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Excess Mortality and Years of Potential Life Lost Among the Black Population in the US, 1999-2020

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IMPORTANCE Amid efforts in the US to promote health equity, there is a need to assess recent progress in reducing excess deaths and years of potential life lost among the Black population compared with the White population.

OBJECTIVE To evaluate trends in excess mortality and years of potential life lost among the Black population compared with the White population.

DESIGN, SETTING, AND PARTICIPANTS Serial cross-sectional study using US national data from the Centers for Disease Control and Prevention from 1999 through 2020. We included data from non-Hispanic White and non-Hispanic Black populations across all age groups.

EXPOSURES Race as documented in the death certificates.

MAIN OUTCOMES AND MEASURES Excess age-adjusted all-cause mortality, cause-specific mortality, age-specific mortality, and years of potential life lost rates (per 100 000 individuals) among the Black population compared with the White population.

RESULTS From 1999 to 2011, the age-adjusted excess mortality rate declined from 404 to 211 excess deaths per 100 000 individuals among Black males (*P* for trend <.001). However, the rate plateaued from 2011 through 2019 (*P* for trend = .98) and increased in 2020 to 395—rates not seen since 2000. Among Black females, the rate declined from 224 excess deaths per 100 000 individuals in 1999 to 87 in 2015 (*P* for trend <.001). There was no significant change between 2016 and 2019 (*P* for trend = .71) and in 2020 rates increased to 192—levels not seen since 2005. The trends in rates of excess years of potential life lost followed a similar pattern. From 1999 to 2020, the disproportionately higher mortality rates in Black males and females resulted in 997 623 and 628 464 excess deaths, respectively, representing a loss of more than 80 million years of life. Heart disease had the highest excess mortality rates, and the excess years of potential life lost rates were largest among infants and middle-aged adults.

CONCLUSIONS AND RELEVANCE Over a recent 22-year period, the Black population in the US experienced more than 1.63 million excess deaths and more than 80 million excess years of life lost when compared with the White population. After a period of progress in reducing disparities, improvements stalled, and differences between the Black population and the White population worsened in 2020.

Supplemental content

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In 1985, the US Department of Health and Human Services (HHS) Secretary Margaret M. Heckler issued the Report of the Secretary's Task Force on Black and Minority Health, also known as the Heckler Report.[1] The landmark report found that the Black population had strikingly higher mortality rates than the White population, resulting in almost 60 000 excess deaths a year relative to the White population. Race offers no intrinsic biological reason for those categorized as Black individuals to have worse outcomes than White individuals, indicating therefore that these disparities are driven by the burden of acquired risk factors, influence of social determinants of health, limitations in access to care, and structural barriers indicative of bias (ie, structural racism).[2-9] Although these static disparities in mortality were and have since been documented, the cumulative magnitude of compounded inequities has not been well articulated. Such metrics, as they relate to racial disparities, can both focus national efforts and communicate progress (or lack thereof).

The Heckler Report focused on excess mortality, as had prior seminal academic reports by Du Bois and others.[10-13] Although comparative death rates are a common way to describe one aspect of health inequity, they do not constitute a summary measure and do not convey the impact of differences in mortality across different age groups. Quantifying excess years of potential life lost provides a complemental and deeper measure of the differential burden of excess mortality as a function of race by giving more weight to deaths at younger ages, thus addressing the impact on the social and economic loss from early deaths.[14,15] Communicating the mortality inequity within a population in terms of excess number of people lost or excess years lost may create the more compelling case for change in the underlying causes of these disparities. However, there is little recent information on the trends in years of potential life lost by race, especially so in Black populations compared with White populations. Because these mortality metrics call attention to the aggregate burden of health inequities, addressing this knowledge gap could motivate national reporting of excess deaths and reporting of years of potential life lost among the Black population.

