MAX PLANCK INSTITUTE
FOR DEMOGRAPHIC RESEARCH

Konrad-Zuse-Strasse 1 · D-18057 Rostock · Germany · Tel +49 (0) 3 81 20 81 - 0 · Fax +49 (0) 3 81 20 81 - 202 · www.demogr.mpg.de

MPIDR Working Paper WP 2021-023 I December 2021
Revised November 2022
https://doi.org/10.4054/MPIDR-WP-2021-023

U.S. Racial/Ethnic Mortality Gap Adjusted for Population Structure

Héctor Pifarré i Arolas I hparolas@lafollete.wisc.edu
Enrique Acosta
Christian Dudel
Jo Mhairi Hale
Mikko Myrskylä

U.S. Racial/Ethnic Mortality Gap Adjusted for Population Structure

Héctor Pifarré i Arolas,[1,2,*] Enrique Acosta,[3] Christian Dudel,[3,4] Jo Mhairi Hale[3,5] and Mikko Myrskylä[4,6]

[1]La Follette School of Public Affairs, University of Wisconsin—Madison, Madison, WI, United States of America,

[2]Center for Demography and Ecology, University of Wisconsin–Madison, Madison, WI 53706,

[3]Max Planck Institute for Demographic Research, Rostock, Germany, [4]Federal Institute for Population Research, Wiesbaden, Germany, [5]School of Geography and Sustainable Development, University of St Andrews, St Andrews, Scotland, [6]Center for Social Data Science and Population Research Unit, University of Helsinki, Helsinki, Finland

[*]Corresponding author. La Follette School of Public Affairs, University of Wisconsin—Madison, Madison, WI 53706, United States of America. E-mail: hparolas@lafollette.wisc.edu

Funding

EA received funding from the Social Sciences and Humanities Research Council (Canada) - Postdoctoral grant No. 756-2019-0768, and the Fonds de recherche du Québec – Société et culture - Postdoctoral grant No. 274299. Support for this research was provided to HPA by the University of Wisconsin-Madison, Office of the Vice Chancellor for Research and Graduate Education with funding from the Wisconsin Alumni Research Foundation.

Data availability

All data and code to fully reproduce the analyses are available at the OSF: https://osf.io/hj8g3 .

Author contributions

HPA and MM contributed to conceptualization, methodology, writing the original manuscript, and review and editing. HPA conducted formal analysis, supervision. EA contributed to methodology, formal analysis, data curation, visualization, and review and editing. CD contributed to methodology, formal analysis, and review and editing. JMH contributed to writing and editing the manuscript.

Conflicts of interest

None declared.

U.S. Racial/Ethnic Mortality Gap Adjusted for Population Structure

Abstract

Background: U.S. racial/ethnic mortality disparities are well-documented and central to debates on social inequalities in health. Standard measures, like life expectancy or years of life lost, are based on synthetic populations and do not account for the real underlying populations experiencing the inequalities.

Methods: We analyze U.S. mortality disparities comparing Asian Americans, Blacks, Hispanics, and Native Americans/Alaska Natives to Whites using 2019 CDC and NCHS data. We develop a novel approach that estimates the mortality Gap, Adjusted for Population structure (GAP) by accounting for real-population exposures. GAP is tailored for analyses where age structures are a fundamental component, not merely a confounder. We highlight the magnitude of inequalities by comparing GAP against standard metrics' estimates of loss of life due to leading causes of death.

Results: Based on GAP, Black and Native American mortality disadvantage is as deadly or deadlier than circulatory diseases (U.S. top cause of death); and is overall 72% (Men: 47%, Women: 98% women) and 65% (Men: 45%, Women: 92%) larger than life-expectancy measured disadvantage. Asian Americans and Hispanics have, according to GAP, a mortality advantage over Whites that is over three (Men: 176% , Women: 283%) and two times (Men: 123%, Women: 190%) larger than that based on life expectancy, respectively.

Conclusions: Mortality inequalities based on standard metrics' synthetic populations can differ markedly from GAP estimates. We demonstrate that standard metrics underestimate racial/ethnic disparities through disregarding actual population age structures. For health policy, exposure-corrected inequalities such as GAP may provide a more reasonable signal on where to allocate scarce resources.

Key words: racial disparities, mortality, age structure, exposure

Introduction

Racial/ethnic disparities in mortality in the U.S. are large and persistent, despite the recent narrowing of the gap between Black and White Americans.[1] The standard indicators for measuring and monitoring these inequalities include life expectancy and years of life lost. By design, these indicators are based either on synthetic populations in which age structure is implicitly derived from the mortality schedule of the observed population or, in the case of years of life lost, on standard populations. That is, these measures disregard differences in the actual population age structures when comparing mortality experiences across populations. This feature may be highly beneficial in contexts in which the underlying differences in real population age structures are considered a nuisance to the analysis.[2] For health policy, however, measures that account for population size and structure may be helpful in providing a signal on where to allocate scarce resources. Insofar as mortality disparities inform social and health policy priorities, and greater inequalities demand more attention, identifying the extent to which some racial groups experience a mortality disadvantage should aid in guiding policy.

Ignoring the actual age structure of populations can result in misleading conclusions in some contexts. The current COVID-19 pandemic offers a salient example, illustrated by the following thought experiment. Consider two cruise ships with populations from the same country; both cruises carry individuals from all ages, but one has a relatively young population , while the other is populated mostly by retirees. In which ship is a COVID-19 outbreak more threatening? Given that the risk of complications and death after infection increase exponentially with age,[3,4] we expect it to be the latter. However, the loss of life as measured by the life expectancy reductions would be identical. This is because changes in life expectancy are determined by the pre-outbreak age-specific mortality rates and the age-specific COVID-19-related increase in mortality, which are shared across scenarios. The actual age structures play no role even though we know that, everything else equal, older populations are bound to be more heavily afflicted by the pandemic.[5] Thus, an assessment of the loss of life from COVID-19 that is based on life expectancy would not detect this age-structure related vulnerability. This shortcoming is known,[6] but often not sufficiently acknowledged; in our analysis we demonstrate its implications for the evaluation of racial/ethnic mortality disparities.

