; 2016 rates for Czech Republic, Germany, Netherlands, and Spain; 2015 rates for Finland. More details provided in the Materials and Methods Section. Straight lines provide linear fits for Black Americans and White Americans mortality.

Table S1: Mortality rates per 1,000 across poverty ventiles, age 0-4.

	1990			2005			2018		
	U.S. Black	U.S. White	Europe	U.S. Black	U.S. White	Europe	U.S. Black	U.S. White	Europe
Overall	4.20	1.82	1.70	2.90	1.36	1.02	2.31	1.13	0.71
Percentile									
5	3.70	1.35	1.47	2.49	1.04	0.80	1.57	0.84	0.54
10	4.20	1.48	1.68	2.48	1.13	0.90	1.81	0.91	0.64
15	3.83	1.50	1.57	2.43	1.18	0.92	1.87	0.92	0.67
20	3.93	1.57	1.64	2.66	1.19	1.00	2.13	1.01	0.68
25	3.93	1.72	1.58	2.47	1.27	0.94	1.90	1.05	0.68
30	4.03	1.73	1.74	2.46	1.35	0.87	2.02	1.08	0.69
35	4.20	1.80	1.63	2.91	1.38	1.03	2.26	1.05	0.65
40	4.06	1.78	1.63	2.82	1.29	1.03	2.33	1.16	0.69
45	4.11	1.79	1.58	3.07	1.38	1.00	2.17	1.14	0.71
50	4.12	1.85	1.71	2.86	1.36	1.04	2.30	1.18	0.78
55	4.07	1.88	1.71	3.20	1.49	1.00	2.60	1.23	0.74
60	4.24	1.90	1.65	3.02	1.49	1.00	2.65	1.24	0.71
65	5.22	1.98	1.83	3.16	1.40	1.00	2.50	1.22	0.88
70	4.07	1.97	1.73	3.04	1.46	1.06	2.61	1.18	0.71
75	4.02	1.89	1.65	3.03	1.48	1.07	2.36	1.01	0.77
80	4.68	1.96	1.80	3.36	1.53	1.09	2.53	1.22	0.76
85	4.23	1.90	1.76	3.41	1.35	1.14	2.71	1.26	0.73
90	4.95	2.08	1.78	2.80	1.32	1.09	2.90	1.36	0.76
95	4.36	2.13	1.86	3.43	1.62	1.10	2.53	1.24	0.72
100	4.14	2.12	1.88	2.81	1.46	1.24	2.47	1.33	0.78
slope (x100)	0.680	0.679	0.289	0.832	0.393	0.296	1.011	0.413	0.159
p-values									
slope $= 0$	0.012	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001
US_B=US_W		0.997			0.054			0.001	
US_W=EU		0.000			0.298			0.001	

Notes: This table shows numerical values of average mortality rates plotted in Figure 1, along with the value of the slopes of the fitted lines shown in Figure 1 and p-values of differences between slopes. Europe refers to population weighted average mortality rates across England, France, Germany, Netherlands, Norway, and Spain. For additional comments see the note of Figure 1 and the Materials and Methods section in the main paper.

Table S2: Mortality rates per 1,000 across poverty ventiles, age 5-19.