Accordingly, excess deaths and years of potential life lost as metrics are presented herein to quantify, track, and drive change in the effect of health inequities on lives and years lost, placing in bright relief the health consequences of race in the US. Importantly, these metrics may summarize the inequitable loss of life in a form that can be readily communicated to the general US public as key—though not sole—indicators of the overall societal progress toward health equity. Over the most recent 22-year period for which data are available, the difference in mortality and years of potential life lost rates were calculated between the Black population and the White population in the US. These disparities were also investigated by causes of death and how they varied by age. Besides focusing on the period before the COVID-19 pandemic, this analysis focused on 2020 to provide an early perspective on differences attributable to the pandemic. These metrics can draw attention to the magnitude of the disparities, thereby attracting resources and promoting action to address the unmet need for progress.[16]

This study focuses on differences in non-Hispanic Black and non-Hispanic White populations to understand recent trends in disparities between these 2 specific groups, with the non-Hispanic White population as the reference group. Nevertheless, subsequent studies using data from other racial, ethnic, and socioeconomic groups would be needed to have a complete understanding of mortality inequities in the US.

Key Points

Question How many excess deaths and years of potential life lost for the Black population, compared with the White population, occurred in the United States from 1999 through 2020?

Findings Based on Centers for Disease Control and Prevention data, excess deaths and years of potential life lost persisted throughout the period, with initial progress followed by stagnation of improvement and substantial worsening in 2020. The Black population had 1.63 million excess deaths, representing more than 80 million years of potential life lost over the study period.

Meaning After initial progress, excess mortality and years of potential life lost among the US Black population stagnated and then worsened, indicating a need for new approaches.

Methods

Data Source

We used national US death certificate data from the Centers for Disease Control and Prevention Wide-ranging Online Data for Epidemiologic Research (CDC WONDER) for the years 1999 through 2020.[17] For this period, we obtained the annual life expectancy by 5-year age groups from the National Center for Health Statistics life tables.[18] The Yale institutional review boards waived this study from review because it used deidentified population-level data that are publicly available; thus, it was designated as not human-participant research.

Study Population

We included data from the non-Hispanic Black or African American (hereafter Black) population and the non-Hispanic White (hereafter White) population. From CDC WONDER, the annual number of deaths, population size, and age-adjusted mortality rate (per 100 000 individuals) by race (Black, White), sex (female, male), and age were obtained. Also included were the 15 leading causes of death from 1999-2020 among both populations, separately, resulting in a total of 18 unique causes of death (eMethods, eTables 1, 2, and 3 in Supplement 1). For 2020 only, we also included deaths due to COVID-19.

Statistical Analysis

For all analyses, we stratified by sex and reported rates per 100 000 individuals. For each year, all-cause excess

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age-adjusted mortality rate was calculated by subtracting the year-specific age-adjusted mortality rate among the White population from that of the Black population. Similarly, the annual age-adjusted mortality rate ratio was estimated by dividing the age-adjusted mortality rate of the Black population by that of the White population.

Separately, to estimate the excess number of deaths, we estimated the annual age-specific mortality rate using 10-year age groups by race and then multiplied the White population age-specific mortality rate by the Black population size for that calendar year. Then, the hypothetical number of deaths among the Black population was divided by the Black population size to arrive at a hypothetical annual Black population mortality rate. We subtracted this hypothetical rate from the observed Black population mortality rate to arrive at the estimated excess age-specific Black population mortality rate, which we multiplied by the observed Black population size to obtain the total annual and 22-year cumulative number of excess deaths among the Black population.[19]

Then, we estimated the rate of annual years of potential life lost (defined as the number of years that a person would have lived had they not died when they did)[20] for each race by multiplying each 5-year age group's crude mortality rate by its respective annual sex- and age-specific life expectancy in years and obtaining the mean rate across all age groups. For both racial groups, year-, age-, and sex-specific White life expectancy was used as the referent metric (eTable 2 in Supplement 1).[18]

To assess the trends over the study period, we graphically assessed the relationship between each metric and study year. Based on this assessment, we used autoregressive integrated moving average models using a 1-year correlation and modeled time as a linear spline with knots that reflected the observed inflection points from 1999 through 2019 (eMethods in Supplement 1) and used a z test to estimate the 2019-2020 change. Separately, annual rates in age-adjusted excess deaths and years of potential life lost rates were calculated and visually evaluated by the leading causes of death (eMethods, eTable 1 in Supplement 1).