A key alternative summary measure to life expectancy is years of life lost (YLL), which is commonly used to assess the relative importance of specific causes of death within a population and thus guide public health interventions.[7] Years of life lost are the sum of the years between the age at which death occurs and the age at which

we would expect death to occur.[8,9] Years of life lost measures are directly age-standardized for cross-population comparisons, using a shared population age structure.[9] This is not without controversy, as there is no generally agreed-upon objective way to choose the standard population, and results may vary strongly depending on the standard,[10] affecting not only the magnitude of disparities but even their direction.[11] The limitations of direct standardization have been acknowledged to be particularly relevant in racial inequality assessments, given the existing differences in age structures across racial/ethnic groups.[12,13] Thus, direct standardization is a partial solution at best.

These two approaches feature prominently in the current literature on population level racial/ethnic mortality disparities . Life expectancy differences have been frequently used to evaluate U.S. trends in racial/ethnic mortality disparities,[1,14,15,16] as well as its geographic patterns.[17] This approach has also been applied to document the disproportionate impact of the COVID-19 pandemic on racial/ethnic minorities in the U.S.,[18] resulting in greater life expectancy disparities.[19] In turn, years of life lost have been used to assess the cause-specific differentials in mortality that result in the overall racial/ethnic mortality disparities. More recently, this framework has also been applied to assess loss of life inequalities during the pandemic.[20,21] This aligns with prior work that evaluates contributions of leading causes to over racial/ethnic disparities using YLL,[22] as well as more targeted work that has focused on specific causes of death and risk factors, such as alcohol consumption,[23] cancer[24] and skin cancer,[25] HIV,[26] among others. All of the above rely either on direct standardization, often based on the 2000 U.S. standard population or, in the case of life expectancy, synthetic population structures that are implied by mortality rates.

We propose a novel measure for evaluating mortality inequalities that accounts for the *actual* age structures of the populations. Our starting premise is that mortality rate differences are based on mutable social inequities, such material deprivation or unequal access to care. Based on this, we suggest a counterfactual approach that is closely related to existing methods, such as indirect standardization and well-established decomposition approaches.[27] We formulate the counterfactual by asking to what extent mortality conditions would improve or worsen for a given racial/ethnic population, given their age composition, if they were to experience non-Hispanic White age-specific mortality rates (our baseline). From a technical perspective, we differ from previous studies that assess racial mortality inequality using indirectly standardized measures by differentially weighting deaths by remaining life expectancy.[28]

However, we believe our primary contribution is conceptual. We explicitly analyze the role of age composition, whereas the literature is dominated by approaches that treat age composition purely as a confounder. Current age-structure related adjustments implicitly or explicitly use age structures that differ from those of real populations. This is clearly the case for measures based on direct standardization, but it also applies to life expectancy comparisons. The life table contains an implicit population age structure; that is, the age-structure that would occur for a population with current mortality rates and no growth rate (just replacement). In that sense, life expectancy can be interpreted as the mean age at death of that synthetic population. These deviations from real population age structures come at a cost, as illustrated by the examples in this introduction.

We employ a life table approach, similar to much of the literature on racial/ethnic mortality differentials. Accordingly, exposures are defined as the population at risk of dying during an age interval, measured in person years. The main difference is that our adjustment procedure then corrects for the age structure of the real population by using its age-specific exposures and weighting mortality risks accordingly; i.e., our method is exposure-corrected. That is, while other methods are based on synthetic populations, our correction uses the *actual population age structure* in the definition of the at risk populations. Exposure adjustments are especially relevant in the assessment of racial/ethnic mortality disparities given the substantial differences in age structures across racial/ethnic groups.

We demonstrate this new measure with a case study evaluating contemporary mortality inequalities in the U.S. among Hispanics, non-Hispanics who are American Indian/Alaska Native (AIAN), Asian American, non-Hispanic Blacks, and non-Hispanic White. To highlight the magnitude of the differences among measures, we compare our measure of exposure-corrected inequalities to the inequalities estimated when using life expectancy and standardized years of life lost. Our findings suggest that standard demographic indicators underestimate the mortality inequalities in the U.S. because they disregard actual population age structures when comparing mortality experiences across populations. The results based on the novel indicator, which we call the Gap Adjusted for Population structure (*GAP*), suggest that inequalities are substantially larger than standard demographic methods would imply.

Methods

Standard measurement of the racial/ethnic mortality gap

The object of interest of this study, the racial/ethnic mortality gap, is measured as the difference between given mortality indices across two racial/ethnic groups (*A,B*). For life expectancy, this is simply:

$$\Delta e_0^{A,B} = e_0^A - e_0^B (1)$$

where e_0^G stands for the life expectancy at birth of group *G*. Another common strategy is based on the years of life lost (YLL) framework.[8,9] While typically YLL are used to assess cause-related mortality, they can also be utilized to assess the mortality gaps. The standard approach calculates YLL per death as the difference between the age at death and remaining life expectancy at that given age. At a population level, they are often expressed in rates (per 100k):

$$YLL_G = \sum_x m_x^G \cdot e_x \cdot C_x^G \cdot 100000 \qquad (2)$$

where m_x^G, e_x, C_x^G are the mortality rates, standard remaining life expectancy (based on some standard; we use best practices, more details on that in the data section), and exposures at age x, respectively. In cross-population comparisons a reference standard population (C_x^S) is often used; we denote this variant of YLL the $sYLL$. Based on $sYLL$ the mortality gap between two populations is:

$$\Delta sYLL_{A,B} = sYLL_A - sYLL_B \qquad (3)$$

A counterfactual approach to mortality inequality

We propose a counterfactual method to the measurement of mortality disparities. The basic idea, in the spirit of indirect standardization methods, consists of measuring the disparity between a population A and its reference B as the mortality change for A that would result from attaining B's mortality rates while holding constant A's age structure. We embed this calculation in the standard years of life lost (YLL) approach. We call this indicator the Gap Adjusted for Population structure (*GAP*). We operationalize this idea in the following manner. Instead of using direct age-standardized YLL ($sYLL$), we compute a counterfactual YLL ($cYLL$), with A's age structure and B's mortality rates.

