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The COVID-19 Pandemic, Years of Life Lost, and Life Expectancy: Decomposition Using Individual-Level Mortality Data

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Abstract

Background
It is essential to understand the mortality impact of the COVID pandemic. Published estimates of COVID's impact on life-expectancy use period-based methods, which assume the mortality rates observed during 2020 will persist indefinitely, account for limited demographic characteristics, and can be updated only on an annual basis. Policymakers need analyses of the impact of COVID on life expectancy that vary with age, gender, race/ethnicity, and socio-economic status, and over time during the pandemic period, and use the more realistic cohort-based approach.

Methods
The researchers used individual-level death-certificate data from three Midwest states (Illinois, Wisconsin, Indiana) and CDC state-level COVID mortality data, plus data on population, life expectancy, and socio-economic status (SES) from the American Community Survey (ACS) and Medicare fee-for-service. They estimated the population fatality rate (PFR) and life expectancy without COVID by age, gender, race/ethnicity and SES quintile, then calculated years of life lost (YLL) and life-expectancy loss (LEL) for various populations, from the pandemic onset through September 30, 2021; and compared cohort-based to period-based estimates.

Findings
For the three Midwest areas, COVID PFR was 0.19%, with mean YLL per COVID decedent of 12.8 years. Population LEL was 0.025 years or 9 days for the Midwest areas and 11 days for the U.S., compared to period-based estimates of over one year. However, LEL exceeded 3 months for persons aged 75+ and was substantially higher for Blacks and Hispanics than for Whites at all ages. Mean age at death was around 80 during 2020, but fell sharply during 2021 to less than 69 overall (57 for Hispanic men).

Interpretation
The researchers' LEL estimates are a small fraction of period-based estimates and allow decomposition of LEL by age and SES and over time during the pandemic. They confirm the disproportionate impact on Black and Hispanic populations. While the pandemic's initial impact was concentrated in the elderly, younger individuals contribute an increasing fraction of COVID-related YLL.

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Background

Over 800,000 American had died of COVID by the end of 2021; the Omicron variant has accelerated a surge spurred by vaccine hesitancy, the virulent Delta variant, and waning vaccine induced immunity. The number of deaths attributed to COVID during 2020 trailed only those due to cancer and heart disease, and even larger numbers of COVID deaths are expected for 2021. Moreover, the mortality impact of the pandemic has varied among different population groups.

A number of authors have used change in population life expectancy to express the impact of COVID on mortality in a way that can be compared across groups and compared to the impact of other health threats, such as rising levels of obesity and the so-called opioid epidemic. However, while the mortality impact of the pandemic is likely to fall, perhaps rapidly, other health threats are more persistent. Different ways of calculating how a health condition affects life expectancy can yield markedly different results both for aggregate effects and how that impact varies across population groups.

Published estimates of the impact of COVID mortality on U.S. population life expectancy during 2020 show decreases of 1-2 years overall, but higher for Blacks and Hispanics Aburto et al., 2021; Andrasfay and Goldman, 2021; Arias et al., 2021; Dugoff et al., 2020; Woolf et al., 2021a). However, these estimates rely on the period-based life-expectancy method, which assumes that 2020 mortality rates will persist indefinitely. If COVID mortality does decline, as is widely expected, then estimates of COVID's impact on life expectancy should examine the impact of a shorter period of high mortality. Therefore, we used a cohort-based life expectancy approach, applied to individual-level mortality data covering the period from March 2020 to September 2021 to provide U.S. estimates of population fatality rate (PFR, the fraction of persons who have died of COVID), mean age at death, years of life lost per decedent (YLL), and life expectancy loss (LEL) to date, including multivariate estimates that vary by age, gender, race/ethnicity, and socio-economic status, and by calendar quarter during the pandemic.

While the limitations of period-based estimates are known, there is no published comprehensive assessment of the impact of COVID on life expectancy using the cohort-based approach, which measures COVID mortality during a specific time period. In the present study, we use the cohort approach to estimate the cumulative impact of the pandemic from March 1, 2020 through September, 2021; the next draft will cover through year-end 2021. We rely on individual-level death-certificate data, which lets us estimate PFR, mean YLL, and LEL, and effects for subgroups defined by age, gender, race/ethnicity, and socio-economic status. We estimate the impact of each of these factors controlling for the others, and how the pandemic's effects have varied over time. We also compare period-based and cohort-based life expectancy estimates for the same population.

METHODS

We provide here an overview of the methods and dataset for this study. The Appendix provides additional methodology details and supplemental results.