To estimate mortality differences by age, we combined all study years and used the average crude mortality rate for each 5-year age group and subtracted the age-specific mortality rate of the White population from that of the Black population. Similarly, to estimate the rate differences by age in years of potential life lost, we estimated the annual mortality rate for each age group, multiplied it by their respective annual sex- and age-specific life expectancy in years, and then estimated the mean rate of years of potential life lost for each age group across the entire study period. Lastly, changes in the relationship between age and the excess mortality rate and the years of potential life lost rate were visually assessed over the study period by analyzing separately data from 5-year periods.

Cause-of-death heatmaps were produced using Python version 3.7.[21-25] All statistical tests performed were 2-sided, with a level of significance of .05, using Stata SE version 17.0 (StataCorp).

Results

Temporal Trends in Racial Differences in Mortality and Years of Potential Life Lost Rates

From 1999 to 2011, the age-adjusted excess mortality rate declined from 404 to 211 excess deaths per 100 000 individuals among Black males (1999-2007, P for trend < .001; 2007-2011, P for trend < .001; **Figure 1**). However, the rate plateaued from 2012 through 2019 (P for trend = .98), with a subsequent single-year increase in 2020 to 395, rates not seen since 2000 (Figure 1). Among Black females, the estimated age-adjusted excess mortality rate declined from 224 excess deaths per 100 000 individuals in 1999 to 87 in 2015 (P for trend <.001; Figure 1). There was no significant change between 2016 and 2019 (P for trend = .71), but in 2020 rates increased to 192—levels not seen since 2005 (Figure 1). Although a similar pattern was observed in the total number of excess deaths, in 2020 the number of excess deaths among both Black males and Black females was higher than in any other year of the entire study period (79 801 and 47 545 excess deaths, respectively; eFigure 1 in Supplement 1). In relative terms, over the study period the age-adjusted mortality rate ranged from 21% to 40% higher among Black males and from 13% to 31% higher among Black females compared with their White counterparts (eFigure 2 in Supplement 1).

In 1999, the excess years of potential life lost for Black males and Black females were 14 964 and 10 806 per 100 000 people, respectively. There was a continuous decline until 2011 among males (P for trend < .001), and until 2012 among females (P for trend < .001; Figure 1). Then there was a plateau until 2019 for both groups (P for trend = .26 for males and P for trend = .90 for females), after which the rate of excess years of potential life lost increased in 2020 to rates similar to those of 2001 and 2005 among Black males and Black females, respectively (Figure 1). Although there was a reduction in absolute numbers of years of potential life lost from 1999 through 2019, in 2020 the total excess years of potential life lost reached its highest number among Black males (2 898 669 years) and reached numbers similar to those in 1999 among Black females (1 940 604 years; eFigure 3 in Supplement 1). The annual years of potential life lost rate ratio followed a similar pattern over the 22-year period (eFigure 4 in Supplement 1).

The rates of age-adjusted mortality and years of potential life lost are reported separately for the Black population and the White population in eFigure 5 in Supplement 1.

When analyzed by cause of death and year, the highest excess mortality rates among the Black population through the study period were due to heart disease (**Figure 2**). In both sex groups, excess mortality rates for leading causes of death (eg, heart disease, cancer, diabetes) generally decreased over the study period, except for deaths due to assault and cerebrovascular disease in Black males. There were similar patterns in rates of years of potential life lost, with the notable exception of perinatal deaths, which had the highest rates of years of potential life lost through the study period (Figure 2).

In 2020, the highest excess age-adjusted mortality rate among Black males was for deaths due to COVID-19 (80 per