	1990			2005			2018		
	U.S. Black	U.S. White	Europe	U.S. Black	U.S. White	Europe	U.S. Black	U.S. White	Europe
Overall	0.63	0.41	0.30	0.41	0.31	0.19	0.36	0.24	0.13
<u>Percentile</u>									
5	0.38	0.29	0.26	0.28	0.23	0.17	0.24	0.19	0.12
10	0.54	0.31	0.27	0.34	0.25	0.16	0.24	0.19	0.12
15	0.59	0.34	0.28	0.32	0.25	0.17	0.26	0.20	0.12
20	0.52	0.35	0.28	0.38	0.28	0.17	0.35	0.23	0.12
25	0.45	0.36	0.30	0.33	0.28	0.19	0.30	0.24	0.13
30	0.59	0.37	0.30	0.37	0.29	0.18	0.30	0.22	0.11
35	0.52	0.40	0.28	0.37	0.30	0.18	0.35	0.23	0.13
40	0.62	0.40	0.30	0.40	0.30	0.18	0.31	0.24	0.12
45	0.49	0.37	0.30	0.43	0.33	0.19	0.34	0.24	0.12
50	0.53	0.40	0.29	0.42	0.30	0.20	0.33	0.24	0.14
55	0.70	0.42	0.29	0.44	0.33	0.19	0.42	0.27	0.13
60	0.68	0.39	0.29	0.47	0.32	0.20	0.45	0.26	0.13
65	0.84	0.41	0.31	0.45	0.30	0.20	0.47	0.26	0.15
70	0.73	0.49	0.32	0.42	0.34	0.21	0.38	0.24	0.13
75	0.73	0.47	0.31	0.44	0.32	0.19	0.36	0.21	0.13
80	0.84	0.43	0.31	0.44	0.35	0.20	0.41	0.27	0.12
85	0.68	0.46	0.30	0.49	0.33	0.22	0.41	0.26	0.11
90	0.74	0.46	0.29	0.46	0.32	0.20	0.48	0.28	0.13
95	0.74	0.49	0.32	0.48	0.39	0.22	0.41	0.27	0.13
100	0.68	0.54	0.31	0.46	0.37	0.22	0.42	0.27	0.12
slope (x100)	0.337	0.206	0.042	0.182	0.121	0.058	0.206	0.070	0.007
<u>p-values</u>									
slope $= 0$	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.316
US_B=US_W		0.041			0.031			0.000	
US_W=EU		0.000			0.000			0.000	

Notes: This table shows numerical values of average mortality rates plotted in Figure 2, along with the value of the slopes of the fitted lines shown in Figure 2 and p-values of differences between slopes. Europe refers to population weighted average mortality rates across England, France, Germany, Netherlands, Norway, and Spain. For additional comments see the note of Figure 2 and the Materials and Methods section in the main paper.

Table S3: Mortality rates per 1,000 across poverty ventiles, age 20-64.

	1990			2005			2018		
	U.S. Black	U.S. White	Europe	U.S. Black	U.S. White	Europe	U.S. Black	U.S. White	Europe
Overall	7.79	4.12	3.67	5.90	3.51	2.82	4.92	3.56	2.28
Percentile									
5	5.20	3.17	3.22	3.56	2.47	2.35	3.16	2.46	1.79
10	6.09	3.58	3.47	4.26	2.69	2.59	3.33	2.71	2.04
15	6.45	3.54	3.48	4.43	2.91	2.57	3.58	2.77	2.02
20	7.19	3.65	3.55	4.83	2.98	2.59	4.14	3.07	2.02
25	6.85	3.63	3.46	5.24	3.03	2.60	4.15	3.07	2.10
30	7.55	3.76	3.64	5.13	3.22	2.70	4.32	3.19	2.12
35	7.48	3.85	3.56	5.48	3.31	2.66	4.11	3.20	2.07
40	7.41	4.10	3.52	6.01	3.38	2.68	4.98	3.55	2.19
45	7.05	4.06	3.65	6.25	3.67	2.75	4.37	3.55	2.21
50	7.43	4.00	3.52	5.71	3.59	2.75	4.61	3.66	2.26
55	7.86	4.44	3.63	6.29	3.59	2.87	5.54	3.78	2.37
60	8.08	4.20	3.67	6.44	3.74	2.86	5.66	3.63	2.36
65	9.60	4.23	3.67	6.83	3.65	2.83	5.87	3.86	2.45
70	8.09	4.36	3.70	6.26	3.76	3.01	5.30	3.67	2.39
75	8.33	4.40	3.67	6.59	3.86	2.88	5.49	3.27	2.47
80	8.77	4.32	3.81	6.75	3.99	2.97	5.66	3.99	2.38
85	8.72	4.40	3.83	7.15	3.81	3.00	5.55	3.97	2.48
90	9.52	4.89	4.22	6.60	3.77	3.28	6.23	4.52	2.70
95	9.06	4.89	4.06	7.44	4.35	3.29	6.11	4.53	2.62
100	9.00	5.00	4.04	6.82	4.42	3.20	6.21	4.74	2.57
slope (x100)	3.539	1.586	0.694	3.297	1.655	0.802	3.130	1.929	0.768
p-values									
slope $= 0$	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
US_B=US_W		0.000			0.000			0.000	
US_W=EU		0.000			0.000			0.000	

