

Racial Disparities in Coronavirus Disease 2019 (COVID-19) Mortality Are Driven by Unequal Infection Risks

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Background. As of 1 November 2020, there have been >230 000 deaths and 9 million confirmed and probable cases attributable to severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) in the United States. However, this overwhelming toll has not been distributed equally, with geographic, race/ethnic, age, and socioeconomic disparities in exposure and mortality defining features of the US coronavirus disease 2019 (COVID-19) epidemic.

Methods. We used individual-level COVID-19 incidence and mortality data from the state of Michigan to estimate age-specific incidence and mortality rates by race/ethnic group. Data were analyzed using hierarchical Bayesian regression models, and model results were validated using posterior predictive checks.

Results. In crude and age-standardized analyses we found rates of incidence and mortality more than twice as high than for Whites for all groups except Native Americans. Blacks experienced the greatest burden of confirmed and probable COVID-19 (age-standardized incidence, 1626/100 000 population) and mortality (age-standardized mortality rate, 244/100 000). These rates reflect large disparities, as Blacks experienced age-standardized incidence and mortality rates 5.5 (95% posterior credible interval [CrI], 5.4–5.6) and 6.7 (95% CrI, 6.4–7.1) times higher than Whites, respectively. We found that the bulk of the disparity in mortality between Blacks and Whites is driven by dramatically higher rates of COVID-19 infection across all age groups, particularly among older adults, rather than age-specific variation in case-fatality rates.

Conclusions. This work suggests that well-documented racial disparities in COVID-19 mortality in hard-hit settings, such as Michigan, are driven primarily by variation in household, community, and workplace exposure rather than case-fatality rates.

Keywords. COVID-19; SARS-CoV-2; social epidemiology; disparities.

As of 1 November 2020, there have been more than 230 000 deaths and 9 million confirmed and probable cases attributable to severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) in the United States, with these numbers undoubtedly reflecting a substantial underestimate of the true toll. Geographic, race/ethnic, age, and socioeconomic disparities in mortality have been key features of the first, second, and ongoing third wave of the US coronavirus disease 2019 (COVID-19) epidemic [1–5]. However, the extent to which this differential mortality is driven by disparities in rates of infection by age, race, and socioeconomic status (SES), or some combination thereof, remains unknown. Addressing the clear inequities

in the toll of death resulting from the COVID-19 pandemic in the United States requires disaggregating the relative role of exposure leading to infection from age-specific case-fatality rates in drivers of the gaping inequity characteristic of SARS-CoV-2 mortality in the United States.

Analyses of other respiratory viruses, such as respiratory syncytial virus and influenza, have documented race/ethnic disparities in both rates of infection and case fatality [6]. This inequality is driven by diverse factors including comorbid conditions that increase susceptibility to infection and disease severity. But it is also a function of structural factors that impact the ability of members of different race/ethnic and socioeconomic groups to avoid infection. Relevant factors include mass incarceration [7, 8], residential segregation [9, 10], and wealth inequality that facilitates social distancing among the well-off while poorer individuals are more likely to be compelled into “essential work” [11]. A recent cross-national systematic review placed the population average infection fatality ratio of COVID-19 infection at 0.75% [12]. However, demographic factors such as population age structure are key shapers of such rates and their variation across social groups [13]. While some studies have illustrated the differential impact of SARS-CoV-2 on non-White populations in the United States using aggregated data [5], no existing

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analyses provide a clear breakdown of these risks by age, sex, and race [14]. In this paper, we aim to partially close this gap using detailed case-level data from the US state of Michigan, which was particularly hard hit by SARS-CoV-2 in the winter and spring of 2020, and where the epidemic has been marked by unmistakable racial and socioeconomic inequality.

