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The COVID Excess Mortality Percentage and Racial-Ethnic Disparities in COVID Mortality: Evidence from Indiana and Wisconsin

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Abstract

Importance: COVID-19 mortality rates increase with age, are higher among men than women, and vary across racial/ethnic groups, but this is also true for other natural causes of death. The authors develop a new measure of COVID-19 mortality burden, the COVID Excess Mortality Percentage (CEMP), defined as COVID-19 deaths as a fraction of all deaths from natural causes other than COVID-19. This measure can control for the effects of underlying population characteristics, including general population health, age, gender, race/ethnicity, and zip-code-level socioeconomic status (zip-SES) in predicting the COVID-19 mortality burden. **Objective:** They use CEMP to study how COVID-19 mortality varies by age, gender, race/ethnicity, and zip-SES and between the pre-vaccine and vaccine-available periods. **Design**: Retrospective analysis of all deaths from natural causes. **Setting:** Indiana and Wisconsin. **Participants:** All adult decedents from natural causes over the pandemic period from April 2020-March 2022. **Exposure:** Demographic factors and vaccine availability. **Main Outcome and Measures:** They report CEMP within sub-populations defined by age, gender, and race/ethnicity during the pre-vaccine (April 2020-March 2021) and vaccine-available (April 2021-March 2022) periods, and odds ratios from multivariable logistic regression.

Results: CEMP is broadly similar for men and women and rises gradually with age during the pre-vaccine period, but peaks at age 40-49 during the vaccine-available period. Racial/ethnic disparities can be very high, especially for Hispanics in the pre-vaccine period, with CEMP ratios for Hispanics to non-Hispanic Whites as high as 9:1 for men aged 50-59, and higher for men than for women. CEMP disparities were smaller but substantial for other minorities and declined with age after 60+. Differences in zip-SES and education explain only a small part of these disparities. National results for 2020 are consistent with our Indiana-Wisconsin findings.

Conclusions and Relevance: The authors studied COVID-19 mortality using a new measure that controls for non- COVID natural mortality rates. This approach is important in understanding racial/ethnic disparities in COVID-19 mortality. Disparities have been observed before, but not the very high Hispanic/White ratios we find for younger and middle-aged persons, especially men. Explanations for these disparities must account for age, gender, and time variation.

Key Points: *Question*. By how much did COVID-19 increase mortality rates; how did this vary with age, gender, and race/ethnicity; and with whether vaccines were available? *Findings.* The COVID Excess Mortality Percentage (CEMP) rose with age during the pre-vaccine period, but peaked at ages 40-49 in the vaccine-available period. Pre-vaccine CEMP rates were dramatically higher for Hispanics than non-Hispanic Whites; especially non-elderly men, and were also elevated for non-elderly Blacks and “other” race persons. Disparities shrank in the vaccine-available period. *Meaning*. The large racial/ethnic disparities in non-elderly CEMP rates, are not explained by underlying health status and call for detailed investigation.

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The COVID Excess Mortality Percentage and Racial/Ethnic Disparities in COVID Mortality: Evidence from Indiana and Wisconsin

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Introduction

The COVID-19 population fatality rate (COVID-PFR, the fraction of the population who died from COVID-19) is generally known to be small for the young, but to rise strongly with age and to be higher for men than for women and for minorities compared to non-Hispanic White Americans.[1-3] However, mortality rates from other natural causes are associated with these same demographic factors.[4] Similarly, lower socio-economic status and less education predict both higher COVID-19 mortality,[5] and higher non-COVID mortality.[6] It is unclear to what extent differences in COVID-PFR reflect differences in underlying health status and mortality risk.[7-9] This is particularly important since the demographic groups most impacted by COVID have changed since vaccines became available.[10]

We propose a novel measure, the COVID Excess Mortality Percentage (CEMP), which controls for underlying health status by dividing COVID-19 mortality for a demographic group by mortality from other natural causes in that group. This measure controls for underlying mortality rates, which are a plausible surrogate for health status. This provides a measure complementary to COVID-PFR, which allows one to ask whether the differential impact of COVID-19 on certain demographic groups reflect differences in health status or other factors.

To better understand how demographic factors affect COVID mortality, we assess the impact of age, gender, race/ethnicity, and vaccine availability on COVID mortality using the CEMP, and compare this to the impact of these variables on COVID-PFR. We further adjust

both measures by decedents' socioeconomic status (SES) and education and examine them before and after vaccines became available.

II. Data and Methods

Data. We obtained de-identified mortality records for all adult decedents in Wisconsin and Indiana for 2020 through the first quarter of 2022 (282,000 decedents and 32,000 COVID-19 decedents, from a population of 9.7 million). These records include 5-digit residence zip code, education, age, marital status, manner of death, and text fields indicating primary cause of death, contributing causes, and other significant conditions. We used text analysis to identify deaths due to COVID-19. This approach attributed more deaths to COVID-19 than did the ICD-10 cause-of-death codes assigned by the National Center for Health Statistics (NCHS). Because immunocompromised persons are particularly likely to die from COVID, we excluded these persons. We defined natural deaths as those decedents whose manner-of-death was not coded as accident, homicide, or suicide. We did not have data on decedents' individual SES, but measured their "zip-SES" based on residence zip code, using quartiles of the Graham Social Deprivation Index.[11] We obtained IN and WI population demographics and zip-SES in 2020 from the American Community Survey.

Analysis. We define CEMP within age group, gender, and race/ethnicity cells as:

$$CEMP = \frac{COVID\ deaths}{Natural\ deaths\ \ - COVID\ deaths} \quad (1)$$

The CEMP denominator (non-COVID natural deaths) serves as a proxy for underlying health. Many risk factors for COVID mortality also predict non-COVID mortality.[12] CEMP ignores any effect of COVID-19 infection on non-COVID mortality. To the extent that COVID-

19 infection predicts higher post-infection, non-COVID mortality,[13-14] CEMP will understate the full COVID mortality burden.

We report CEMP levels for adults aged 18+ within cells defined by age, gender, and race/ethnicity, for ages 18-39, 40-49, 50-59, 60-69, 70-79, 80-89, and 90+. We divide the decedents into non-Hispanic White ("White"), Black, non-Black Hispanic ("Hispanic") and Other (including Asian, Native American, and mixed race); our sample is too small to permit further disaggregation. We report CEMP ratios for Black/White, Hispanic/White, and Other/White. We do not study children due to their low COVID mortality.