Notes: This table shows numerical values of average mortality rates plotted in Figure 3, along with the value of the slopes of the fitted lines shown in Figure 3 and p-values of differences between slopes. Europe refers to population weighted average mortality rates across England, France, Germany, Netherlands, Norway, and Spain. For additional comments see the note of Figure 3 and the Materials and Methods section in the main paper.

Table S4: Mortality rates per 1,000 across poverty ventiles, age 65-79.

	1990			2005			2018		
	U.S. Black	U.S. White	Europe	U.S. Black	U.S. White	Europe	U.S. Black	U.S. White	Europe
Overall	42.99	31.43	31.47	33.73	25.45	23.42	28.22	22.02	18.17
Percentile									
5	37.07	29.47	29.35	27.36	22.95	20.34	22.60	18.12	15.41
10	41.26	31.68	30.50	28.92	23.09	21.83	23.46	18.77	16.71
15	39.05	29.63	30.18	30.22	24.30	21.74	24.60	19.38	16.73
20	41.41	29.74	29.85	31.68	24.15	21.73	26.15	20.19	16.56
25	41.97	30.15	30.50	31.93	23.54	22.06	26.08	19.90	17.10
30	43.19	28.54	31.41	30.97	24.85	22.36	26.78	20.83	17.31
35	43.34	30.02	31.19	32.13	24.49	22.45	27.02	20.77	17.11
40	40.48	31.42	30.67	33.64	23.46	22.80	28.46	21.44	17.84
45	42.16	30.87	31.54	34.81	26.08	23.24	25.75	20.78	17.82
50	44.64	31.06	30.84	33.59	25.38	23.02	26.62	22.60	18.08
55	45.07	31.74	31.67	35.59	25.29	23.78	30.00	22.20	18.84
60	44.77	32.01	31.82	36.18	26.76	23.78	29.93	21.86	18.66
65	45.94	32.88	30.98	35.72	25.71	23.64	31.35	23.65	18.82
70	42.75	31.69	31.72	34.77	26.18	24.09	30.09	23.04	18.69
75	44.29	32.14	31.58	36.61	26.85	24.03	30.17	21.22	19.28
80	43.82	32.51	33.05	37.19	27.55	24.54	30.11	23.48	19.20
85	45.66	32.01	32.05	36.86	26.65	24.82	29.58	23.62	19.21
90	44.68	33.52	34.28	34.80	25.84	26.08	32.65	25.82	20.22
95	43.95	33.52	33.33	37.39	28.27	26.15	30.90	26.07	19.75
100	44.24	34.00	32.94	34.32	27.69	25.89	32.15	26.57	20.01
slope (x100)	5.766	4.309	3.654	8.357	4.827	5.183	9.023	7.496	4.298
p-values									
slope $= 0$	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
US_B=US_W		0.332			0.026			0.138	
US_W=EU		0.445			0.571			0.000	

Notes: This table shows numerical values of average mortality rates plotted in Figure 4, along with the value of the slopes of the fitted lines shown in Figure 4 and p-values of differences between slopes. Europe refers to population weighted average mortality rates across England, France, Germany, Netherlands, Norway, and Spain. For additional comments see the note of Figure 4 and the Materials and Methods section in the main paper.