Study population

We use two distinct populations for this study. First, we study three Midwest areas (Cook County, Illinois; Milwaukee County, Wisconsin; and the State of Indiana) for which we are able to obtain individual-level COVID mortality data from death certificates, from March 1, 2020 through September 30, 2021. These three areas have different demographics and a combined population of around 13 million. We have data on age, gender, race/ethnicity (White (non-Hispanic), Black, Hispanic (white), Asian, and other), 5-digit residence zip code for the decedents (from death records), population (from American Community Survey (ACS) and Census data and, for age 65+, Medicare data). For ages 65+, we also use ACS data to calculate quintiles of the Graham Social Deprivation Index (SDI), as a measure of socio-economic status (SES) at the 5-digit zip-code level. The SDI elements are percentages of: households who don't own a car; percent of homes not owner-occupied; homes with more than one person per room, population 16-64 years unemployed, single-parent families, population age 25+ with less than 12 years of education, and population below poverty line {Butler et al., 2012}. For younger ages, due to the limited granularity of population data in the ACS, we can estimate the effects on COVID mortality rates of age, gender, location, and also either SES or race/ethnicity but not both at the same time.

Second, for national COVID mortality estimates, we use state-level data (including the District of Colombia. and Puerto Rico) on COVID deaths by age, gender, and race/ethnicity from the Centers for Disease Control and Prevention (CDC). We obtain data on the population of each state, including distribution by age, gender and race/ethnicity, from the US Census Bureau.

For some results, we drop ages 0-19, 95+, or both, due to imprecise estimates for these ages.

Overview:

To estimate life expectancy lost (LEL) due to COVID for a population, we first estimate the life expectancy of the COVID decedents within that population, at the time they died. Summing these years over all COVID decedents gives total years-of-life-lost due to COVID. We then divide years of life lost by population to get the average LEL for that population.

Estimating Life Expectancy without COVID

For persons aged 65+, we estimate life expectancy using national Medicare data for a 5% random sample of Medicare FFS beneficiaries aged 65+ in 2000. We first estimate survival through 2018 (thus, a 19-year estimation period), as a function of age in years, gender, age interacted with gender, race/ethnicity (White, Black, Hispanic, Asian, other), state, and SDI, using the semi-parametric Cox proportional hazard model. We use this model to estimate mean survival time for persons aged 65+ in 2000. Since we only have 19 years of survival data, we extrapolate the survival curves estimated during our observation period to age 100. To adjust our estimates, which are based on Medicare beneficiaries alive in 2000, for changes in life expectancy from 2000-2018, we add the increase in life expectancy over this period, if any (by age, gender, and race/ethnicity), as reported by the National Center for Health Statistics (NCHS), to the Cox-model estimates. In robustness checks, we obtained similar results with the Cox model and a Gompertz model (see Appendix Figure App-11).

For persons aged 20-64, we use life expectancy reported by the NCHS, which is available by age, gender, and race/ethnicity (for Black, White, and Hispanic, but not Asian).(e.g., Arias and Xu, 2020) For Asians, we use the NCHS average for Whites plus the Asian-White difference in life expectancy at age 65 measured from the Medicare data; for "other" race (who have survival times similar to Blacks in the Medicare sample), we use the NCHS data for Blacks.

Estimating COVID PFR

To estimate COVID PFR, we obtain the observed number of COVID related deaths from mortality records for the three Midwest areas, and from state-level data for national estimates. We provide separate estimates for the elderly (age 65+) and non-elderly (age 20-64). We do not estimate mortality for ages 0-19 because of the small number of COVID deaths in this age range. For the elderly, we construct a synthetic population by inflating our 5% Medicare random sample to match the ACS population in age, gender, and race/ethnicity for each zip code (Chicago, Indiana, Milwaukee analysis) or state (national analysis). The denominator for the non-elderly comes from ACS population estimates by age, gender, and race/ethnicity. When ACS does not provide population by individual year of age, we estimate population by year of age within an age group (e.g., age 22-24) using annual survival probabilities from NCHS.

We estimate COVID mortality COV^{mort}, using the following logit regression. The covariate vector **X** includes age (using a cubic functional form (in age – 65 for the elderly; and age - 20 for the non-elderly)), gender (female is the baseline), race\ethnicity (White is the baseline), SDI quintile (quintile 1 (highest SES) is the baseline), and location (Indiana is the baseline). We observe gender differences in the association of COVID mortality with age and with race/ethnicity. We therefore also include in the covariate vector **X** interactions between gender and race/ethnicity and between gender and age:

$$COV_i^{mort} =^{logit} \alpha_l + \boldsymbol{\beta}_i * \boldsymbol{X}_i + \epsilon_i \qquad (1)$$

For Table 1, we use this two-way interaction model. For figures that show PFR or LEL by race/ethnicity, we apply eqn. (1) to White, Black, and Hispanic subsamples separately, for more accurate estimates of the effects of age on PFR and LEL within these subsamples.