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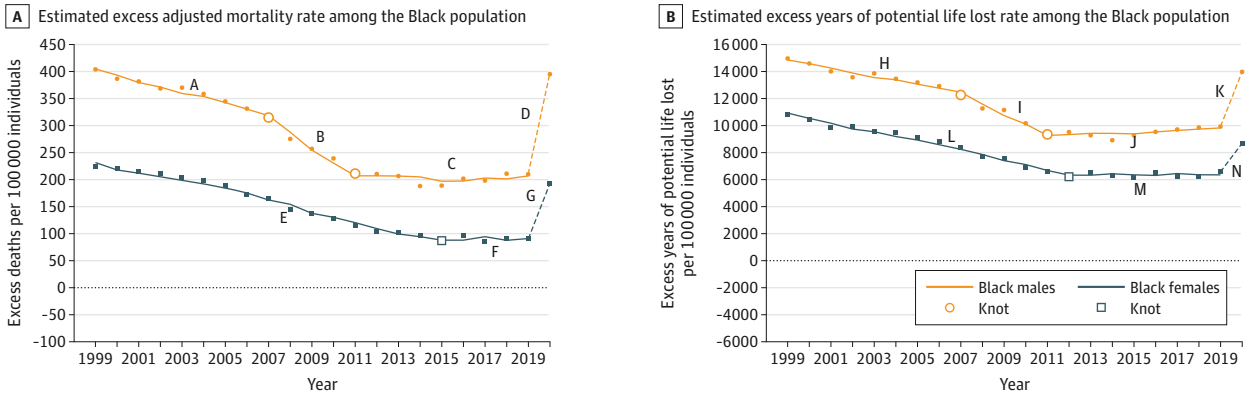
Figure 1. US Black Population Excess Age-Adjusted Mortality and Years of Potential Life Lost Rates, 1999-2020



Excess age-adjusted mortality rate

Period	Segment	Annualized rate of change (95% CI)	*P* value
Males			
1999-2007	A	-11.0 (-15.9 to -6.1)	<.001
2008-2011	B	-28.2 (-34.6 to -21.9)	<.001
2012-2019	C	-0.03 (-2.8 to 2.8)	.98
2020	D	185.3 (177.0 to 193.6)	<.001
Females			
1999-2015	E	-9.0 (-10.1 to -8.0)	<.001
2016-2019	F	0.9 (-3.9 to 5.8)	.71
2020	G	101.9 (96.3 to 107.5)	<.001

Excess years of potential life lost rate

Period	Segment	Annualized rate of change (95% CI)	*P* value
Males			
1999-2007	H	-304.2 (-389.5 to -218.9)	<.001
2008-2011	I	-797.6 (-952.0 to -643.2)	<.001
2012-2019	J	69.7 (-50.9 to 190.4)	.26
2020	K	4050.4 (2755.4 to 5345.5)	<.001
Females			
1999-2012	L	-349.7 (-389.6 to -309.8)	<.001
2013-2019	M	4.8 (-67.9 to 77.5)	.90
2020	N	2102.7 (904.3 to 3301.1)	<.001

To assess trends over time, the relationship between each metric and study year was graphically assessed, and time was modeled as a linear spline with knots that reflected the observed inflection points from 1999 to 2019. For excess mortality rates, these inflection points were from 2007 to 2011 for males and 2015 for females. For excess rates of years of potential life lost, the knots were 2007 and 2011 for males and 2012 for females. Rates that fall above the dotted line indicate rates higher than the White population and those that fall below, rates lower than the White population. Autoregressive integrated moving average models using a 1-year correlation were implemented to account for the serial correlation of annual rates. The 2019-2020 change was estimated using a *z* test.

100 000 individuals), whereas it was only second to heart disease among Black females (47 per 100 000 individuals). Similarly, the excess years of potential life lost due to COVID-19 (per 100 000 individuals) was 2572 among Black males and 1759 among Black females, in both groups ranking third below conditions from the perinatal period and heart disease (eFigure 6 in Supplement 1).

Cumulative 22-Year Excess Mortality and Years of Potential Life Lost Among the Black Population

From 1999 to 2020, the mean age-adjusted mortality rate among White males and females was 930.7 and 667.7, respectively, whereas among Black males and females it was 1214.9 and 816.3, respectively. There was a total of 997 623 estimated excess deaths among Black males and 628 464 excess deaths among Black females over the study period. The distribution of excess deaths by age group is shown in eFigure 7 in Supplement 1. The mean 22-year rate per 100 000 individuals of years of potential life lost among White males and females was 20 365 and 15 428, respectively, whereas among Black males and females it was 31 944 and 23 360, respectively. This represented an estimated total of 47 005 048 and 34 938 070 excess years of potential life lost among Black males and Black females, respectively.