Table S5: Cause-specific contributions to life expectancy gains and to the reduction of the Black-White life expectancy gap, 1990-2018

Cause	Contributions to life LE (in yrs)		% contribution to LE gap reduction
	Black	White	
Fetal/infancy origin	0.552	0.234	11.05
Unintentional injury	0.287	0.267	0.71
Homicide	0.426	0.067	12.51
Deaths of despair	-0.144	-0.608	16.18
HIV	0.475	0.191	9.89
Flu/Pneu/Resp	0.252	0.103	5.17
Septicemia	0.008	-0.037	1.59
Cardiovascular	2.678	2.662	0.54
Cancer	1.438	0.979	15.96
Parkin./Alzheimer	-0.124	-0.202	2.72
Undefined disease	0.103	0.001	3.57
Other	0.224	-0.353	20.11

Notes: This table shows the hypothetical change in Black and White life expectancy between 1990 and 2018 had only the selected group of cause obtained its 2018 mortality rate. ICD codes for all causes included in each group are listed in Table S6. Note that these contributions only reflect the causes individual contributions and not the interaction terms with other causes, which are positive in most cases (hence, the contributions tend to understate the overall contributions). The third column calculates the percent of the reduction in the Black-White life expectancy gap contributed to each cause.

Table S6: ICD-9 and ICD-10 codes included in different groups of causes of death

Group	ICD 9 (1990)	ICD 10 (2018)
Fetal/infancy origin:		
	Congenital anomalies (740-759), Certain conditions originating in the perinatal period (760-779), Sudden infant death syndrome (798)	Certain conditions originating in the perinatal period (P00-P96), Congenital malformations, deformations and chromosomal abnormalities (Q00-Q99), Sudden infant death syndrome (R95)
Unintentional injury:		
	Motor vehicle accidents (E810-E825), All other accidents and adverse effects (E800-E807, E826-E949)	Motor vehicle accidents (V02-V04, V09.0, V12-V14, V19.0-V19.2, V19.4-V19.6, V20-V79, V80.3-V80.5, V81.0-V81.1, V82.0-V82.1, V83-V86, V87.0-V87.8, V88.0-V88.8, V89.0, V89.2), All other accidents and adverse effects (V01, V05-V06, V09.1, V09.3-V09.9, V10-V11, V15-V18, V19.3, V19.8-V19.9, V80.0-V80.2, V80.6-V80.9, V81.2-V81.9, V82.2-V82.9, V87.9, V88.9, V89.1, V89.3, V89.9, V90-X39, X46-X59, Y40-Y86, Y88)
Homicide:		
	Homicide and legal intervention (E960-E978)	Assault (homicide) (*U01-*U02,X85-Y09,Y87.1)
Deaths of despair:		
	Liver disease (571), Drug Poisoning (E850-E860, E980), Suicide (E950 -E959)	Chronic liver disease and cirrhosis (K70,K73-K74), Drug Poisoning (X40-X45), Intentional self-harm (suicide) (X60-X84,Y87.0)
HIV:		
	Other viral diseases (042-044)	Human immunodeficiency virus (HIV) disease (B20-B24)
Flu/Pneu/Resp:		
	Acute upper respiratory infections (460-465), Bronchitis and bronchiolitis (466, 490-491), Pneumonia and influenza (480-487), Pneumonia (480-486), Influenza (487), Remainder of diseases of respiratory system (470-478, 492-519)	Influenza and pneumonia (J10-J18), Other acute lower respiratory infections (J20-J22), Chronic lower respiratory diseases (J40-J47), Pneumoconioses and chemical effects (J60-J66,J68), Pneumonitis due to solids and liquids (J69), Other diseases of respiratory system (J00-J06,J30-J39,J67,J70-J98)
Septicemia:		
	Septicemia (038)	Septicemia (A40-A41)
Cardiovascular:		
	Major cardiovascular diseases (390-448)	Major cardiovascular diseases (I00-I78)
Cancer:		
	Malignant neoplasms, including neoplasms of lymphatic and hematopoietic tissues (140-208)	Malignant neoplasms (C00-C97)
Parkinson / Alzheimer:		
	Parkinson’s disease (332), Alzheimer's Disease (331)	Parkinson’s disease (G20-G21), Alzheimer’s disease (G30)
Undefined disease:		
	Symptoms, signs, and ill-defined conditions (780-797, 799)	Symptoms, signs and abnormal clinical and laboratory findings, not elsewhere classified (excluding Sudden infant death syndrome) (R00-R94,R96-R99)