CEMP represents the odds, for natural cause decedents, of dying from COVID-19 versus other natural causes. The ratio of CEMPs for two different groups, say Hispanics and Whites, is an odds ratio, which can be recovered from logistic regression. We accordingly use logistic regression to conduct multivariate analysis and report odds ratios for how race/ethnicity and other factors affect CEMP. We run regressions separately for men and women and for persons aged 18-59 and those aged 60+ (reflecting evidence presented below that racial/ethnic disparities are higher for ages 18-59). The predictors are age group, race/ethnicity, zip-SES, education and marital status.

One concern with using CEMP to measure disparities is that the denominator (natural deaths from other causes) reflects pre-existing disparities in mortality rates. Therefore, we also report COVID PFRs, non-COVID natural mortality rates (Non-COVID NMR), and PFR ratios:

$$\text{COVID PFR} = \frac{COVID\ deaths}{Population}$$

$$\text{Non-COVID NMR} = \frac{Non{-}Covid\ natural\ deaths}{Population}$$

Note that CEMP = $\frac{COVID\ PFR}{Non{-}COVID\ NMR}$.

We report results for two time periods: a "pre-vaccine" period from April 2020-March 2021, and a "vaccine-available period" from April 2021-March 2022. There was limited vaccine availability during the first quarter of 2021, principally for the elderly and healthcare workers, but we find similar results excluding this period (Appendix). We begin analysis in April 2020. COVID-19 was declared a national emergency in mid-March 2020, but COVID-19 mortality relative to other natural causes was low for March 2020 as a whole.

III. Results

Study population

Table 1 provides summary statistics for our sample of decedents. Men are a higher proportion of COVID decedents than of all decedents. Hispanics have non-COVID natural deaths well below their share of population, reflecting younger average age, yet COVID-19 deaths much closer to their share of population.

Pre-Vaccine Period

Table 2 presents data on COVID-PFR, non-COVID NMR, CEMP, and Black/White, Hispanic/White, and Other/White CEMP ratios for men and women, and the pre-vaccine (Panel A) and vaccine-available (Panel B) periods. The Appendix provides 95% confidence intervals (Cis) for the CEMP ratios.

As expected, COVID-PFR increases monotonically with age for both genders and all race/ethnicity gender groups. The COVID-PFR for ages 90+ is at least 30 times that for persons aged 18-39. CEMP, which adjusts for the higher underlying mortality rates of men and older individuals, shows a more complex pattern. For Whites, CEMP rises with age, but much more

slowly than COVID-PFR, and is similar for men and women. The CEMP age pattern is also much less uniform across different race/ethnicity groups.

Within age bands, CEMP levels for Blacks are consistently above those for Whites. The COVID-PFR is much higher for Blacks than Whites in all age groups, for both genders. CEMP attenuates the difference in PFRs, because the denominator reflects pre-existing Black-White disparities in non-COVID NMR. Nonetheless, the Black/White CEMP ratio is generally around 2 for persons aged 18-59, for both genders; it then falls with age for ages 60+.

Within age bands, Hispanic COVID-PFR is similar to Blacks for women, but higher for non-elderly men. However, Hispanic non-COVID natural mortality is well below that for Blacks, and generally similar to and sometimes below Whites, consistent with the known Hispanic life-expectancy advantage over Whites.[15] Hispanic CEMP levels, which reflect higher COVID-PFR but similar non-COVID natural mortality, are far above White levels, especially for men. The largest relative difference is for men ages 50-59, where the Hispanic CEMP of 65.3% is nearly 9 times White CEMP of 7.3%. Hispanic/White CEMP ratios are higher for men than for women. Similar to the Black/White ratios, they generally fall with age above age 60.

The Other group has CEMP ratios well above one, higher for ages 18-59 versus 60+ (3.10 vs. 1.63) and for men age 60+ versus women (1.84 vs. 1.43).

The bottom rows in Table 2 provide a summary measure of racial/ethnic differences in COVID-PFR and CEMP levels averaged across all ages. This summary measure weights the sample by non-COVID natural mortality. The overall CEMP ratios are 2.77 for Hispanics/Whites; 1.66 for Other/White, and 1.24 for Blacks/Whites. While well above 1, these summary ratios obscure the much higher ratios for the non-elderly.

In Figure 1, we display CEMP levels graphically. In the pre-vaccine period (Panel A), CEMP levels are highest for Hispanics and lowest for Whites, generally rise moderately with age for Whites and Blacks, but for Hispanics are highest for the middle-aged. Figure 2, Panel A, reports CEMPs ratios. Overall, the broad pattern during the pre-vaccine period is of higher minority than White CEMP levels, especially for younger ages, with some tendency for higher male than female ratios. Ratios are especially high for Hispanics, both men and women.

In Figure 2, Panel B, we provide PFR-based ratios of Hispanic/White, Black/White, and Other/White COVID-19 mortality. In contrast to the CEMP ratios presented in Panel A, the Black/White PFR ratios approach Hispanic/White ratios. The Black/White PFR ratio is around 5:1 in the pre-vaccine period for ages up to 59, and exceeds 6:1 for men aged 18-39.

Vaccine-Available Period

We turn next to analysis of CEMP and racial/ethnic disparities in the vaccine-available period. We present numerical results in Table 2, Panel B; graphical results for CEMP in Figure 1, Panel B, and CEMP and PFR ratios in Figure 2. For Whites, the CEMP age pattern is very different than in the pre-vaccine period. CEMP generally falls with age, even as COVID-PFR rises.

For Blacks, CEMP levels during the vaccine-available period are around 1 for ages 18-59, and close to 1 for men aged up to 79, but rise for older women to around 1.60 for women aged 80-89.

For Hispanics, the very high non-elderly Hispanic/White CEMP ratios seen in the pre-vaccine period drop, but remain much higher than for Blacks or Other, at around 2-2.5, with limited variation by age, except for the very old (90+). As Figure 2, Panel B, shows, CEMP

levels for Hispanics are well above those for the other racial/ethnic groups. For the Other group, male ratios are around 1 for women and for men through age 69, but rise above 1 for men for ages 70+.