$$cYLL_A = \sum_x m_x^B \cdot e_x \cdot C_x^A \cdot 100000 \quad (4)$$

Then, we measure the mortality gap as the difference between $cYLL$ and the actual YLL, i.e. the YLL at both A's current mortality rates and age structure of exposures; that is, the *GAP* ($\Delta cYLL$) is the difference between (2) and (4).

$$\Delta cYLL_{A,B} = YLL_A - cYLL_A = GAP_{A,B} \quad (5)$$

Thus, a positive *GAP* (5) shows how many years of life are lost (a "disadvantage") and a negative *GAP* how many years are gained (an "advantage") relative to a reference population's mortality. This age-structure-dependent measure of mortality differences can then be used as the foundation to study the racial/ethnic mortality disparity, without arbitrarily choosing a population for (direct) age standardization.

Similar counterfactual approaches are frequently used in demography, epidemiology, and public health. Our proposal follows the logic of indirect standardization methods.[29] Indirect standardization measures, such as the standardized mortality ratio (SMR), compare observed death counts to a counterfactual based on the actual population age structure and the reference population's mortality rates. We embrace this approach, which is often but not exclusively used in data-sparse situations, and extend it to consider the age gradient of the loss of life accrued by deaths. That is, the loss of life accrued to age-specific deaths in our measure is based on remaining life expectancy, whereas the SMR implicitly weights each death equally (regardless of age). How can these counterfactual mortality rates be understood? Mortality disparities are rooted in mutable social inequities, such as socioeconomic disparities and racial discrimination. For example, the approximately double infant mortality rates Blacks suffer compared with Whites[30] have been tied to access to care,[31] race-related biases at treatment,[32] and other social factors.[33] Thus, it is conceivable that disadvantaged racial/ethnic groups might achieve the lower mortality rates of the more advantaged. This is our counterfactual.

Intuitively, there may be a tendency to place more importance on mortality risks affecting larger fractions of the population. In the infant mortality rate example above, for a group with a young population with high fertility rates, reducing infant mortality could represent a greater reduction in loss of life than improving mortality rates at the upper end of the mortality distribution. And the contrary could be true for a relatively older population group, as in the COVID-19 example above, where focusing more resources on COVID-19 prevention and treatment could lead to fewer YLL. Thus, adjusting for the actual age structure of the population may lead to a greater understanding

of how to prioritize public health interventions to reduce loss of life. Our measure, the *GAP*, allows us to evaluate these trade-offs.

Comparisons to other approaches

In order to compare our results to those of existing methods measuring the mortality gap using life expectancy (Δe_0) or standardized YLL ($\Delta sYLL$), we normalize each measure by dividing it by the (race/ethnicity specific) loss of life from leading causes of death. Note that this normalization is not necessary for interpreting *GAP* alone, but this is useful for comparative purposes. First, it serves as a reference for the magnitude of the *GAP*,[2] by comparing it with important causes of death (COD) with which we are already familiar. Second, it facilitates the comparison of the gap across metrics that use different units of measure. The importance of these causes of death within a racial/ethnic group is assessed using standard approaches; for e_0, we use a cause-deleted life table approach[11] and for YLL, we compute the YLL associated with each COD.[8,9]

The *GAP* measures mortality gaps through counterfactuals based on examining actual populations with alternative mortality rates. In contrast, both Δe_0 and $\Delta sYLL$ evaluate the mortality disparities for counterfactuals based on synthetic populations with actual mortality rates. In the case of $\Delta sYLL$, it captures the mortality inequalities that would exist should all races/ethnicities share the age structure of a reference population (e.g., the U.S. standard population). In turn, Δe_0-based assessments can be given a population interpretation, whereby differences in life expectancy at birth between specific populations are the disparity in mean ages at death in their respective stationary populations. Therefore, both approaches evaluate mortality disparities in synthetic or theoretical populations which may not reflect the disparities that occur in the actual populations.

Figure 1 illustrates the differences in age structure by race/ethnicity and gender between the real U.S. population and the U.S. standard and the life table populations. For instance, compared to the actual age distribution of the total White population in 2019, the proportion of those under one year of age is 39% and 27% larger in the U.S. standard and life table populations, respectively. Asian American, AIAN, Hispanic, and Black actual populations are younger than the standard and life table populations suggest (more so in the Asian American and Hispanic cases), whereas the reverse is true for Whites. The gender-specific age structures show patterns that are, generally speaking, aligned with those of their respective racial/ethnic groups.

Data

Life tables for year 2019 by single year of age, sex, race, and Hispanic origin were retrieved from the National Center for Health Statistics (NCHS) Life Tables website's public files.[34] Death counts for 2019 by cause, single-year of age, sex, and bridged race and Hispanic origin were obtained from the Underlying cause of death data, available through the CDC WONDER Online Databases.[35] Causes of death were defined following the 10th revision of the International Statistical Classification of Diseases (ICD-10). The U.S. standard population and U.S. population estimates by single year of age (0, 1, 2,..., 85 years and over), abridged race, Hispanic origin, and sex, on July 1, 2019, were taken from the abridged-race intercensal estimates of the resident population of the United States website.[36] Standard life expectancies by single year of age and a 85+ open-ended age interval were taken from the WHO.[8,9] For the exposure adjustment, we use age-specific exposures taken from the Human Mortality Database,[37] and combine them with the racial/ethnic distribution by age to calculate race- and age-specific exposures.