Table S7: Percent contributions to the reduction of the Black-White life expectancy gap, by age, 1990-2018.

	1990-2000	2000-2018	overall 1990-2018
Age 0-4	19.60	9.83	14.61
Age 5-19	5.87	-1.40	1.71
Age 20-49	59.06	46.04	53.50
Age 50-64	18.71	34.85	27.92
Age 65-79	-1.98	10.76	3.54
Age 80 plus	-1.25	-0.08	-1.30
Sum	100	100	100

Notes: This table shows the contributions to the reduction of the Black-White life expectancy gap due to mortality improvements at different ages, in percent of the total gap reduction. These percent contributions are calculated by constructing race-specific hypothetical life expectancies that only let mortality rates in the given age group change between 1990 and 2018. Additional information is provided in Supplementary Material.

Table S8: Contributions of avoidable mortality to life expectancy gains and to the reduction of the Black-White life expectancy gap, 1990-2018

	Contributions to life LE (in yrs)		% contribution to
Cause	Black	White	LE gap reduction
Amenable to Medical Care	1.291	0.390	23.25
Amenable to Interventions	1.069	0.653	10.72
Ischaemic Heart Disease	0.595	0.469	3.26
HIV/AIDS	0.496	0.198	7.69

Notes: This table shows the hypothetical change in Black and White life expectancy between 1990 and 2018 had only the selected type of avoidable mortality obtained its 2018 mortality rate. ICD codes for all causes included in each avoidable mortality group are listed in Table S9. Note that these contributions only reflect the causes individual contributions and not the interaction terms with other causes, which are positive in most cases (hence, the contributions tend to understate the overall contributions). The third column calculates the percent of the reduction in the Black-White life expectancy gap contributed to each cause.