These are complex patterns, that defy easy explanation. The very different patterns by race/ethnicity, by time period, and by age range within each racial/ethnic group have not, to our knowledge, been previously reported.

PFR ratios in the vaccine-available period (Figure 3, Panel B) are similar to CEMP ratios for Hispanic/White and (Other)/White. For Blacks, the PFR ratios are higher than the CEMP ratios, but generally decline with age. The higher PFR ratios reflect higher Black mortality from other natural causes, for which the Black-White mortality gap declines with age.

Multivariate Logistic Regression Results

The CEMP measure controls for population health through the denominator. Thus, minority/White ratios substantially different than 1 are unlikely to reflect underlying health differences. In Table 3, we use multivariate logistic regression to assess whether other factors materially change the CEMP-ratios reported above. We run separate regressions by gender, for pre and post vaccine periods and ages 18-59 and ages 60+. The predictors are race/ethnicity (White is omitted); age groups (youngest group is omitted), zip-SES quartiles (highest quartile is omitted), education (college-graduate-or-higher is omitted), and marital status (unknown is omitted). CIs are in brackets. See Appendix for age-group-specific results.

The odds ratios for Black, Hispanic, and Other reported in Table 3 correspond to the CEMP ratios in Table 2. Controlling for additional covariates only slightly changes inference. For example, the Hispanic/White odds ratio of 7.56 for men, ages 18-59, is close to the 7.79

CEMP ratio in Table 2. Thus, zip-SES, education, and marital status do not explain the disparities reported above.

Generalizability. In the Appendix, we report national results for 2020 (2021 data not yet available), which are consistent with the results reported below for the pre-vaccine period.

Discussion

We report results for COVID-19 mortality risk using a new measure of COVID mortality risk – the COVID Excess Mortality Percentage (CEMP), which asks by how much did COVID-19 increase background natural mortality rates. (We used a similar measure in prior work focusing on elderly mortality.)[16] This measure demonstrates that higher COVID-19 mortality among older individuals is broadly consistent with their higher mortality from all causes. This also applies to higher male versus female COVID-19 mortality. Analyses using CEMP make clear that the disproportionate impact of COVID-19 on Blacks is partially explained by discrepancies in underlying health that were present before the pandemic, while the disparate impact on the Hispanic population reflects factors that are more specific to the COVID-19 pandemic. COVID-19 was the largest cause of natural death for Hispanics in 2020 up to at least age 69, ahead of heart disease, cancer, and all other natural causes.

Prior research has reported higher minority COVID-19 mortality rates, but has not attended to differences in background mortality rates.[17-18] This prior work also often does not controlled for population age, or else reports age-adjusted mortality rates across all ages, rather than providing breakdowns by age group. For example, a recent CDC study reports age-adjusted Hispanic/White COVID-19 mortality rate ratios of 2.78 for 2020 and 1.71 for 2021.[19] Prior work has not stressed the greater relative impact of COVID-19 on younger minorities, nor the far

greater relative COVID-19 burden for Hispanics, especially younger men, relative to background mortality risk.

Finally, during the vaccine-available period, the relative contribution of COVID-19 to overall natural mortality was higher for younger persons than in the pre-vaccine period, yet lower for the elderly. This age pattern likely reflects higher vaccination rates for the elderly, but may also reflect behavioral differences, with the elderly trying harder to avoid infection.

Advantages of the CEMP Measure. Any mortality measure will have strengths and limitations. However, CEMP has attractive features relative to other measures, such as COVID-PFR. Most importantly, it controls, albeit imperfectly, for population health, as reflected in non-COVID NMR. Population health is otherwise difficult to observe. Comorbidity data from electronic medical records (EMR) is subject to the variable quality of reporting of comorbid conditions, but in the U.S. is not available at the population level. Thus, most COVID-19 studies that address the impact of comorbid conditions examine only those people who present for medical care for COVID-19 infection,[8,20] missing the impact of underlying health factors on who becomes infected and infection severity.

Second, CEMP has important implementation advantages, notably the feasibility of gathering complete population data, since the measure uses death certificates, which are available for all decedents. This has advantages over approaches that require estimating the population at risk. Some populations may be undercounted in population statistics because of non-participation in the Census or provision of inaccurate data. While race/ethnicity can also be inaccurately captured in death-certificate data, it is unlikely that any inaccuracies will differ systematically between those who die of COVID-19 versus other natural causes. Death certificates usually have personal identifiers, making it feasible to enhance analyses by adding

information on the decedents' COVID-19 vaccination status, which is collected at the individual level by many states. Linkage to individual EMR data may also be possible.

Implications of our findings regarding age and racial disparities. While many reports have emphasized the disproportionate impact of COVID-19 on older adults, CEMP demonstrates that COVID-19 was a major contributor to death in middle aged adults throughout the pandemic, and during the vaccine-available period caused a larger percentage increase in mortality for persons aged 18-59 than persons aged 60+. From April 2021 to March 2022, COVID-19 increased mortality in persons aged 18-59 by more than 20% overall, and by more than 50% in Hispanic men. Thus, continued attention to mitigation of risk in the working age population is needed.

The pre-vaccine-period Hispanic/White ratios for ages 18-59, averaging 5.9:1 for women and 7.8:1 for men are stunning, and are not explained by population health, zip-SES, or education. These disparities call for close study of the reasons for them, and why they vary with age, gender, and between the pre-vaccine and vaccine-available periods. Any explanation will surely be multifactorial, and will likely depend on factors we don't observe, including infection rates,[2] (although many infections are not captured in the available datasets),[21] racial/ethnic variation in vaccination rates,[22] variation across hospitals in COVID-19 survival rates,[23] and possible variation across racial/ethnic groups in where and how soon they seek treatment and post-hospitalization outcomes.[24-25,8,26]

In particular, our CEMP ratio data underscores that the COVID-19 impact on Hispanic mortality was in marked contrast to the Hispanic paradox of life-expectancy advantage relative to Whites, despite socioeconomic disadvantage. Research is needed to understand why COVID-19 mortality is so different than cancer, heart disease and other causes of death.

In contrast, comparing the PFR and CEMP results for Blacks emphasizes that the impact of COVID-19 on Blacks should be viewed as partly COVID-19 specific, but also reflecting underlying health disadvantage. While understanding COVID-19-specific factors will benefit the Black community, attention to systemic factors that affect overall health is even more vital.