Application

We use the GAP to re-analyze contemporary racial/ethnic mortality inequalities in the U.S.. We compare non-Hispanic American Indian or Alaska Native, non-Hispanic Asian Americans, non-Hispanic Blacks, non-Hispanic Whites, and Hispanics (irrespective of race) to non-Hispanic Whites (each group compared to non-Hispanic Whites). We use circulatory diseases (ICD codes I00-I99), the leading cause of death in the U.S., for normalizing disparities. Table 1 displays all the elements of these calculations and the results. We divide the mortality difference calculated according to each approach (Table 1, column 4) by the loss of life from a cause of death (Table 1, column 5). For Blacks, the normalized mortality disparity is interpreted as "the mortality disadvantage of Blacks compared to Whites is X times as much loss of life as circulatory diseases." That is, from the perspective of Blacks, achieving White mortality across all ages would result in an overall reduction in loss of life X times the gain from eliminating circulatory diseases. Realistically, the former intervention would likely involve improving in a variety of causes of death. Hispanics and Asian Americans have lower mortality than Whites, so the ratio captures the mortality advantage of Hispanics and Asian Americans. We calculate similar relative metrics based on Δe_0 and $\Delta sYLL$. In addition to circulatory diseases, we also normalize disparities with the following four leading causes of death in the U.S.: cancers (ICD codes C00-D48), external causes (V01-Y89), respiratory diseases (J00-J98), and diseases of the nervous system (G00-G98).

Results

Figure 2 (Panel A) shows the mortality disparity for all groups but Whites (our baseline) based on life expectancy (Δe_0), the direct age standardized (using the U.S. standard population) YLL ($\Delta sYLL$), and the *GAP* ($\Delta cYLL$). Each point represents the ratio of the racial/ethnic disparity to the gains from removing circulatory diseases. We find that, across race/ethnicity and gender, mortality disparities based on GAP are larger than those captured by Δe_0.

The Black/White disparity in Δe_0 is two thirds (0.67) the size of the loss of life expectancy from circulatory diseases for the total Black population. However, based on YLL – both $\Delta sYLL$ and GAP – the racial disadvantage is as deadly as the leading COD (1.07 and 1.15). That is, the Black/White racial disparity is 72% (1.15/0.67) larger based on our approach. In the same way, AIAN/White disparities, already deadlier than circulatory diseases according to Δe_0 (1.5), increase 65% (2.48/1.5) based on the GAP.

For racial/ethnic groups with a mortality advantage over Whites, the disparities are also markedly larger as measured by the *GAP*. The Hispanic mortality advantage based on $\Delta sYLL$ and GAP (1.24 and 1.39) is more than two times larger than what the Δe_0-based metric implies (0.57). In the case of Asian Americans, the mortality difference as measured by GAP (3.85) is more than triple the amount Δe_0 indicates (1.19), with respect to the loss of life from circulatory diseases.

In some cases $\Delta sYLL$ and GAP differ substantially. For instance, for Hispanic men compared with White men, $\Delta sYLL$ indicates that ethnic disparities are roughly as deadly as circulatory diseases (1.01), while the GAP indicates that ethnic disparities are considerably larger (1.18). The extent to which real age structures differ from those of the life table or the standard population plays a role in the differences between methods, with larger deviations in age structures resulting in larger disparities in the resulting gaps. The Asian American, Hispanic, and AIAN populations deviate the most (across races/ethnicities) from synthetic age structures, and we find large differences between our method and existing approaches.

Gender specific results

When interpreting race/ethnicity and gender specific results, we note that the difference to cause ratio will depend on both the gender-specific importance of the reference cause of death and of the gender racial mortality gap itself. Thus, for a given racial/ethnic group, a given gender may have a larger mortality gap, but a smaller difference to cause ratio. This is not a limitation intrinsic to the *GAP*, but rather a consequence of the normalization undertaken to facilitate the interpretation of the magnitudes with respect to other approaches. This consideration plays a role in the gender specific results across races/ethnicities.

For this reason, direct comparisons of the mortality difference (Table 1, column 4) across genders are also informative. We find, based on GAP, that the mortality advantage for Asian Americans and Hispanics is larger for males than for females, and the mortality disadvantage for Blacks and AIAN is more pronounced for males. This is aligned with the findings based on Δe_0 for most racial/ethnic groups, with the exception of Hispanics. The Hispanic mortality advantage as measured by GAP (Table 1, column 4) is larger for males than for females (-2997 and -2722, respectively), whereas an evaluation based on Δe_0 indicates that males (-2.73) have a smaller life expectancy advantage over females (-3.17).

Nonetheless, an analyst may also be concerned with the magnitude of the gender-specific racial gap with respect to the within gender circulatory diseases mortality; i.e. the difference to cause ratio (Table 1, column 6). Overall, results based on GAP indicate larger disparities than those based on Δe_0 for both genders. In that regard, the mortality advantage for Asian Americans is 283% (4.10/1.07) and 176% (3.56/1.29) larger, for females and males respectively, than the disadvantage as measured by Δe_0. Similarly, the Hispanic advantage is 190% (1.71/0.59) larger for females and 123% (1.18/0.53) larger for males than life expectancy-based disparities would imply. For racial/ethnic groups experiencing a mortality disadvantage, we also find larger disparities based on GAP. The Black mortality disadvantage is also larger based on GAP, 47% (1.29/0.88) for males and 98% (1.03/0.52) for females. Finally, we find similar patterns for AIAN, with larger disadvantages for both males, 45% (2.34/1.61), and females, 92% (2.74/1.43).

Comparison to other leading causes of death

In Figure 2 (Panel B) we normalize by the five leading causes of death in the U.S. to assess whether our results are idiosyncratic to circulatory disease or demonstrative of a pattern. We find that racial/ethnic disparities based on existing approaches (Δe_0, $\Delta sYLL$) are smaller across almost all causes of death. The only exception is external causes, particularly for Hispanics, for which the disparity is larger based on Δe_0 than on our approach. This is because, like racial/ethnic disparities, loss of life due to external causes is also under-valued by current approaches, especially for Hispanics. This is because it is the combination of a cause with higher mortality at early ages and a considerably younger subpopulation than the U.S. standard or life table populations suggest (see Figure 1).