METHODS

Data

We used data from 73 441 people with polymerase chain reaction (PCR)-confirmed and probable COVID-19 infections recorded by the Michigan Disease Surveillance System (MDSS) from 8 March 2020 through 5 July 2020. Probable cases were defined using the criteria outlined in the Michigan State and Local Public Health COVID-19 Standard Operating Procedures [15]. From this dataset, we excluded 25 cases who did not reside in Michigan or were missing a state of residence, 8613 people for whom race or ethnicity was not recorded, and 27 people who did not have age recorded or had an age more than 116 years old, indicating entry errors. We combined 68 pairs of records that had duplicate patient identification numbers, resulting in 34 fewer cases. Finally, we dropped 28 patients whose sex at birth was unknown, leading to a final dataset of 49 701 people with a confirmed or probable COVID-19 infection and with known age, race or ethnicity, state of residence, sex at birth, and state prisoner status. To mitigate the potential of right-censored deaths to erroneously deflate mortality rates, we truncated the data at the 97.5% quantile of the distribution of times to death from case referral date, which was 46 days, after which our data comprise 58 428 individuals.

After filtering the case data, we binned age by 10-year intervals to age 80, with ages 80 and above in 1 bin. We also assigned cases to race/ethnicity categories of Black/African American, Latino, Asian/Pacific Islander, Native American, Other, and White, where Other comprised the census category of “other” and mixed-race individuals. To model per-capita rates of disease we used IPUMS public-use microdata from the 2018 American Community Survey (ACS) [16] to obtain population counts for each age/sex/race stratum. For additional information on data preparation and assignment of cases to race/ethnic categories, see Section 2.1 of the [Supplementary Materials](#).

COVID-19 Cumulative Incidence Rates

To calculate age-specific, per-capita rates of COVID-19 infection in each age (i), sex (j), and race (k) bin, we fit a Poisson regression model with a population offset term, $\log(n_{ijk})$, where n_{ijk} is the size of the population for the ijk -th group from the 2018 ACS. We included age \times sex, age \times race, and sex \times race interaction terms to capture the full spectrum of potential heterogeneity in our outcome data. We denote the observed number of cases in each group as y_{ijk} and the per-capita cumulative

incidence rate in each bin as λ_{ijk} . To ensure comparability of incidence and mortality rates across race/ethnic groups, we employed a direct standardization approach to provide age- and sex-adjusted results where necessary. For all analyses of per-capita age-specific incidence rates, we used a log-Gaussian prior distribution with a mean of 0 and standard deviation of 0.1.

Case-Fatality Rates

Age-specific case-fatality rates (CFRs) were estimated by fitting a binomial model to the number of deaths (z_{ijk}) as a proportion of the number of total cases (y_{ijk}) in each age/sex/race bin. We denote the CFR for each group as ρ_{ijk} , so, $z_{ijk} \sim \text{Binomial}(y_{ijk}, \rho_{ijk})$.

Counterfactual Analysis of Mortality Disparities

To understand the relative importance of age-specific incidence versus case fatality as drivers of race/ethnic disparities as drivers of mortality disparities, we examined a pair of counterfactual scenarios in which: (1) age- and sex-specific COVID-19 incidence rates for each non-White race/ethnic group were replaced by the corresponding age-/sex-specific rate among White individuals, with original age- and sex-specific CFRs maintained and (2) the same procedure was repeated for CFRs, keeping race/ethnic incidence rates fixed for non-White individuals, while substituting White case-fatality for each non-White age/sex bin. We then used posterior simulation to obtain the difference in the number of deaths expected under each scenario to calculate the percentage reduction in observed deaths.

Software

All analyses were completed in R 4.0.3, using the `rstanarm` package [17] for Bayesian regression analysis, the `tidybayes` package for post-processing [18], and `ggplot2` for visualization [19] (R Foundation for Statistical Computing).

RESULTS

In our dataset, there were 49 701 probable and confirmed COVID-19 cases and 5815 deaths attributable to COVID-19, for an overall CFR of 12%. Of these, 19 662 were among individuals identified as Black or African-American, 23 301 were among individuals identified as White, 1346 among individuals identified as Asian or Pacific Islander, 123 among individuals identified as Native American, and 1612 among individuals identified as belonging to any other racial/ethnic group in the 2018 ACS. [Table 1](#) shows unadjusted per-capita case and mortality rates by race/ethnic group, as well as corresponding CFRs. Notably, the raw incidence rate among all non-White groups is substantially higher than among White individuals for all groups identified in the data except for Native Americans. However, the overall CFR for White individuals is on par with the CFR for Black individuals, potentially due to different distributions of ages among cases and deaths between these groups. Among White individuals, the average