Limitations of CEMP and this paper

CEMP and CEMP ratios should not be the only measure of COVID-19 impact – we show that COVID-PFR ratios more clearly identifies the Black–White disparity in COVID-19 mortality. CEMP does not address other important COVID-19 health outcomes, including hospitalizations, ICU admissions and long COVID.

While adjusting for underlying natural mortality is an important feature of CEMP, natural mortality rates are population-based measures and cannot capture all factors that affect individual risk. Some of the disparities we see with CEMP could reflect biological risk factors that do not contribute to other causes of natural mortality. We did not have access to such variables, except through the limited lens of death certificates. Moreover, CEMP may obscure factors that may warrant individual attention; zip-SES, education, and marital status were only modestly significant predictors of CEMP (Table 3), but have been more significant predictors of COVID-19 mortality in studies using PFR.[27,5]

CEMP is a downward-biased measure of excess mortality due to COVID, because it ignores COVID's effect on natural deaths, not directly attributable to COVID. Moreover, COVID-19 deaths could be underreported on death certificates, although our textual analysis of cause of death information increased the number of deaths attributed to COVID-19. Aron and Muellbauer have argued that "excess mortality" – deaths in excess of those predicted based on

pre-pandemic experience – is a more complete measure of COVID-19 impact since it does not rely on coding accuracy and includes collateral deaths such as deaths caused by failure to seek care because of fear of contracting COVID-19 during the healthcare encounter.[28-29] But excess mortality requires estimating expected deaths based on pre-pandemic experience, which is difficult for smaller subgroups and less reliable over longer estimation periods. There is also no obvious reason why downward bias in measuring COVID-19 deaths should cause important bias in CEMP or PFR ratios. At the same time, it would be possible to study excess mortality relative to expected mortality in a manner similar to how we use CEMP.

Our study population also had important limitations. We examined only two Midwestern states, but confirmed similar nationally for 2020 (see Appendix). We lacked vaccination data. We lacked sufficient sample size to decompose the broad Other group. That group includes Asians, who as a group have higher vaccination rates than Whites,[30,22] and lower COVID mortality rates,[3] although large differences in COVID outcomes exist within this broad group;[31] Native Americans, who have faced relatively high COVID-19 infection and mortality rates.[32,5,33], and other (e.g., mixed race).

Conclusion

We present a new measure of COVID mortality risk (CEMP), which adjusts COVID-19 mortality for underlying population health. Minority/White CEMP ratios were very large, especially in the pre-vaccine period. These ratios are generally lower for ages 60+, and substantially lower, often close to 1:1, in the vaccine available period. Large disparities in CEMP suggest that differences in COVID-19 mortality, particularly between Hispanic and non-Hispanic White communities, are inadequately explained by known disparities in risk factors or

healthcare. The large variation in CEMP levels by age, gender, race/ethnicity, and time period (pre-vaccine versus vaccine-available) defies easy explanation.

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Table 1. Summary Statistics on Study Population

Table shows summary population statistics (from ACS, as of 2020) and mortality statistics (from death certificates) for Indiana and Wisconsin residents aged 18+ in 2020, and decedents over April 1, 2020-March 31, 2022. Racial/ethnic categories are non-Hispanic White, non-Black Hispanic, Black, and Other. Zip-SES is measured using Graham Social Deprivation Index; quartile 1 = highest SES; quartiles are defined using all natural deaths in both states. Non-COVID natural deaths are all deaths excluding manner of death = accident, homicide, or suicide.

	Covid Deaths	Non-Covid Natural Deaths	Population
	N (%)	N(%)	N (%)
Female	15,132 (46.21%)	109,039 (50.00%)	4,925,504 (51.00%)
Male	17,617 (53.79%)	109,037 (50.00%)	4,733,030 (49.00%)
Race/Ethnicity			
White	28,006 (85.52%)	196,480 (90.10%)	8,146,673 (84.35%)
Hispanic	1,393 (4.25%)	3,689 (1.69%)	473,615 (4.90%)
Black	2,737 (8.36%)	15,041 (6.90%)	684,284 (7.08%)
Other	613 (1.87%)	2,866 (1.31%)	353,962 (3.66%)
Age			
18-39	521 (1.59%)	3,297 (1.51%)	3,620,889 (37.49%)
40-49	1,048 (3.20%)	5,858 (2.69%)	1,499,375 (15.52%)
50-59	2,648 (8.09%)	17,120 (7.85%)	881,931 (9.13%)
60-69	5,771 (17.62%)	38,338 (17.58%)	1,494,655 (15.47%)
70-79	8,416 (25.70%)	53,579 (24.57%)	847,089 (8.77%)
80-89	8,973 (27.40%)	59,752 (27.40%)	394,676 (4.09%)
90+	5,399 (16.49%)	40,132 (18.40%)	108,774 (1.13%)
Zip-SES (1 = highest)			
Quartile 1	7,588 (23.26%)	55,772 (25.66%)	2,478,055 (25.66%)
Quartile 2	8,188 (25.10%)	55,367 (25.48%)	2,099,415 (21.74%)
Quartile 3	8,366 (25.65%)	55,489 (25.53%)	2,684,019 (27.79%)
Quartile 4	8,475 (25.98%)	50,699 (23.33%)	2,397,046 (24.82%)
Education			
Unknown	487 (1.49%)	2,621 (1.20%)	n.a.
Not high school grad	5,683 (17.35%)	33,888 (15.54%)	892,453 (9.24%)
High school grad	16,539 (50.50%)	11,0347 (50.60%)	3,016,607 (31.23%)
Some college	5,783 (17.66%)	38,988 (17.88%)	2,898,406 (30.00%)
College grad or higher	4,257 (13.00%)	32,235 (14.78%)	2,852,067 (29.53%)
Marital Status			
Unknown	140 (0.43%)	900 (0.41%)	n.a.
Single, never married	3,190 (9.74%)	22,640 (10.38%)	3,255,513 (33.71%)
Married	12,992 (39.67%)	80,273 (36.81%)	4,618,016 (47.81%)
Divorced	5,395 (16.47%)	39,217 (17.98%)	1,242,541 (12.86%)
Widowed	11,032 (33.69%)	75,049 (34.41%)	542,464 (5.62%)