The size of the mortality difference, as measured by other leading causes of death, varies substantially by race/ethnicity and gender. However, the magnitude of the differences we report are similar, across racial/ethnic groups, for the case of respiratory diseases, and even more so for nervous diseases (see Figure 2). That is, the magnitude of the disparity is not uniquely high for circulatory diseases.

Discussion

Our results show that racial/ethnic mortality evaluations that account for actual exposures indicate larger mortality disparities than analyses based on mortality rates and their implied age structure, such as life expectancy. Based on our exposure-corrected measure, the GAP, we find a larger Black/White (72%) and AIAN (65%) mortality disadvantage, and a greater Asian American (224%) and (144%) Hispanic mortality advantage than what life expectancy-based calculations would imply. These disparities are also larger than the results obtained using standardized years of life lost measures, indicating that using real age structures instead of standard age structures identifies greater racial/ethnic mortality disparities in the U.S. context.

Our measure complements existing approaches to estimate mortality trends and disparities; ultimately, the best approach depends on the question. We have posited that exposures ought to play a central role in understanding population-level disparities, and as such, the GAP is particularly well-suited to study racial/ethnic mortality inequalities. The focus on exposures might not always be warranted. Age-specific life expectancies are commonly used as population-based estimates of remaining life years for actuarial calculations, such as the ones involved in the forecasts of pension expenditures.[38] In trying to understand and model individual behaviour (e.g. savings decisions), individual survival probabilities play a central role.[39] Finally, we might want to hold age structures constant in

assessing temporal trends in issues such as the burden of disease, as to assess the improvement of condition-specific mortality rates.[40] Our approach is thus tailored for analyses in which age-structures are a fundamental component, not merely a confounder.

Similar to existing approaches, a shortcoming of our approach is that we do not consider the effect that changing mortality rates could have on age structures. This is clearly the case for $\Delta sYLL$, since direct age standardization assumes that different mortality rates can coexist with an identical age distribution. It might appear that Δe_0 does not suffer for this shortcoming. Indeed, in the calculation of e_0, the age structure is implicitly derived from the mortality rates. However, the implicit age structure of the life table is based exclusively on mortality rates, and thus does not represent a realistic approximation of the age structure under alternative mortality distributions.

Beyond technical considerations, the approaches to mortality evaluation we have presented also correspond to distinct perspectives on racial/ethnic equity in mortality. The underlying notion of equity behind Δe_0-based analysis is that equality will be achieved when any two individuals born in the same birth cohort in the U.S., regardless of race/ethnicity, have the same life expectancy. Alternatively, we have presented a different version whereby equality implies that, given their age structure, no race/ethnicity would be better off exchanging their mortality rates with those of any other race/ethnicity. The two notions are not equivalent, as we have illustrated in this work, and thus can lead to different recommendations for policies that pursue the reduction of disparities. Given that both approaches have similar data requirements and analytical complexity, the preferred approach will depend on the research question.

Conclusion

The purpose of this piece is to introduce a new approach to measuring mortality disparities. The GAP explicitly incorporates actual age structures in cross-population analyses. We also compare the GAP to the disparity found using two common alternatives - life expectancy and years of life lost. Other indicators that quantify additional dimensions of mortality and health disparities might benefit from insights from this work, such as measures of life table based longevity like the median and modal ages at death[41] and lifespan inequality indices.[42] Other measures, such as quality adjusted years of life years (QALY), often used in policy evaluations,[43] consider the disability status of years lived. While these measures provide additional insights on racial/ethnic mortality disparities beyond those covered by our approach, the exposure-related considerations at the core of our contribution also

apply. Exploring the quantitative implications of incorporating exposure corrections into these measures represents an interesting potential avenue for future research.

Data availability

All data and code to fully reproduce the analyses are available at the OSF: https://osf.io/hj8g3 .

References

1. Harper S, MacLehose RF, Kaufman JS. Trends in the black-white life expectancy gap among US states, 1990–2009. *Health affairs*. 2014 Aug 1;33(8):1375-82.
2. Wrigley-Field E. US racial inequality may be as deadly as COVID-19. Proceedings of the National Academy of Sciences. 2020 Sep 8;117(36):21854-6
3. Sasson I. Age and COVID-19 mortality: A comparison of Gompertz doubling time across countries and causes of death. *Demographic Research*. 2021 Feb 17;44:379-96.
4. Goldstein JR, Lee RD. Demographic perspectives on the mortality of COVID-19 and other epidemics. Proceedings of the National Academy of Sciences. 2020 Sep 8;117(36):22035-41.
5. Dudel C, Riffe T, Acosta E, van Raalte A, Strozza C, Myrskylä M. Monitoring trends and differences in COVID-19 case-fatality rates using decomposition methods: Contributions of age structure and age-specific fatality. PLOS one. 2020 Sep 10;15(9):e0238904.
6. Vaupel JW. How change in age-specific mortality affects life expectancy. *Population studies*. 1986 Mar 1;40(1):147-57.
7. Adam T. Making choices in health: WHO guide to cost-effectiveness analysis. World Health Organization; 2003.
8. Martinez R, Soliz P, Caixeta R, Ordunez P. Reflection on modern methods: years of life lost due to premature mortality—a versatile and comprehensive measure for monitoring non-communicable disease mortality. *International journal of epidemiology*. 2019 Aug 1;48(4):1367-76.
9. WHO G. WHO methods and data sources for global burden of disease estimates 2000-2011. Geneva: Department of Health Statistics and Information Systems. 2013 Nov.
10. Wyper GM, Grant I, Fletcher E, McCartney G, Fischbacher C, Stockton DL. How do world and European standard populations impact burden of disease studies? A case study of disability-adjusted life years (DALYs) in Scotland. *Archives of Public Health*. 2020 Dec;78(1):1-8.
11. Preston S, Heuveline P, Guillot M. *Demography: measuring and modeling population processes*. 2001. Malden, MA: Blackwell Publishers. 2000.
12. Krieger N, Williams DR. Changing to the 2000 standard million: are declining racial/ethnic and socioeconomic inequalities in health real progress or statistical illusion? *Am J Public Health*. 2001 Aug;91(8):1209-13.
13. Thurber KA, Thandrayen J, Maddox R, et al. Reflection on modern methods: statistical, policy and ethical implications of using age-standardized health indicators to quantify inequities. *Int J Epidemiol*. 2022;51(1):324-333.
14. Harper S, Rushani D, Kaufman JS. Trends in the black-white life expectancy gap, 2003-2008. *JAMA*. 2012;307(21):2257-2259.
15. Schwandt H, Currie J, Bär M, et al. Inequality in mortality between Black and White Americans by age, place, and cause and in comparison to Europe, 1990 to 2018. Proc Natl Acad Sci U S A. 2021;118(40):e2104684118. doi:10.1073/pnas.2104684118.
16. Arias E, Johnson NJ, Vera BT. Racial disparities in mortality in the adult hispanic population. SSM Popul Health. 2020;11:100583. doi:10.1016/j.ssmph.2020.100583.
17. GBD US Health Disparities Collaborators. Life expectancy by county, race, and ethnicity in the USA, 2000-19: a systematic analysis of health disparities. *Lancet*. 2022;400(10345):25-38.
18. Arias E, Tejada-Vera B, Ahmad F, Kochanek KD. Provisional life expectancy estimates for 2020. NVSS Vital Statistics Rapid Release: From the Centers for Disease Control and Prevention, National Center for