Table 1. Incidence, Mortality, and Demographic Characteristics of COVID-19 Cases and Deaths in Michigan, United States: March–June 2020 by Race/Ethnic Group

Race	No. of Cases	No. of Cases/ 100 000	No. of Deaths	No. of Deaths/ 100 000	CFR, %	Avg. Age Years	Avg. Age at Death, Years	Female, %
Black	19 662	1445	2430	179	11	51	71	54
Latino	3657	734	133	27	2	38	67	48
Other	1612	626	104	40	5	45	72	51
Asian / Pacific Islander	1346	440	76	25	5	44	77	52
White	23 301	311	3064	41	11	53	79	53
Native American	123	266	8	17	5	49	74	47

Abbreviations: Avg., average; CFR, case-fatality rate; COVID-19, coronavirus disease 2019.

age of all reported cases was 53.4 years (95% posterior credible interval [CrI] = 53.2, 53.7), slightly older than among blacks (51.4 years; 95% CrI = 51.1, 51.6), and significantly older than among Latinos (38.1 years; 95% CrI = 37.6, 38.6) and those in the “other” race/ethnicity group. For all groups, the mean age among individuals with COVID-19 listed as their cause of death was significantly higher than for all cases within the same group. Among White individuals, the average age at death was greatest, at 79.2 years (95% CrI = 78.6, 79.9), 8 years higher than among Black individuals at 71.2 years (95% CrI = 70.5, 71.9), with Latinos having the youngest average age at death at 66.7 years (95% CrI = 63.6, 69.8).

Standardized Incidence and Mortality Rates

Table 2 contains age- and sex-standardized incidence and mortality rates per 100 000 population and corresponding between-group rate ratios, by race/ethnic group. Rows of the table are ordered by raw incidence per 100 000 individuals for comparability with Table 1. This shows that the general patterns in the raw incidence and mortality hold after adjustment, although the age- and sex-adjusted incidence among Latinos increased, reflecting the younger average age of cases identified as Latino. The provided incidence rate ratios (IRRs) and mortality rate ratios (MRRs) show the enormous disparity in incidence and mortality between Black and White individuals, with an IRR of 5.5 and an MRR of nearly 7. Again, these IRRs and MRRs reflect the fact that all groups other than Native Americans had higher rates of incidence and mortality than White individuals

and that these differences do not simply reflect the age and sex distribution of cases. For Native Americans, rates were statistically indistinguishable from those for White individuals, although this may be due to the very small number of cases and deaths overall in this group in our data. In the following sections, we will examine age-stratified incidence and mortality rates by race/ethnicity for Black, Latino, Asian/Pacific Islander and White individuals. Native Americans are excluded from age-stratified analyses due to a small sample size, as are individuals in the “Other” race/ethnic categorization.

Cumulative Incidence Rates

Figure 1 illustrates the dramatically higher overall and age-specific incidence rates among Black individuals and individuals in the “Other” race/ethnic category than for White individuals, particularly at older ages at which individuals are far more likely to die from their infection. In addition, the horizontal dashed line in each panel of Figure 1 shows the raw incidence rate for each group. The extent of these disparities in incidence is clearly in evidence in the left-hand panel of Figure 3, which shows the ratio of the age-specific cumulative incidence rate (IRR) for each race/ethnic group as compared with the comparable rate for White individuals. In this case, rates for all non-White groups are significantly higher, with these disparities most pronounced at older ages for Black individuals and younger ages for Latinos. The IRR for individuals in the “other” group was fairly consistent across ages, with a small drop in the 20–40-year age range.

Table 2. Age- and Sex-Standardized COVID-19 Incidence and Mortality Rates and Corresponding Rate Ratios, by Race/Ethnic Group, in Michigan, United States: March–June 2020

Race	Incidence/100 000	IRR	Mortality/100 000	MRR
Black	1626 (1602, 1649)	5.5 (5.4, 5.6)	244 (234, 255)	6.7 (6.4, 7.1)
Latino	912 (879, 946)	3.1 (3, 3.2)	69 (57, 82)	1.9 (1.6, 2.3)
Other	1150 (1088, 1216)	3.9 (3.7, 4.1)	123 (99, 149)	3.4 (2.7, 4.1)
Asian/Pacific Islander	498 (469, 529)	1.7 (1.6, 1.8)	51 (41, 64)	1.4 (1.1, 1.8)
White	297 (293, 300)	Ref	36 (35, 38)	Ref
Native American	285 (237, 341)	1 (0.8, 1.2)	29 (13, 54)	0.8 (0.3, 1.5)

The table shows incidence rates and mortality rates and 95% CrI, as well as corresponding standardized IRRs and MRRs. For all ratio measures of association, the incidence and mortality rate among White individuals is used as the reference group. Abbreviations: COVID-19, coronavirus disease 2019; CrI, posterior credible interval; IRR, incidence rate ratio; MRR, mortality rate ratio; Ref, reference.