Table 2. Mortality Rates by Age, Gender, and Race/Ethnicity for Wisconsin and Indiana

COVID-19 PFR, Non-COVID natural mortality rate, and CEMP for Wisconsin and Indiana during pre-vaccination period (April 1, 2020 – March 31, 2021) and vaccine-available period (April 1, 2021-March 31, 2022). The last column in each panel for Black, Hispanic, and Other reports the ratio of CEMP to the corresponding CEMP for White. **Panel A**. Pre-vaccination period. **Panel B**. Vaccine-available period. See Table App-4 for confidence intervals for all reported CEMP Ratio to White values.

$$\text{PFR} = \frac{COVID\ deaths}{Population}\ ;\ \text{Non-COVID Natural Mortality Rate (NMR)} = \frac{Non{-}Covid\ natural\ deaths}{Population}\ ;\ \text{CEMP} = \frac{COVID\ deaths}{Non{-}COVID\ natural\ deaths}$$

Panel A. Pre-Vaccine Period (April 2020 – March 2021)

	White Female			Black Female				Hispanic Female				Other Female			
Age	COVID PFR	Non-Covid NMR	CEMP	COVID PFR	Non-Covid NMR	CEMP	CEMP Ratio to White	COVID PFR	Non-Covid NMR	CEMP	CEMP Ratio to White	COVID PFR	Non-Covid NMR	CEMP	CEMP Ratio to White
18-39	0.00%	0.04%	5.70%	0.01%	0.08%	10.71%	1.88	0.01%	0.04%	26.09%	4.58	0.01%	0.04%	17.50%	3.07
40-49	0.01%	0.16%	5.96%	0.05%	0.37%	12.67%	2.13	0.06%	0.14%	40.74%	6.83	0.02%	0.09%	28.00%	4.70
50-59	0.03%	0.40%	7.82%	0.13%	0.82%	15.53%	1.99	0.15%	0.28%	54.29%	6.94	0.07%	0.31%	21.74%	2.78
60-69	0.11%	0.95%	11.23%	0.36%	2.20%	16.59%	1.48	0.43%	1.09%	39.53%	3.52	0.17%	0.81%	20.59%	1.83
70-79	0.39%	2.57%	15.04%	0.90%	3.73%	24.13%	1.60	0.66%	2.46%	26.86%	1.79	0.52%	1.94%	26.97%	1.79
80-89	1.17%	6.59%	17.70%	2.13%	9.57%	22.29%	1.26	2.03%	6.39%	31.69%	1.79	1.30%	5.67%	22.84%	1.29
90+	3.30%	18.31%	18.02%	3.65%	17.92%	20.36%	1.13	2.98%	13.78%	21.64%	1.20	3.88%	18.17%	21.37%	1.19
18-59	0.01%	0.16%	7.17%	0.04%	0.30%	13.98%	1.95	0.04%	0.09%	42.35%	5.91	0.02%	0.09%	21.64%	3.02
60+	0.52%	3.20%	16.21%	0.85%	4.10%	20.82%	1.28	0.75%	2.48%	30.42%	1.88	0.47%	2.02%	23.10%	1.43
Total	0.18%	1.19%	15.39%	0.21%	1.10%	19.37%	1.26	0.12%	0.37%	32.85%	2.13	0.09%	0.39%	22.82%	1.48

	White Male			Black Male				Hispanic Male				0ther Male			
Age	COVID PFR	Non-Covid NMR	CEMP	COVID PFR	Non-Covid NMR	CEMP	CEMP Ratio to White	COVID PFR	Non-Covid NMR	CEMP	CEMP Ratio to White	COVID PFR	Non-Covid NMR	CEMP	CEMP Ratio to White
18-39	0.00%	0.05%	4.56%	0.01%	0.10%	11.45%	2.51	0.01%	0.03%	32.00%	7.01	0.01%	0.03%	30.30%	6.64
40-49	0.02%	0.21%	7.40%	0.06%	0.56%	10.75%	1.45	0.11%	0.20%	52.17%	7.05	0.03%	0.17%	17.39%	2.35
50-59	0.04%	0.60%	7.39%	0.20%	1.21%	16.21%	2.19	0.37%	0.57%	64.71%	8.75	0.12%	0.56%	22.12%	2.99
60-69	0.18%	1.49%	12.13%	0.61%	3.36%	18.12%	1.49	0.97%	1.45%	66.80%	5.51	0.41%	1.12%	36.25%	2.99
70-79	0.66%	3.60%	18.26%	1.44%	5.94%	24.28%	1.33	2.46%	3.98%	61.72%	3.38	0.98%	2.40%	40.79%	2.23
80-89	1.84%	8.93%	20.58%	3.17%	11.25%	28.19%	1.37	2.25%	7.48%	30.11%	1.46	1.97%	7.76%	25.37%	1.23
90+	4.23%	20.28%	20.88%	4.72%	19.33%	24.42%	1.17	5.31%	13.56%	39.13%	1.87	2.79%	14.28%	19.57%	0.94
18-59	0.02%	0.23%	7.09%	0.06%	0.41%	13.94%	1.97	0.07%	0.13%	55.25%	7.79	0.03%	0.13%	22.40%	3.16
60+	0.64%	3.54%	17.96%	1.15%	5.10%	22.59%	1.26	1.50%	2.82%	52.97%	2.95	0.72%	2.17%	33.13%	1.84
Total	0.20%	1.23%	16.53%	0.25%	1.25%	20.26%	1.23	0.21%	0.40%	53.64%	3.25	0.12%	0.40%	30.12%	1.82

Panel B. Vaccine-Available Period (April 2021 – March 2022)