Health Statistics, National Vital Statistics System. 2021 Jul 1;15: 1-12. http://dx.doi.org/10.15620/cdc:107201.
19. Aburto JM, Tilstra AM, Floridi G, Dowd JB. Significant impacts of the COVID-19 pandemic on race/ethnic differences in US mortality. Proc Natl Acad Sci U S A. 2022;119(35):e2205813119. doi:10.1073/pnas.2205813119.
20. Pierce JB, Harrington K, McCabe ME, et al. Racial/ethnic minority and neighborhood disadvantage leads to disproportionate mortality burden and years of potential life lost due to COVID-19 in Chicago, Illinois. Health Place. 2021;68:102540. doi:10.1016/j.healthplace.2021.102540.
21. Xu JJ, Chen JT, Belin TR, Brookmeyer RS, Suchard MA, Ramirez CM. Racial and Ethnic Disparities in Years of Potential Life Lost Attributable to COVID-19 in the United States: An Analysis of 45 States and the District of Columbia. Int J Environ Res Public Health. 2021;18(6):2921. doi:10.3390/ijerph18062921.
22. Aragón TJ, Lichtensztajn DY, Katcher BS, Reiter R, Katz MH. Calculating expected years of life lost for assessing local ethnic disparities in causes of premature death. BMC Public Health. 2008;8:116. doi:10.1186/1471-2458-8-116.
23. Shield KD, Gmel G, Kehoe-Chan T, Dawson DA, Grant BF, Rehm J. Mortality and potential years of life lost attributable to alcohol consumption by race and sex in the United States in 2005. PLoS One. 2013;8(1):e51923. doi:10.1371/journal.pone.0051923.
24. Lortet-Tieulent J, Soerjomataram I, Lin CC, Coebergh JWW, Jemal A. U.S. Burden of Cancer by Race and Ethnicity According to Disability-Adjusted Life Years. *Am J Prev Med*. 2016;51(5):673-681.
25. Ekwueme DU, Guy GP Jr, Li C, Rim SH, Parelkar P, Chen SC. The health burden and economic costs of cutaneous melanoma mortality by race/ethnicity-United States, 2000 to 2006. J Am Acad Dermatol. 2011;65(5 Suppl 1):S133-S143. doi:10.1016/j.jaad.2011.04.036.
26. Trepka MJ, Niyonsenga T, Fennie KP, McKelvey K, Lieb S, Maddox LM. Sex and Racial/Ethnic Differences in Premature Mortality Due to HIV: Florida, 2000-2009. *Public Health Rep*. 2015;130(5):505-513.
27. Kitagawa, EM. Components of a difference between two rates. *J Am Stat Assoc*. 1955;50(272):1168-1194.
28. Satcher D, Fryer GE Jr, McCann J, Troutman A, Woolf SH, Rust G. What if we were equal? A comparison of the black-white mortality gap in 1960 and 2000. *Health Aff (Millwood)*. 2005;24(2):459-464.
29. Inskip H, Beral V, Fraser P, Haskey J. Methods for age‐adjustment of rates. *Statistics in medicine*. 1983 Oct;2(4):455-66.
30. Driscoll AK, Ely DM. Effects of Changes in Maternal Age Distribution and Maternal Age-specific Infant Mortality Rates on Infant Mortality Trends: United States, 2000-2017. National Vital Statistics Reports: From the Centers for Disease Control and Prevention, National Center for Health Statistics, National Vital Statistics System. 2020 Jun 1;69(5):1-8.
31. Kitsantas P, Gaffney KF. Racial/ethnic Disparities in Infant Mortality. *Journal of perinatal medicine*. 2010;38(1):87-94.
32. Greenwood BN, Hardeman RR, Huang L, Sojourner A. Physician–patient racial concordance and disparities in birthing mortality for newborns. Proceedings of the National Academy of Sciences. 2020 Sep 1;117(35):21194-200.
33. Geronimus AT. The weathering hypothesis and the health of African-American women and infants: evidence and speculations. *Ethnicity & disease*. 1992 Jan 1;2(3):207-21.
34. NCHS, Life tables. https://www.cdc.gov/nchs/products/life_tables.htm (6 October 2022, date last accessed).
35. NCHS, CDC WONDER online databases portal. https://wonder.cdc.gov/ (6 October 2022, date last accessed).
36. NCHS, Abridged-race population estimates. https://www.cdc.gov/nchs/nvss/bridged_race/216data_documentation.htm (6 October 2022, date last accessed).
37. HMD, Human Mortality Database. https://www.mortality.org/ (6 October 2022, date last accessed)
38. Social Security Administration, The 2021 Annual Report of the Board of Trustees of the Federal Old-Age and Survivors Insurance and Federal Disability Insurance Trust Funds, 2021, https://www.ssa.gov/oact/TR/2021/index.html (accessedNovember 15, 2021)
39. Post T, Hanewald K. Longevity risk, subjective survival expectations, and individual saving behavior. *Journal of Economic Behavior & Organization*. 2013 Feb 1;86:200-20.