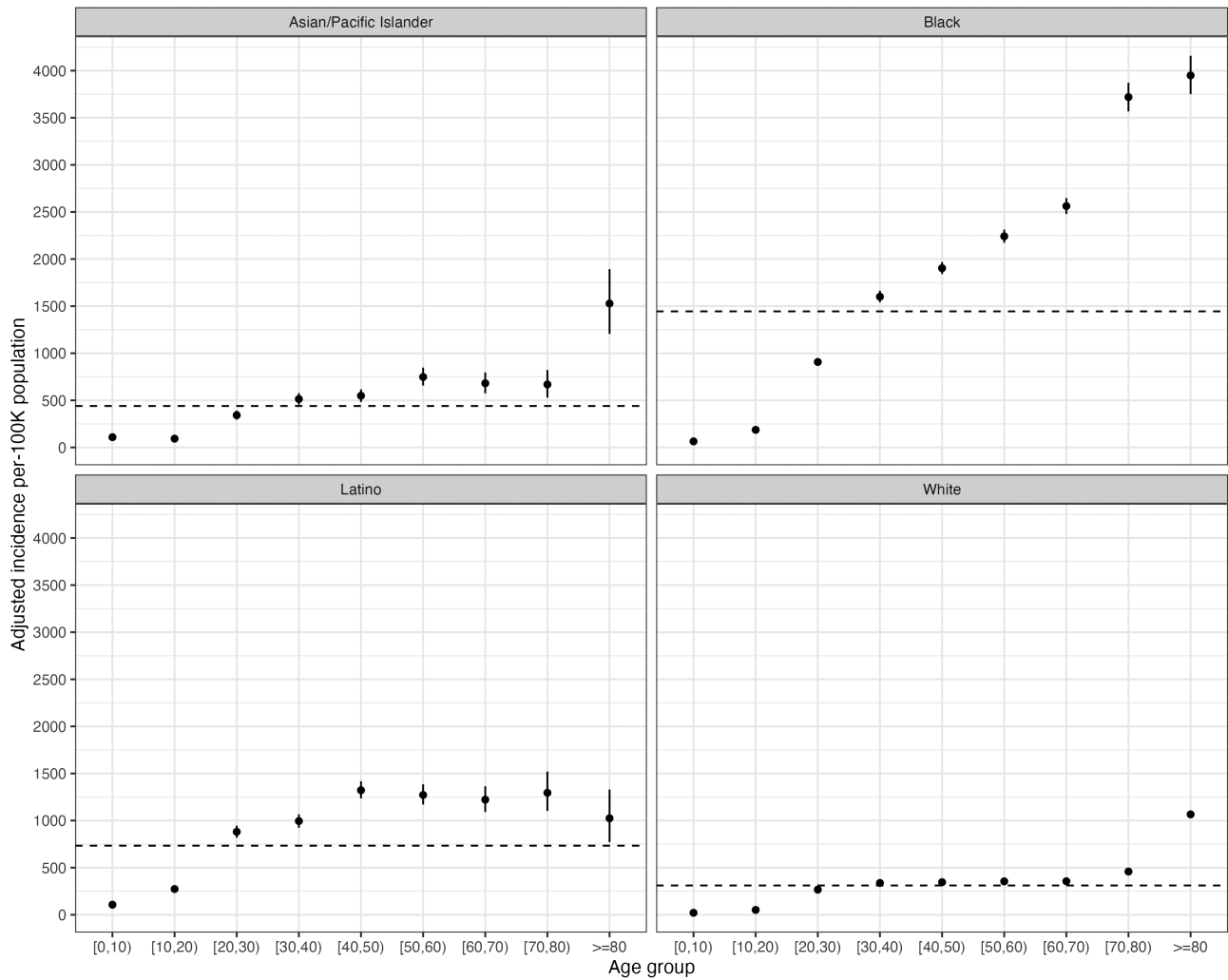


Figure 1. Incidence rate estimates (points) and 95% CrI (vertical lines) of COVID-19 infection per 100 000 population by 10-year age groups, stratified by race/ethnic group. Dashed lines indicate the crude rate for each group. Abbreviations: COVID-19, coronavirus disease 2019; CrI, posterior credible interval.