	White Female			Black Female				Hispanic Female				Other Female			
Age	COVID PFR	Non-Covid NMR	CEMP	COVID PFR	Non-Covid NMR	CEMP	CEMP Ratio to White	COVID PFR	Non-Covid NMR	CEMP	CEMP Ratio to White	COVID PFR	Non-Covid NMR	CEMP	CEMP Ratio to White
18-39	0.01%	0.04%	22.27%	0.02%	0.07%	23.97%	1.08	0.01%	0.04%	22.92%	1.03	0.01%	0.03%	38.46%	1.73
40-49	0.03%	0.14%	20.67%	0.08%	0.35%	24.27%	1.17	0.05%	0.12%	41.67%	2.02	0.06%	0.12%	44.44%	2.15
50-59	0.07%	0.36%	20.21%	0.14%	0.72%	19.58%	0.97	0.12%	0.34%	35.29%	1.75	0.07%	0.35%	18.75%	0.93
60-69	0.15%	0.97%	15.77%	0.37%	1.90%	19.55%	1.24	0.32%	0.79%	40.00%	2.54	0.16%	0.89%	18.12%	1.15
70-79	0.33%	2.71%	12.16%	0.59%	3.59%	16.59%	1.36	0.69%	2.20%	31.41%	2.58	0.32%	2.27%	14.04%	1.16
80-89	0.60%	6.55%	9.11%	1.12%	7.67%	14.56%	1.60	0.94%	7.76%	12.16%	1.34	0.39%	6.37%	6.04%	0.66
90+	1.13%	17.41%	6.50%	1.77%	15.90%	11.14%	1.71	1.03%	14.29%	7.19%	1.11	1.09%	14.29%	7.61%	1.17
18-59	0.03%	0.15%	20.55%	0.06%	0.26%	21.57%	1.05	0.03%	0.09%	33.70%	1.64	0.03%	0.09%	28.87%	1.41
60+	0.32%	3.20%	10.16%	0.58%	3.60%	16.04%	1.58	0.51%	2.40%	21.18%	2.08	0.25%	2.14%	11.65%	1.15
Total	0.13%	1.18%	11.03%	0.17%	0.97%	17.23%	1.56	0.09%	0.37%	23.94%	2.17	0.06%	0.41%	14.94%	1.35

	White Male			Black Male				Hispanic Male				Other Male			
Age	COVID PFR	Non-Covid NMR	CEMP	COVID PFR	Non-Covid NMR	CEMP	CEMP Ratio to White	COVID PFR	Non-Covid NMR	CEMP	CEMP Ratio to White	COVID PFR	Non-Covid NMR	CEMP	CEMP Ratio to White
18-39	0.01%	0.05%	21.49%	0.02%	0.10%	19.11%	0.89	0.02%	0.05%	47.22%	2.20	0.02%	0.05%	38.30%	1.78
40-49	0.06%	0.20%	27.32%	0.10%	0.42%	24.78%	0.91	0.14%	0.21%	65.63%	2.40	0.04%	0.22%	20.00%	0.73
50-59	0.12%	0.55%	21.35%	0.17%	1.03%	16.86%	0.79	0.29%	0.61%	46.95%	2.20	0.10%	0.59%	16.95%	0.79
60-69	0.24%	1.49%	16.01%	0.47%	2.95%	15.77%	0.99	0.55%	1.29%	42.40%	2.65	0.17%	1.20%	14.04%	0.88
70-79	0.52%	3.72%	13.85%	0.67%	5.25%	12.85%	0.93	1.16%	4.19%	27.73%	2.00	0.57%	2.64%	21.56%	1.56
80-89	1.01%	8.95%	11.34%	1.47%	10.25%	14.36%	1.27	1.93%	6.64%	29.09%	2.57	1.22%	7.76%	15.67%	1.38
90+	1.82%	20.05%	9.06%	1.69%	16.48%	10.27%	1.13	1.77%	18.67%	9.47%	1.05	1.55%	12.73%	12.20%	1.35
18-59	0.05%	0.22%	22.62%	0.07%	0.34%	19.25%	0.85	0.08%	0.15%	52.41%	2.32	0.03%	0.15%	22.22%	0.98
60+	0.46%	3.57%	12.86%	0.64%	4.51%	14.15%	1.10	0.84%	2.78%	30.13%	2.34	0.38%	2.27%	16.76%	1.30
Total	0.17%	1.23%	14.05%	0.17%	1.09%	15.47%	1.10	0.15%	0.41%	37.32%	2.66	0.08%	0.43%	18.43%	1.31

Table 3. Racial/Ethnic Disparities in COVID Mortality Rates: Multivariate Logit Analysis

Table reports odds ratios for indicated variables calculated using multivariate logit models of the probability of COVID death among the sample of natural deaths, and 95% confidence intervals (CIs). Sample period from April 2020 to March 2022. Sample includes natural cause deaths for persons 18 and older occurring in the states of Wisconsin and Indiana over the sample period. Sample excludes immunocompromised persons. **Panel A**: women. **Panel B**: men. Panel C pools males and females and adds an odds ratio for male. Age bins for ages 18-59 are 18-39 (omitted), 40-49 (bin 2), an 50-59 (bin 3). Age bins for age 60+ are 60-69 (omitted) 70-7 (bin 2), 80-89 (bin 3) and 90+ (bin 4). Omitted categories for the other variables are: White (race/ethnicity), First (most affluent) zip-SES quartile, College degree or higher education, and unknown marital status.