40. Murray CJ, Vos T, Lozano R, et al. Disability-adjusted life years (DALYs) for 291 diseases and injuries in 21 regions, 1990–2010: a systematic analysis for the Global Burden of Disease Study 2010. *Lancet*. 2012 Dec 15;380(9859):2197-223.
41. Canudas-Romo V. Three measures of longevity: Time trends and record values. *Demography*. 2010 May;47(2):299-312.
42. van Raalte AA, Sasson I, Martikainen P. The case for monitoring life-span inequality. *Science*. 2018 Nov 30;362(6418):1002-4.
43. Neumann PJ, Cohen JT, Weinstein MC. Updating cost-effectiveness—the curious resilience of the $50,000-per-QALY threshold. *N Engl J Med*. 2014 Aug 28;371(9):796-7.

Tables and figures

Race	Gender	Metric	Mortality difference	Gain from circulatory diseases elimination	Ratio of mortality difference to life loss circulatory diseases
Asian	Female	Δe_0	-6.17	5.74	1.07
		$\Delta sYLL$	-6452.88	1624.44	3.97
		GAP	-6919.50	1688.27	4.10
	Male	Δe_0	-7.12	5.53	1.29
		$\Delta sYLL$	-9733.46	2987.21	3.26
		GAP	-9690.15	2718.56	3.56
	Total	Δe_0	-6.79	5.72	1.19
		$\Delta sYLL$	-8073.29	2232.05	3.62
		GAP	-8355.41	2172.03	3.85
Black	Female	Δe_0	3.16	6.04	0.52
		$\Delta sYLL$	4875.13	4841.84	1.01
		GAP	5150.98	5023.60	1.03
	Male	Δe_0	5.01	5.66	0.88
		$\Delta sYLL$	9369.15	8193.86	1.14
		GAP	9425.65	7294.22	1.29
	Total	Δe_0	3.99	5.98	0.67
		$\Delta sYLL$	6753.40	6330.30	1.07
		GAP	7012.41	6115.05	1.15
Hispanic	Female	Δe_0	-3.17	5.39	0.59
		$\Delta sYLL$	-3350.31	2170.04	1.54
		GAP	-2722.47	1595.72	1.71
	Male	Δe_0	-2.73	5.15	0.53
		$\Delta sYLL$	-3974.91	3918.96	1.01
		GAP	-2997.18	2546.89	1.18
	Total	Δe_0	-3.08	5.42	0.57
		$\Delta sYLL$	-3702.54	2975.08	1.24
		GAP	-2875.87	2069.03	1.39
Native	Female	Δe_0	6.31	4.40	1.43
		$\Delta sYLL$	11178.17	4058.96	2.75
		GAP	11214.59	4087.90	2.74
	Male	Δe_0	7.69	4.77	1.61
		$\Delta sYLL$	16086.81	7338.55	2.19
		GAP	16116.01	6881.70	2.34
	Total	Δe_0	7.03	4.67	1.50
		$\Delta sYLL$	13494.89	5599.07	2.41
		GAP	13535.15	5459.49	2.48

Table 1. The table presents Δe_0, $\Delta sYLL$, GAP for: the racial gap between each race and Whites (column 4), the loss of life from circulatory diseases for each race (column 5), and the ratio of the two (column 6). In the

case of Asians and Hispanics, the mortality gap is negative (advantage), whereas for Blacks and AIAN it is positive (disadvantage).