Table S9: Avoidable mortality, replicated from Macinko and Elo (44), Table A1

ICD 9 (1990)	ICD 10 (2018)
Amenable to Medical Care Treatment and Prevention: Causes: Intestinal infections, Tuberculosis, Other infectious (Diphtheria, Tetanus, Poliomyelitis, Septicaemia, Whooping Cough), Measles, Malignant neoplasm of colon and rectum, skin, breast; cervix uteri, testis; Hodgkinas disease,Leukaemia, Diseases of the thyroid, Diabetes mellitus, Epilepsy, Chronic rheumatic heartdisease, Hypertensive disease, Cerebrovascular disease, All respiratory diseases (excluding pneumonia/influenza),Influenza and Pneumonia, Peptic ulcer, Appendicitis, Abdominal hernia, Cholelithiasis and cholecystitis, Nephritis and nephrosis, Benign prostatic hyperplasia, Maternal deaths, Congenital cardiovascular anomalies, Perinatal deaths (excl. stillbirths), Misadventures to patients during surgical/medical care.	
001-009, 010--018, 137, 032, 033, 037, 038, 045, 55, 153--154, 173, 174, 180, 186, 201, 204--208, 240--246, 250, 345, 393--398, 401--405, 430--438, 460--479, 488--519, 487, 480--486, 531--533, 540--543, 550--553, 571, 574--575.1, 580--589, 600, 630--676, 745--747, 760--779, E870--E876, E878--E879	A00--A09, A15--A19, B90, A36, A35, A37, A40--A41, A80, B05, C18--C21, C44, C50, C53, C62, C81, C91--C95, E00--E07, E10--E14, G40--G41, I05--I09, I10--I13, I15, I60--I69, J00--J09,J20--J99, J10--J11, J12--J18, K25--K27, K35--K38, K40--K46, K80--K81, N00--N07, N17--N19, N25--N27, N40, O00--O99, Q20--Q28, P00--P96, A33, Y60--Y69, Y83--Y84
Amenable to Policy and Behavioural Interventions: Causes: Malignant neoplasm of the trachea, bronchus, and lung; Road traffic injuries; Homicide	
162, E810--E819, E960--E969	C33, V01, V03, V06, V09, V13, V15, V19, V20, V25--V29, V40--49, V80, V82, V87--89, X85--Y09, K70
Ischaemic Heart Disease (IHD): Causes considered amenable to both policy/behavioural interventions and medical care treatment	
410--414, 429.2	I20--I25
HIV/AIDS: Deaths from early infections considered not avoidable; amenable to policy/behavioural interventions until 1996, and amenable to medical care and policy/behaviour post-HAART (1996--2005).	
042--044	B20--B24

B Additional life expectancy decomposition details

Calculating age, cause, and ventile-specific contributions to Black and White life expectancy. We start with the description of the calculation of age contributions before turning to contributions by cause and ventile (the calculation of contributions by cause or ventile is equivalent and we will explain the method using cause contributions as the example). The age contribution calculation analyzes how much life expectancy was gained (or lost) due to mortality changes solely at a single year of age, keeping mortality at all other ages at their 1990 value. Specifically, we calculate a hypothetical life expectancy at age a using the 2018 mortality rate at age a while all other ages enter with their 1990 mortality rates. The difference between the resulting hypothetical life expectancy for age a and the actual 1990 life expectancy is then the life expectancy change contributed to the mortality change at age a. This procedure is repeated at each individual year of age.[1]

For cause (or ventile) contributions, we calculate hypothetical life expectancies the same way, letting only one cause category change while mortality rates for all other categories are kept constant. However, this calculation is somewhat complicated by the fact that the construction of life expectancy requires mortality rates at each single year of age while cause- or ventile-specific mortality encompasses deaths at all ages. We therefore translate cause-specific mortality rates in 2018 at each single year of age to hypothetical cause-by-age mortality counts in 1990 (multiplying the 2018 cause-by-age rate with the 1990 population at each age), then replace the actual 1990 cause-by-age mortality counts with these hypothetical counts across all ages, before finally collapsing these hypothetical age-specific mortality rates into hypothetical life expectancy. The

[1] Since we do not observe mortality rate above age 84, we use a Gompertz extrapolation for mortality at age 85-110. In particular, we fit a linear regression line through the logarithm of mortality between age 60 and 84 and then predict this line forward to age 110. Fitting the regression line over a longer or shorter age window (e.g. age 75-84 instead of age 60-84) only marginally changes life expectancy estimates.

difference between the resulting hypothetical life expectancy for cause c and the actual 1990 life expectancy is then the life expectancy change contributed to the mortality change in cause c.

Calculating the age, cause, and ventile-specific percent contributions to the reduction in the Black-White life expectancy gap. We use the age-, cause-, and ventile-specific contributions to changes in Black and White life expectancy described above to calculate each categories contribution to the reduction in the Black-White life expectancy gap the following way. First, we subtract the contributions to White life expectancy from the contributions to Black life expectancy for each category, which gives us a measure of the change in the life expectancy gap due to this category. We then express this change as the percent relative to the sum of changes across all categories for a given factor.