Racial Differences in Rates of Mortality and Years of Potential Life Lost Rate by Age Group

Among those younger than 1 year, excessive deaths per 100 000 individuals among Black males were 776 and among Black females, 654. Such rates narrowed among those aged 1 to 14 years among males, and among those aged 1 through 20 years among females. The maximum excess death rate occurred among those between the ages of 75 and 79 years, reaching 1302 per 100 000 males and 677 per 100 000 females (**Figure 3**; eFigure 8 in Supplement 1). The greatest difference in years of potential life lost rate between the Black population and the White population was among those younger than 1 year (59 232 per 100 000 Black males and 53 061 per 100 000 Black females), decreasing to its minimum among those between the ages of 1 and 14 years. Consistent with the excess mortality pattern, the rate of excess years of potential life lost increased with age among males older than 15 years and among females older than 20 years, increasing up to those aged 65 to 69 years old and decreasing among those older (Figure 3; eFigure 9 in Supplement 1). The strength of the association between age and the rates of excess mortality and years of potential life lost shifted lower from 1999 through 2018, increasing again in 2019-2020, particularly among middle aged and older adults (eFigure 10 in Supplement 1).

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Figure 2. US Black Population Excess Age-Adjusted Mortality and Years of Potential Life Lost Rates by Leading Causes of Death, 1999-2020

Excess mortality or the years of potential life lost rates were defined as the difference in each year's mortality rate or years of potential life lost rate between the Black population and the White population. All rates are estimated per 100 000 individuals. Presented herein are the 22-year leading causes of death among both populations (details are in the Methods section). For visualization purposes, causes of death are presented in descending order based on the mean 22-year excess mortality rate among Black males. An excess mortality rate or years of potential life lost rate of 0 is shown in white and represents the absence of a difference. In shades of red are the annual metrics for which the Black population estimates were higher than those of the White population. In shades of blue are the annual metrics for which the White population estimates were higher than those of the Black population.

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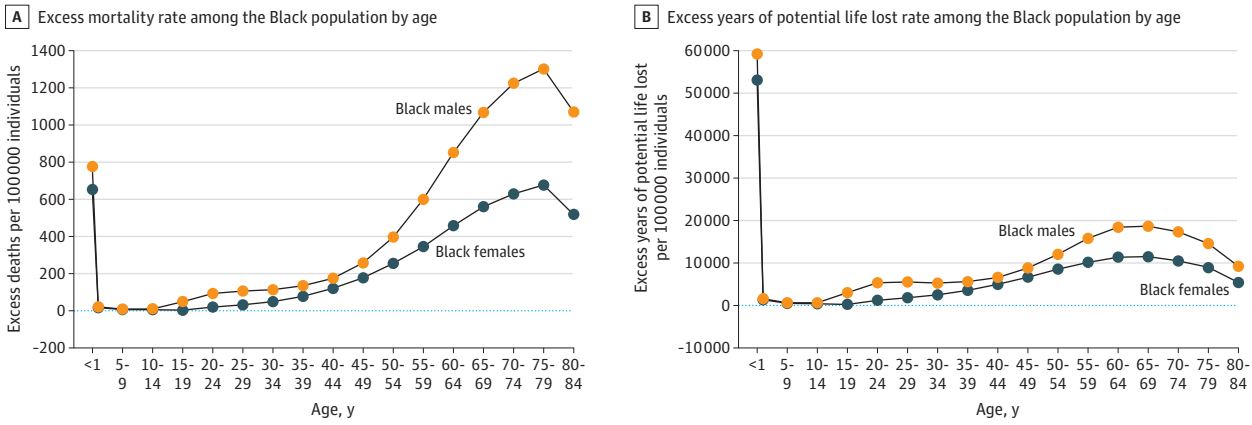
Figure 3. US Black Population Excess Mortality Rate and Years of Potential Life Lost by Age Group



Excess mortality rates among the US Black population by age group were calculated by subtracting the mortality rate of the White population from that of the Black population. Excess years of potential life lost rates among the US Black population were defined as the difference in years of potential life lost within each age group between the Black population and the White population. An excess mortality or years of potential life lost rate of 0 represents the absence of a difference. Rates were estimated per 100 000 individuals. Rates that fall above the blue dotted line indicate rates higher than the White population and those that fall below, rates lower than the White population.