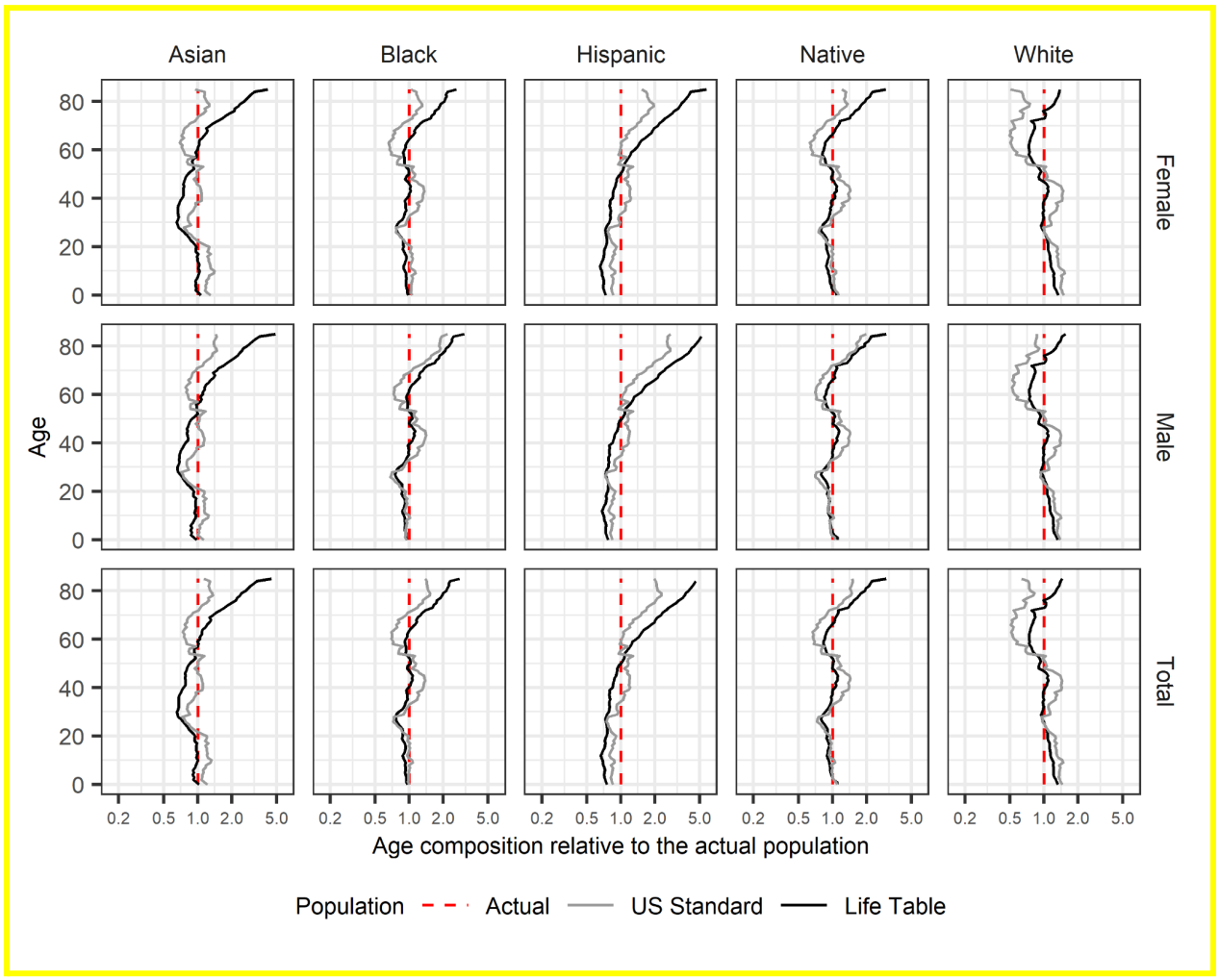

Figure 1. Deviations from the actual age distribution (2019).

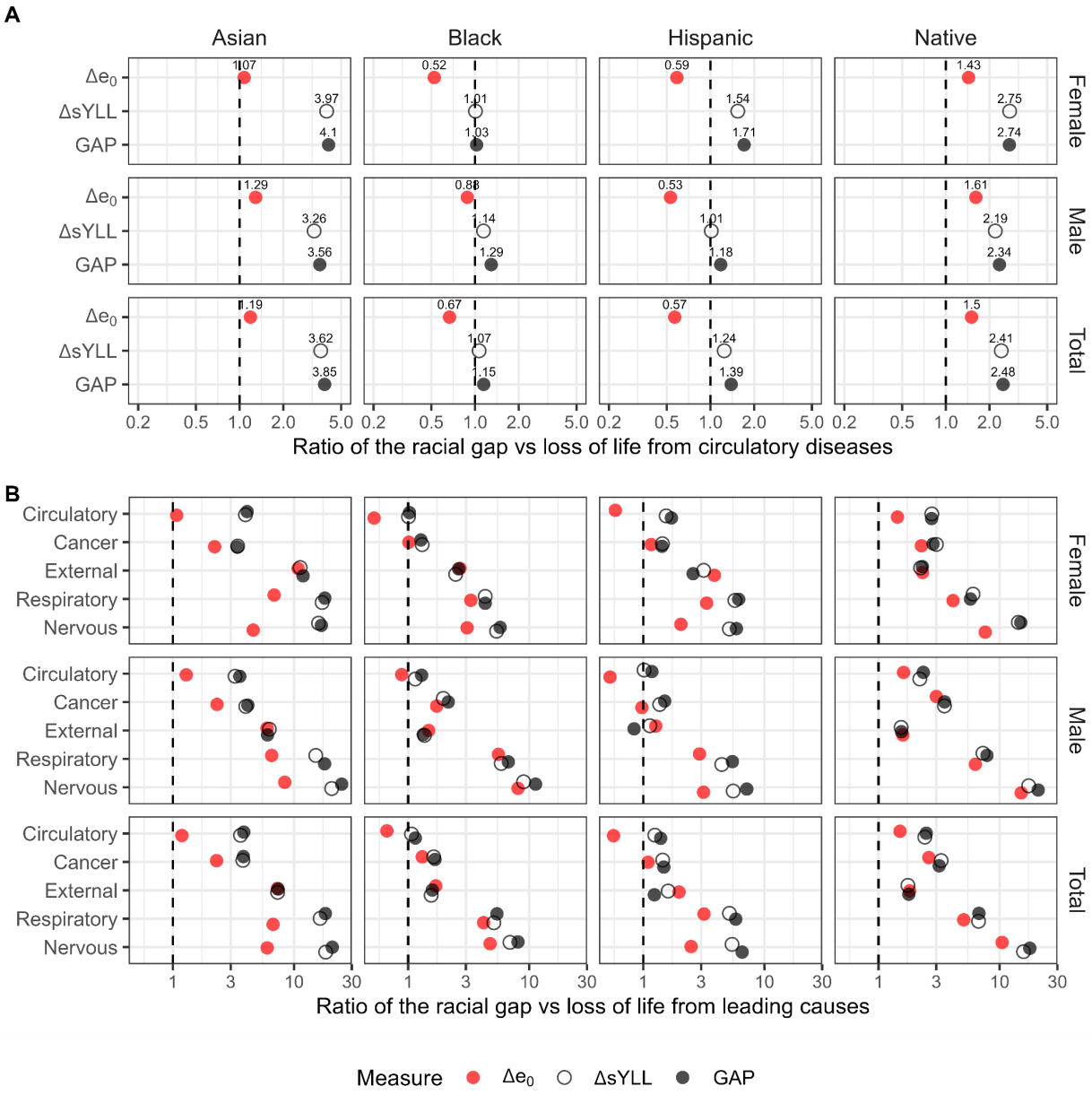

Figure 2. Mortality gap based on life expectancy (Δe_0), standardized YLL ($\Delta sYLL$) and the *GAP*. Panel A displays the racial/ethnic disparity for females, males, and total in relation to circulatory diseases. Panel B reports the racial/ethnic disparity for females, males, and total using other causes of death (top 5 causes) as a reference.