C Data Availability

Czech Republic

Years: 1994-2018
Area type: District
Area ranking measure: Mean income
Death data source: Mortality register data can be purchased from the Czech Statistical Office. Data must be requested following the instructions at this link https://www.czso.cz/csu/czso/zadosti-o-poskytnuti-pristupu-k-duvernym-statistickym-udajum-pro-ucely-vedeckeho-vyzkumu
Population data source: Population counts by gender and age can be requested and purchased from the Czech Statistical Office following the procedure at this link https://www.czso.cz/csu/czso/zadosti-o-poskytnuti-pristupu-k-duvernym-statistickym-udajum-pro-ucely-vedeckeho-vyzkumu
Ranking measure data source: Data taken from the annual publication titled "Okresy Ceske republiky v roce" published by the Czech Statistical Office (available as hard copies for the least recent years) and own calculation using data at the regional level for most recent years (Data available from https://vdb.czso.cz/vdbvo2/faces/en/index.jsf?page=statistiky&katalog=31799

England

Years: 1992-2017
Area type: Local authority Area ranking measure: Index of multiple deprivation
Death data source: ONS Vital Statistics (lookup necessary to convert from LSOA to Local Authority) https://www.ons.gov.uk/peoplepopulationandcommunity/birthsdeathsandmarriages/deaths/adhocs/009628birthsanddeathsbylowersuperoutputarealsoaenglandandwales1991to1992to2016to2017
Population data source: https://www.ons.gov.uk/peoplepopulationandcommunity/populationandmigration/populationestimates/datasets/populationestimatesforukenglandandwalesscotlandandnorthernireland
Ranking measure data source: English indices of deprivation from GOV.UK https://www.gov.uk/government/statistics/english-indices-of-deprivation-2019

Finland

Years: 1990-2016
Area type: Municipality
Area ranking measure: Poverty rate
Death data source: Cause-of-death records, Statistics Finland https://www.stat.fi/meta/til/ksyyt_en.html
Population data source: FLEED and FOLK registers, Statistics Finland

https://www.stat.fi/tup/mikroaineistot/aineistot_en.html
Ranking measure data source: FLEED and FOLK registers (demographics, family links and labor market information of all Finnish residents from 1988-2016/2018) Statistics Finland
https://www.stat.fi/tup/mikroaineistot/aineistot_en.html

France

Years: 1990-2018
Area type: Departement
Area ranking measure: Poverty rate
Death data source: https://www.cepidc.inserm.fr/
Population data source: https://www.insee.fr/fr/accueil
Ranking measure data source: https://www.insee.fr/fr/accueil

Germany

Years: 1990, 1995-2016
Area type: District (Kreise/Landkreise)
Area ranking measure: Per capita disposable income
Death data source: Federal Statistical Office (account needed, then code 12613-93-01-4). Data for 1990 not publicly available, requiring data requested
www.regionalstatistik.de
Population data source: Federal Statistical Office (account needed, then code 12411-02-03-4). Data for 1990 not publicly available, requiring data requested
www.regionalstatistik.de
Population counts pre-2011 adjusted according to estimates by Kluesener et al. (2018) data appendix: https://comparativepopulationstudies.de/index.php/CPoS/article/view/251
Ranking measure data source: Federal Statistical Office (and Statistical Offices of the Laender
https://www.statistikportal.de/de/vgrdl/ergebnisse-kreisebene/einkommen-kreise

Netherlands

Years: 1990-2018
Area type: Municipality
Area ranking measure: Poverty rate
Death data source: 1990-1994 death counts obtained from Statline
https://opendata.cbs.nl/statline/#/CBS/nl/dataset/03747/table?ts=1613379024732
1995 onwards are based on own calculations using non-public microdata on death registries from Statistics Netherlands. For information on data applications, visit
https://www.cbs.nl/en-gb/onze-diensten/customised-services-microdata/microdata-conducting-your-own-research

Population data source: Non-public microdata on personal records database from Statistics Netherlands. For information on data applications, visit
https://www.cbs.nl/en-gb/onze-diensten/customised-services-microdata/microdata-conducting-your-own-research.
Ranking measure data source: Poverty rates for 1990 can be accessed at
https://opendata.cbs.nl/#/CBS/nl/dataset/70050ned/table?dl=4C0D7
For the years 2005 & 2016, poverty measure based on regional income distribution data using (non-public) household level tax registries data from Statistics Netherlands. For information on data applications, visit
https://www.cbs.nl/en-gb/onze-diensten/customised-services-microdata/microdata-conducting-your-own-research.