Panel A. Female

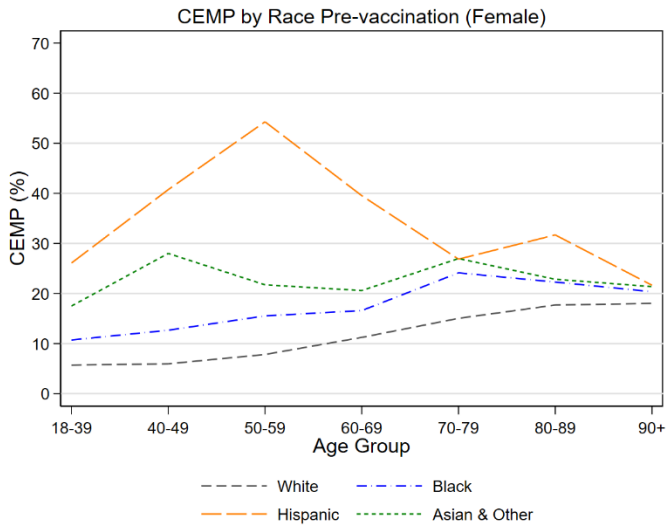
	April 2020 - March 2021				April 2021 - March 2022			
	18-59		**60+**		18-59		60+	
Category	Odds ratio	95% CI	Odds ratio	95% CI	Odds ratio	95% CI	Odds ratio	95% CI
Black	1.99	[1.52, 2.61]	1.21	[1.10, 1.33]	1.09	[0.88, 1.34]	1.36	[1.21, 1.52]
Hispanic	6.13	[4.49, 8.38]	1.80	[1.53, 2.13]	1.66	[1.22, 2.26]	1.83	[1.51, 2.21]
Other	3.02	[1.97, 4.63]	1.40	[1.15, 1.70]	1.41	[0.98, 2.02]	1.01	[0.79, 1.30]
Age bin								
2	1.20	[0.86, 1.67]	1.31	[1.21, 1.43]	0.96	[0.77, 1.20]	0.77	[0.71, 0.83]
3	1.52	[1.12, 2.06]	1.48	[1.37, 1.61]	0.88	[0.71, 1.07]	0.55	[0.51, 0.60]
4			1.48	[1.36, 1.62]			0.39	[0.35, 0.43]
zip SES Quartile								
2	1.15	[0.85, 1.55]	1.11	[1.04, 1.19]	1.00	[0.82, 1.23]	1.13	[1.04, 1.23]
3	1.06	[0.78, 1.42]	1.12	[1.05, 1.20]	1.00	[0.82, 1.22]	1.11	[1.02, 1.21]
4	1.05	[0.78, 1.42]	1.25	[1.16, 1.34]	0.99	[0.81, 1.21]	1.19	[1.09, 1.30]
Education Level								
Unknown	1.06	[0.51, 2.22]	1.60	[1.31, 1.96]	0.77	[0.38, 1.55]	1.38	[1.03, 1.85]
No High School	0.86	[0.62, 1.19]	1.21	[1.11, 1.33]	0.96	[0.73, 1.25]	1.49	[1.33, 1.68]
High School	0.72	[0.55, 0.95]	1.15	[1.06, 1.24]	1.25	[1.01, 1.54]	1.34	[1.21, 1.48]
Associate/Some College	0.81	[0.60, 1.09]	1.09	[0.99, 1.19]	1.29	[1.04, 1.61]	1.31	[1.17, 1.47]
Marital Status								
Never Married	0.95	[0.37, 2.42]	0.96	[0.61, 1.51]	2.15	[0.66, 7.03]	0.73	[0.41, 1.29]
Married	0.96	[0.38, 2.46]	0.80	[0.51, 1.26]	2.77	[0.85, 9.03]	0.92	[0.53, 1.61]
Divorced	0.76	[0.30, 1.95]	0.90	[0.57, 1.41]	1.97	[0.60, 6.43]	0.90	[0.52, 1.58]
Widowed	0.82	[0.30, 2.25]	0.88	[0.56, 1.38]	2.34	[0.70, 7.88]	0.97	[0.55, 1.69]

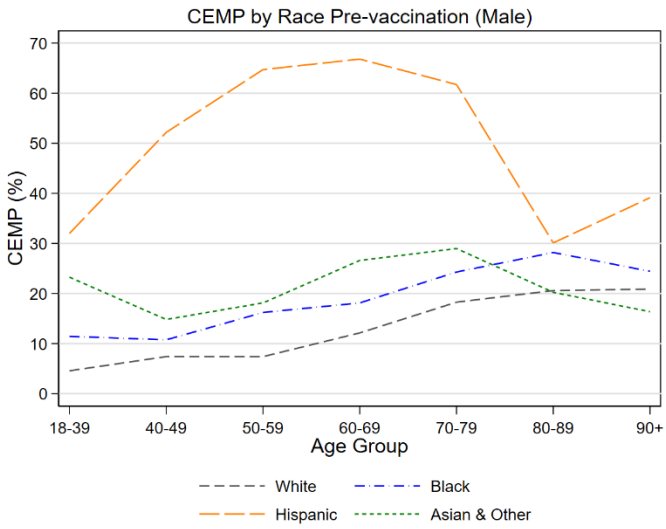
Panel B. Male

	April 2020 - March 2021				April 2021 - March 2022			
	18-59		60+		18-59		60+	
Category	Odds ratio	95% CI	Odds ratio	95% CI	Odds ratio	95% CI	Odds ratio	95% CI
Black	2.01	[1.62, 2.50]	1.30	[1.18, 1.43]	1.00	[0.83, 1.20]	1.06	[0.94, 1.19]
Hispanic	7.56	[6.00, 9.51]	2.99	[2.61, 3.41]	2.46	[2.00, 3.03]	2.17	[1.84, 2.54]
Other	3.14	[2.22, 4.44]	1.90	[1.59, 2.28]	0.92	[0.67, 1.27]	1.27	[1.00, 1.60]
Age bin								
2	1.23	[0.92, 1.64]	1.41	[1.31, 1.50]	1.03	[0.86, 1.25]	0.82	[0.76, 0.88]
3	1.38	[1.06, 1.79]	1.50	[1.40, 1.61]	0.77	[0.65, 0.91]	0.65	[0.60, 0.70]
4			1.47	[1.35, 1.60]			0.50	[0.45, 0.55]
zip SES Quartile								
2	1.13	[0.88, 1.45]	1.07	[1.00, 1.14]	0.80	[0.69, 0.94]	1.09	[1.02, 1.18]
3	1.13	[0.89, 1.45]	1.14	[1.07, 1.22]	0.83	[0.71, 0.97]	1.06	[0.99, 1.15]
4	1.18	[0.93, 1.50]	1.14	[1.06, 1.23]	0.72	[0.61, 0.85]	1.06	[0.97, 1.15]
Education Level								
Unknown	1.34	[0.76, 2.36]	1.18	[0.96, 1.45]	1.62	[1.04, 2.53]	1.18	[0.89, 1.56]
No High School	0.76	[0.57, 1.01]	1.14	[1.05, 1.23]	0.86	[0.69, 1.08]	1.38	[1.25, 1.52]
High School	0.84	[0.65, 1.07]	1.07	[1.00, 1.14]	1.22	[1.02, 1.46]	1.28	[1.18, 1.39]
Associate/Some College	0.88	[0.67, 1.16]	1.02	[0.94, 1.10]	1.23	[1.02, 1.50]	1.20	[1.09, 1.31]
Marital Status								
Never Married	2.31	[0.66, 8.16]	0.91	[0.65, 1.26]	0.82	[0.44, 1.54]	1.36	[0.83, 2.22]
Married	3.55	[1.01, 12.53]	0.91	[0.66, 1.26]	1.71	[0.92, 3.20]	2.07	[1.28, 3.35]
Divorced	2.15	[0.60, 7.63]	0.81	[0.58, 1.12]	0.98	[0.52, 1.83]	1.40	[0.87, 2.28]
Widowed	2.50	[0.64, 9.72]	1.00	[0.72, 1.39]	1.31	[0.64, 2.68]	2.01	[1.23, 3.27]