Case-Fatality Rates

Figure 2 illustrates a steadily increasing trend in the probability of death among identified cases from age 50 onwards across groups, although there are differences in these rates at younger ages. These are visible in the right-hand panel of Figure 3, which shows the ratio of the age-specific CFR for Black individuals, Latinos, and those in the “other” group versus White CFRs. Because of the small number of deaths among individuals younger than 20 years of age, these groups are excluded from the figure. For Black individuals, all age groups from 30 to 70 years experienced higher CFRs than White individuals, with this disparity most pronounced among 40- to 49-year-olds. However, for Latinos and those in the “other” race/ethnic group, there are no significant differences in age-specific CFRs as compared with White individuals. These results and those in Table 2 suggest that, although there are meaningful differences in case fatality by race and age, the large disparities in COVID-19 mortality cannot be explained by CFRs alone.

Counterfactual Analysis of Mortality Disparities

We found that substituting the incidence rates of White individuals for those of non-White individuals would result in a decrease of 82% (95% CrI = 81%, 84%) of the observed deaths among Blacks individuals, 57% (95% CrI = 47%,66%) among Latinos, and 35% (95% CrI = 18%,49%) among Asian/Pacific Islanders. In the second scenario (ie, when White CFRs were substituted for non-White CFRs but group-specific incidence rates maintained), we found no significant change in the expected number of deaths for any group except for Blacks individuals, who saw a smaller but still meaningful decrease of 19% (95% CrI = 14%,25%) of deaths.

These results suggest that, while differential CFRs can account for some of the disparity in Black versus White mortality rates, the large majority of COVID-19 deaths among African-Americans in Michigan can be attributed to the large differences in age-specific incidence illustrated in Figure 1. Similarly, although Latinos and Asian/Pacific Islanders had similar crude