Discussion

In this study of US mortality data from 1999 through 2020, an estimated 997 623 excess deaths occurred among Black males and 628 464 excess deaths among Black females relative to their White counterparts—accounting for a total of 1.63 million excess deaths. These excess deaths corresponded to a total of 47 million and 35 million excess years of potential life lost among Black males and Black females, respectively. After a period of progress from 1999 to the early 2010s, improvements stalled at least through 2020 when, coincident with the first year of the pandemic, the number of excess deaths increased abruptly and exceeded that of any previous year of the study. Moreover, even at the lowest of excess of deaths and years of potential life lost there were more than 50 000 annual excess deaths and 3 million annual excess years of potential life lost among the Black population compared with the White population. Differences in loss of life were most prominent among infants, with Black-White mortality and years of potential life lost rate ratios greater than 2.3 among those younger than 1 year old. Heart disease in both sexes and cancer in males were the largest drivers of differences in excess deaths. Broadly, these findings indicate that current efforts to curb or eliminate mortality disparities have been minimally effective, and progress, when made, has been fragile.

This study should serve as a call to action—especially for policy makers—as we highlighted and contextualized the substantial toll of structural racism on life in the US. Although the specific causes and drivers of differences in deaths and years of potential life lost are multifactorial and warrant further study, the sheer scale of the difference requires a revisiting of our national approach to combatting disparities. A wealth of prior work, however, points to the contribution of structural racism, unmet social needs, and systemic bias as root causes.[2-5] This study also demonstrated that a brief period of progress stalled and disparities substantially worsened at the onset of and well into the early pandemic. Although this study was not equipped to address the long-term effect of the pandemic on racial disparities, these early trends are consistent with the fear that the pandemic both disproportionately attacked populations experiencing structural inequities and increased existing disparities. The increase in excess mortality among the Black population relative to the White population during the pandemic was so large that it reached levels not seen in the prior 2 decades. In addition to pandemic-specific factors (eg, disproportionately higher infection exposure, financial instability, food insecurity, psychological distress), the pervasive social factors that contributed to such high vulnerability among the Black population include persistently higher barriers to health care, higher prevalence of multimorbidity, and worse average health status.[6,7,26] Overall, these findings demonstrate the potential for progress but indicate the fragility of the gains and herald a need for new approaches to ensure sustainability of advancements.

Prior studies have found persistently large numbers of excess deaths among the Black population but have not explicitly quantified excess years of potential life lost, nor have they measured excess deaths over a recent period. A study found that the disparity in mortality rates between the Black population and the White population remained mostly stable from 1960 to 2000, and another report estimated that 2.7 million excess deaths occurred among the Black population from 1970 to 2004.[27] A separate study found that from 1990 to 2000, the decade leading to the current study period, nearly a million deaths among the Black population would have been averted had their mortality rates been comparable with those of the White population.[19]

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We found that excess mortality declined substantially from 1999 through the early 2010s, consistent with other studies of Black and White mortality rates.[28,29] In the current study, there were no substantial increases in all-cause age-adjusted mortality rates for White males and females. These observations could indicate the success of efforts toward reducing disparities. However, the disproportionately higher increases in mortality among White younger adults in the 2000s[30-32] could also marginally contribute to the narrowing of these disparities.

In addition, studies have described disparities in the COVID-19 pandemic toll by comparing the observed mortality rates during this period and the expected mortality rates for specific populations based on recent temporal trends.[33-35] This study places the pandemic toll in context of rates of excess mortality and years of potential life lost as additional metrics of racial disparity that may be useful should another pandemic-type public health calamity occur.

The excess deaths and years of potential life lost were elevated among most of the major causes of death, even though heart disease was the most prominent. This is consistent with a study by Kyalwazi and colleagues[36] who found that, despite a decline in the absolute difference, age-adjusted cardiovascular mortality rates were persistently higher among the Black population than among the White population from 1999 to 2019. It is likely that disparities in rates of hypertension control and other factors associated with heart disease are in part responsible for this excess loss of life.[37,38] Cancer was also an important source of the disparity. Both heart disease and cancer have modifiable risk factors that are importantly affected by social determinants of health. Targeted and renewed efforts aimed at diseases that disproportionately drive differences are necessary to make sure clinical advancements are experienced uniformly across the population.