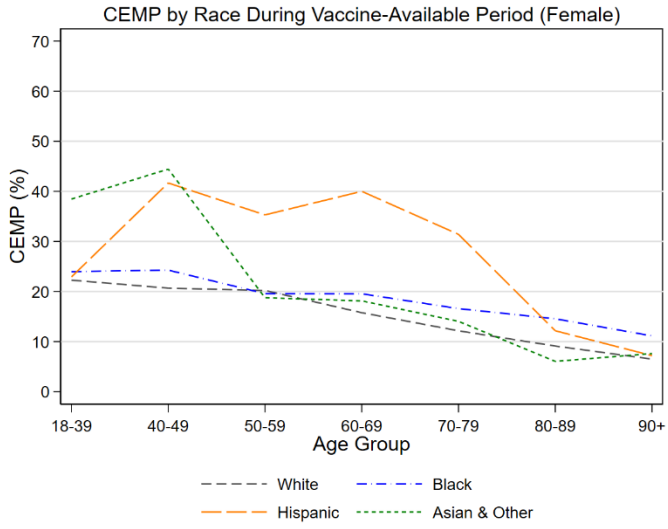
Figure 1. COVID Excess Mortality Percentage (CEMP) Levels by Gender and Race/Ethnicity

Panel A. April 2020 – March 2021 (Pre-Vaccine)





Panel B. April 2021 – March 2022 (Vaccine-Available)



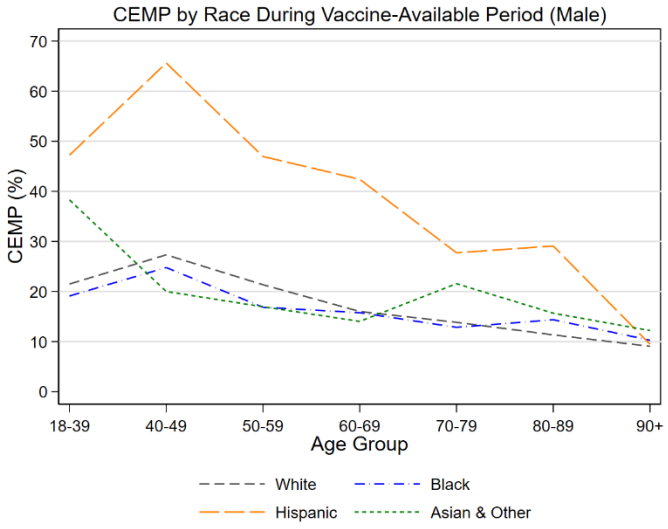
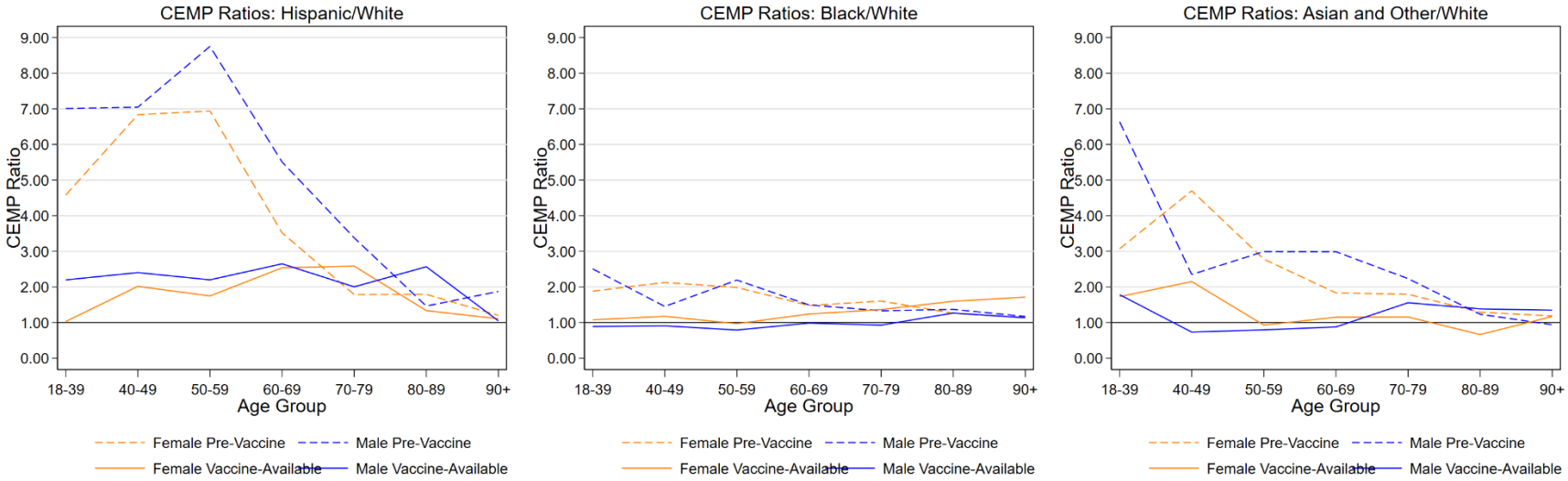


Figure 2. COVID Excess Mortality Percentage and Population Fatality Rate Ratios by Race/Ethnicity and Age Group

Figure shows CEMP ratios (**Panel A**) and PFR ratios (**Panel B**) for Hispanic, Black, and Other to White, by age range for adults (age 18+), separately for pre-vaccine period (April 2020-March 2021) and vaccine-available period (April 2021-March 2022), separately for men and women.

Panel A. CEMP Ratios: Hispanic/White; Black/White; and Other/White



Panel B. PFR Ratios: Hispanic/White; Black/White; and Other/White