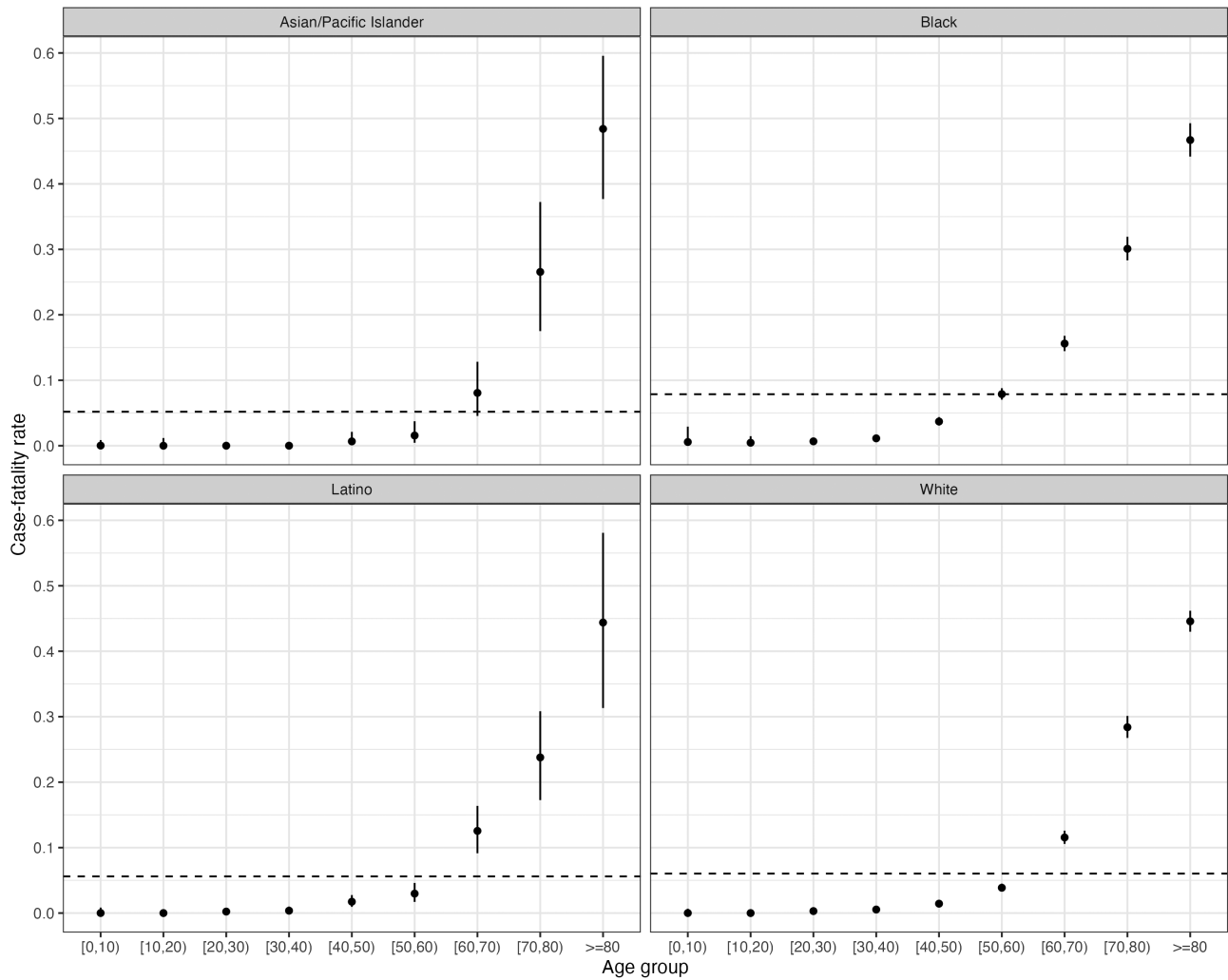


Figure 2. COVID-19 case-fatality rate estimates (points) and 95% CrI (vertical lines) by 10-year age groups, stratified by race/ethnic group. Dashed lines indicate the crude rate for each group. Abbreviations: COVID-19, coronavirus disease 2019; CrI, posterior credible interval.

mortality rates to White individuals (Table 1), these results indicate that these rates would be significantly lower if their exposure risks were more similar to their White peers.

Sensitivity to Case Definition

To ensure that our results were not strongly impacted by the combined analysis of probable [15] and PCR-confirmed SARS-CoV-2 cases, we conducted a sensitivity analysis in which all results were re-generated using data from only PCR-confirmed cases. Descriptive analysis showed that younger and White individuals were more likely to have a probable infection than older and non-White individuals. When these probable cases were excluded, incidence and mortality disparities for younger non-White individuals increased, but our results for older individuals—who experienced the bulk of mortality—remain qualitatively unchanged, as do our population-level conclusions. For full results of this analysis, see the Supplementary Materials.

DISCUSSION

Our results highlight large gaps in COVID-19 incidence and mortality in Michigan that cannot be explained by differences in population age and sex composition. Results from our counterfactual analysis suggest that the stark differences in crude and adjusted mortality between Black individuals and all other race/ethnic groups shown in Tables 1 and 2 are driven in large part, but not exclusively, by disparities in infection risk at all ages, particularly an extremely high rate of COVID-19 infection among older Black individuals in particular. This group had a CFR similar to same-aged White individuals, but reported infection rates 6–8 times greater than their White counterparts. Some of this disparity is also driven by the higher CFR among middle-aged Black people, as compared with same-aged White individuals, in combination with the 5–6 times greater risk of infection among middle-aged Black individuals as compared with White individuals.