The sobering disparity noted in this study among infants and during childhood accounted for a markedly elevated number of excess deaths and an even more pronounced disparity in years of potential life lost. This excess mortality occurred in a period of life of highest vulnerability and warrants new dedicated public health initiatives targeting early childhood health. After childhood, the excess deaths and years of potential life lost became evident in early adulthood and generally increased with age. This finding is consistent with a recent report by the National Academies of Sciences, Engineering, and Medicine that found consistently higher mortality rates among Black adults aged 25 through 65 years from 1990 to 2017 compared with other racial and ethnic groups of the same age, despite increasing trends among their White counterparts and regardless of educational attainment or geography.[32,39] These alarming excess deaths in working-aged groups may be the most socially disruptive[15] given the destabilizing effect on productivity and economic gains for Black families, potentially contributing to the perpetuation of generational racial disparities. Among those older than 65 years, these disparity metrics declined, as would be expected because of the persistently lower average lifespan among the Black population.[40,41]

The implications of these findings are important. The Black population in the US, regardless of cause or the burden of risk factors, continue to die at much greater rates than the White population, with dramatic long-run consequences when accounting for the effect of premature mortality. These metrics, especially years of potential life lost, are suitable for public reporting and may inspire strategies directed toward more in-depth root-cause analysis and where qualified by evidence of efficacy, implementation of steps to improve these disparities. As such, an annual publicly reported metric of race-based years of potential life lost may be useful for national accountability. Excess mortality and years of potential life lost by race could serve as a major national (and local) gauge of progress toward achieving health equity. Although achieving equity in these metrics may need persistent multigenerational efforts, it is crucial to advance rapidly in that direction.

Limitations

Our study has limitations. First, there are known inaccuracies in race and ethnicity information reported in death certificates.[42,43] However, there is near complete agreement between self-reported race and the race reported in non-Hispanic Black and non-Hispanic White decedents' death certificates.[44] Second, the cause of death may be uncertain in many cases, especially during the pandemic, but that does not detract from our central findings of a sustained major difference in mortality. Third, the CDC WONDER does not provide rates or population estimates for subsamples of decedents 85 years or older, which prevented evaluation of some disparities in these age groups. Fourth, although there may be differences in mortality rates by country of origin, such data are not publicly available for incorporation in these analyses.

Conclusion

Excess deaths and years of potential life lost among the US Black population persist and by scale warrant national attention. Over a recent 22-year period, the US Black population experienced 1.63 million excess deaths and much greater losses in years of potential life. Although encouraging gains were noted in the early 2000s, the disparities abruptly increased in 2020 and years of potential life lost replicated 1999 benchmarks. The call to action generated more than 100 years ago from Du Bois and echoed nearly 40 years ago by the Heckler Report remains extant today. With millions more lives and life-years at stake, new strategies are needed.

ARTICLE INFORMATION

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Correction: This article was corrected on August 28, 2023, to change the y-axis label on the B panel of Figure 2 to "Excess deaths per 100 000 individuals."

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Author Contributions: Dr Caraballo had full access to all of the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis.
Concept and design: Caraballo, Massey, Nunez-Smith, Watson, Faust, Krumholz.
Acquisition, analysis, or interpretation of data: Caraballo, Massey, Ndumele, Haywood, Kaleem, King, Liu, Lu, Taylor, Watson, Herrin, Yancy, Faust, Krumholz.
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Statistical analysis: Caraballo, Massey, Kaleem, Liu, Lu.
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Administrative, technical, or material support: Ndumele, Kaleem, Nunez-Smith, Watson.
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Conflict of Interest Disclosures: Dr Haywood reported that he is the chief medical officer of Zing Health and had served as deputy chief medical officer for the Centers for Medicare & Medicaid Services, Blue Cross Blue Shield Association, and Vizient. Dr Taylor reported serving as an advisor and consultant for UnitedHealth Group, Pfizer, and Novartis. Dr Yancy reported spousal (former) employment at Abbott Labs, Inc. Dr Krumholz reported receiving personal fees from UnitedHealth, Element Science, Eyedentifeye, and F-Prime; being a cofounder of Refactor Health and HugoHealth; and being associated with contracts, through Yale New Haven Hospital, from the Centers for Medicare & Medicaid Services and through Yale University from the US Food and Drug Administration, Johnson & Johnson, Pfizer, and Google. No other disclosures were reported.

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