Norway

Years: 1990-2018
Area type: Municipality
Area ranking measure: Poverty rate
Death data source: Cause of Death Registry
https://www.fhi.no/en/hn/health-registries/cause-of-death-registry/
and medical Birth Registry
https://www.fhi.no/en/hn/health-registries/medical-birth-registry-of-norway/
Death data access: Both registries are maintained by the Norwegian Public Health Institute (FHI) and are restricted to researchers with data use agreements only. Interested researchers can apply for data access from the maintainer by following their data application guide at https://www.fhi.no/en/more/access-to-data/applying-for-access-to-data/.
Population data source: Population Registry at Statistics Norway (SSB)
https://www.ssb.no/en/omssb/tjenester-og-verktoy/data-til-forskning/befolkning
Population data access: Data are restricted to researchers with data use agreements only. Interested researchers outside of Norway can apply for microdata access following the steps described at the SSB website
https://www.ssb.no/en/omssb/tjenester-og-verktoy/data-til-forskning.
Ranking measure data source: Statistics Norway
https://www.ssb.no/en/omssb/tjenester-og-verktoy/data-til-forskning/inntekt
Ranking measure data access: Data are restricted to researchers with data use agreements only. Interested researchers from outside of Norway can apply for microdata access following the steps described at the SSB website
https://www.ssb.no/en/omssb/tjenester-og-verktoy/data-til-forskning.

Portugal

Years: 1990-2018
Area type: Municipality
Area ranking measure: Deprivation index based on illiteracy, unemployment and hous-

ing conditions (three indicators are normalized and added) Death data source: Instituto Nacional de Estatistica -Mortality data
https://ine.pt/xportal/xmain?xpid=INE&xpgid=ine_main
Population data source: Instituto Nacional de Estatistica -Census and Estimated data
https://ine.pt/xportal/xmain?xpid=INE&xpgid=ine_main
Ranking measure data source: Instituto Nacional de Estatistica -Census data
https://ine.pt/xportal/xmain?xpid=INE&xpgid=ine_main

Spain

Years: 1990-2018
Area type: Municipality
Area ranking measure: Mean income
Death data source: Death Statistics microdata (INE)
https://ine.es/dyngs/INEbase/en/operacion.htm?c=Estadistica_C&cid=1254736177008&menu=ultiDatos&idp=1254735573002
Population data source: INE Continuous Register Statistics, results by municipalities (1996-2018)
https://ine.es/dyngs/INEbase/en/operacion.htm?c=Estadistica_C&cid=1254736177012&menu=ultiDatos&idp=1254734710990
and INE 1991 Population Census
https://ine.es/dyngs/INEbase/en/operacion.htm?c=Estadistica_C&cid=1254736176992&menu=ultiDatos&idp=1254735572981
Ranking measure data source: Household Income Distribution Map
https://www.ine.es/en/experimental/atlas/experimental_atlas_en.htm

United States

Years: 1990-2018
Area type: county
Area ranking measure: poverty rate
Death data source: US Vital Statistics
https://www.cdc.gov/nchs/data_access/vitalstatsonline.htm
Population data source: US Census bridged race
https://www.cdc.gov/nchs/nvss/bridged_race/data_documentation.htm#vintage2019
Ranking measure data source: US Census and ACS
accessed at www.socialexplorer.org