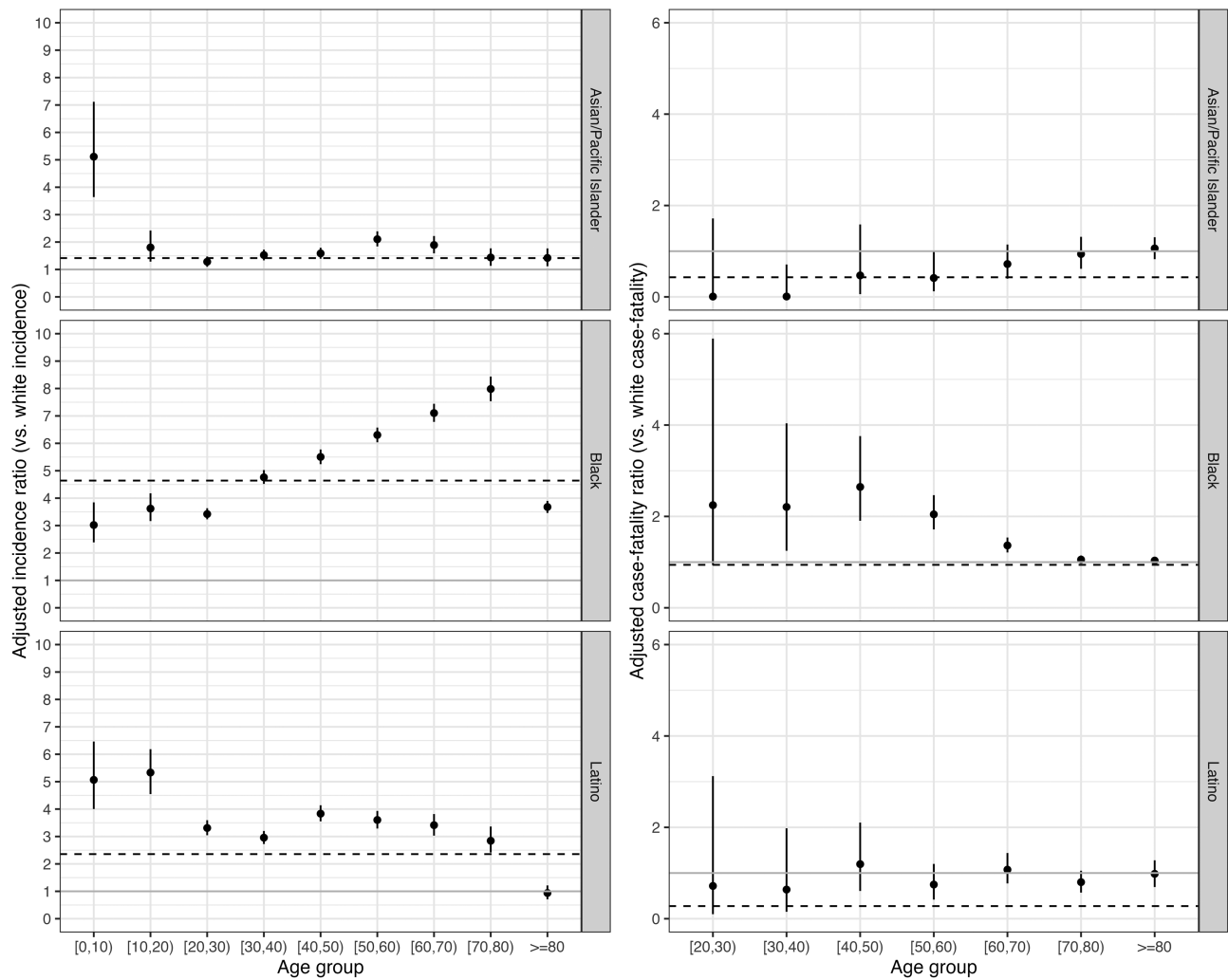


Figure 3. Disparities (as measured by rate ratios [points]) and 95% CrI (vertical lines) of COVID-19 incidence (left-hand column) and case-fatality rate (right-hand column) by age and race/ethnic group compared with White individuals. Dashed lines indicate the ratio of the crude overall rate for each group; the solid gray line is a guide for assessing the strength of association, representing a rate ratio of 1.0 (no association). Abbreviations: COVID-19, coronavirus disease 2019; CrI, posterior credible interval.

Despite these unambiguous results, the full extent of racial and socioeconomic disparities in COVID-19 outcomes in Michigan and the rest of the United States is likely to be even worse than is reflected in administrative data of the type analyzed here. Results from other hard-hit cities, states, and countries have indicated high rates of excess mortality reflective of unrecognized and unreported COVID-19 infection [20]. In a recent analysis of excess mortality using state-level data, Weinberger et al [21] found that there were approximately 4700 unreported deaths likely due to COVID-19 or another respiratory infection in the United States during the period from 1 March to 30 May 2020, for a rate of 61 per 100 000 unreported deaths from COVID-19 above reported totals. In addition, the damage to health from the pandemic goes beyond the direct impact of infections and deaths from SARS-CoV-2. For example, Woolf et al [22] showed that 33% of the total excess deaths during the period from 1 March to 25 April 2020

in Michigan were attributable to noninfectious causes, with the remainder associated with respiratory infections, primarily COVID-19. Although these results are not broken down by race/ethnicity, it is likely that the burden of mortality is not equally shared across race/ethnic groups and socioeconomic strata. Beyond delays in healthcare seeking due to the pandemic, it is quite likely that these patterns of excess death reflect underlying disparities in chronic illnesses that predispose individuals to mortality from COVID-19, lack of access to healthcare for Black and Latinx individuals and other minority groups, and variable quality of care delivered based on racial/ethnic identity.

When interpreting these and other results illustrating racial disparities in COVID-19 incidence and mortality, it is key not to portray race as a risk factor independent of health conditions, wealth, and other potentially modifiable risk factors [23] that may predispose individuals to COVID-19 infection and death.

For example, McClure et al [24] illustrate how a focus on—and adjustment for—individual-level “underlying conditions” obscures the role of racial inequality in shaping the prevalence of these chronic health conditions and other factors such as residence in multigenerational households, which may increase risk among racial and ethnic minority groups.

A strength of our analysis is the use of detailed case data obtained directly from the MDSS. This allowed us to identify age- and race-specific risks of COVID-19 infection and death. Nonetheless, there are some limitations that are important to highlight. First, our reliance on census-defined race/ethnicity as a proxy for exposure and mortality risk is necessarily reductive and does not shed light on factors that can be modified to reduce these disparities [25]. Future analyses are necessary using either prospectively collected data inclusive of SES or spatial analyses that join neighborhood-level information on wealth and other markers of SES with individual-level case data. The set of cases obtained from MDSS during this period is also necessarily incomplete, with large numbers of asymptomatic and less-severe infections undoubtedly missing from this registry.

In addition, although the disparities in our data likely mirror those nationwide, it is important to remember that these results reflect patterns of infection and death in Michigan during the first wave of the COVID-19 pandemic. Although its relatively large population size and socioeconomic and racial composition make Michigan a bellwether of many national trends, this analysis should be interpreted relative to its context. Consequently, similar analyses are sorely needed to understand how these outcomes vary across locales and populations. For a complete discussion of these issues, see the [Supplementary Materials](#).

Because of the deep structural roots of the disparities identified in this analysis, it is easy—but wrongheaded—to conclude that there is nothing to be done. The fluid nature of the COVID-19 pandemic and its response provides opportunities to narrow these appalling inequities in infection and death, particularly as new therapeutics and vaccines against SARS-CoV-2 become available. For this to be the case, however, similar amounts of effort to what has been done to open college campuses and other workplaces need to be focused on increasing the quality and quantity of testing, healthcare, and social support among people of color. While understanding the causes of disparate outcomes is important, it does not necessarily instruct us on what to do. If the current pandemic teaches us something, it is that closing the gap in infection and mortality during the current catastrophe—and preventing such inequities in the next one—requires addressing the racialized dismantling of public infrastructure and systematic divestment that has made these disparities in exposure, susceptibility, and mortality a foregone conclusion [26]. Accomplishing this necessitates an urgent re-orientation around an “epidemiology of consequence” [27] that can identify and attack the structural and practical barriers to health equity before the next disaster strikes.

Supplementary Data

Supplementary materials are available at *Clinical Infectious Diseases* online. Consisting of data provided by the authors to benefit the reader, the posted materials are not copyedited and are the sole responsibility of the authors, so questions or comments should be addressed to the corresponding author.

Notes

Author contributions. J. Z. and R. T. conceptualized and completed data analysis; J. Z., R. T., R. N., A. C., N. M., and P. D. participated in data preparation and cleaning; all authors participated in the writing and editing of the final manuscript.

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