Computing Population Fatality Rate (PFR)

We use the coefficients from the logit model above, to construct the conditional population fatality rate for persons within a combination of a (age), g (gender), r (race/ethnicity), D (SDI quintile, only available for the elderly), and *l* (location), as:

$$PFR_i = \frac{exp(\alpha_i + \boldsymbol{\beta}_i * \boldsymbol{X}_i)}{\left(1 + exp(\alpha_i + \boldsymbol{\beta}_i * \boldsymbol{X}_i)\right)} \qquad (2)$$

Calculating Life Expectancy Loss (LEL) Due to COVID Using the Cohort Approach

One can combine the life expectancy estimates without COVID and the PFR estimates from eqn. (2), to estimate life expectancy loss due to COVID (*LEL*). Using the cohort approach, this is simple multiplication:

$$LEL_{agrDs} = LE_{agrDs} \times PFR_{agrDs} \qquad (3)$$

Calculating Life Expectancy Loss (LEL) Due to COVID Using the Period Approach

To compare cohort-based LEL estimates to the period-based approach used in other studies, we also need to compute period-based LEL. Consider a person aged *a*; let PFR_a denote COVID mortality risk from age *a* to age *a*+1, LE_a be life expectancy at age *a*, LEL_a be life expectancy loss due to COVID from age a to age a+1 ($LEL_a = LE_a * PFR_a$); s_a be probability of survival from age *a* to age *a*+1 due to *all other causes of death*; and $surv_a$ be the total probability of survival from age *a* to age *a*+1 ($surv_a = s_a * (1-PFR_a)$). The period-based approach measures total LEL (call this $LEL\text{-}per_a$) by summing the annual LEL_a values over an expected future lifetime. More formally:

$$LEL\text{-}per_a = LEL_a + (surv_a * LEL_{a+1}) + (surv_a * surv_{a+1} * LEL_{a+2}) + + (surv_a * surv_{a+1} * surv_{a+2} * LEL_{a+3}) + \ldots + [\text{up to age } 100] \quad (3)$$

RESULTS

COVID PFR and Life Expectancy Loss for the Three Midwest Areas

The combined estimated population of Cook County, Milwaukee County, and Indiana residents was 12,828,178, including **7**,587,128 aged 20-64 and 1,988,270 age 65+. For these persons, their mean age was 38.47 years and 48.94% were female. As shown in Appendix Table App-4, the majority (67.3%) were white, 15.5% were Black, and 11.8% were Hispanic. Through September 30, 2021, 24,663 residents of these areas aged 20+ had died of COVID, of whom 19,404 (78.7%) were age 65+. The population fatality rate was 0.69/1000 for individuals age 20-64 and 9.76/1000 for persons 65+.

Because we can include SDI as a predictor only for the elderly, we present in Table 1 the average marginal (adjusted for other factors in the model) effects of gender, race/ethnicity, and SDI for persons aged 65+ separately from the marginal effects for persons aged 20-64. We show marginal effects of race/ethnicity separately for men and women because of a significant interaction between those factors. Note the large marginal impact of being Hispanic for men. The marginal effect of being Black is about half that of being Hispanic for men in both age groups. Hispanic and Black women also faced higher mortality than Whites (the omitted group) but less sharply and with similar marginal Black and Hispanic effects.

PFR is higher for residents of zip codes in any but the first (highest) SES quintile, and generally increases as SES decreases. Residence in a fifth-quintile zip code has predictive value similar to being Black (average across genders). Controlling for SES reduced the marginal effects of race/ethnicity but only modestly. This suggests that SES differences can explain only a fraction of the higher mortality of racial/ethnic minorities.

Figure 1 presents PFR by age, gender and race/ethnicity, and shows substantially higher PFR for Blacks and Hispanics at similar ages, especially for men, and especially for the non-elderly. These differences are presented as ratios in Figure 2. The PFR among non-elderly Hispanic men is generally more than 4 times that of White men of the same age. Black-White ratios for men are lower but still exceed two until age 70. Asian-to-White ratios are close to one except at very high ages.

In Figure 3, we present mean age at death (Panel A) and mean years-of-life lost (YLL) (Panel B) for COVID decedents, by racial/ethnicity and calendar quarter (2Q 2020 includes March-June). In 2021, mean age at death decreases substantially, from around 80 during 2020 to less than 69 years in the third quarter (3Q) of 2021. and YLL increases. These trends are particularly remarkable for Hispanic and Black men. By 3Q 2021, mean YLL for Hispanic male decedents exceeds 26 years.

COVID and Life Expectancy

Figure 4, Panel A, shows LEL due to the COVID pandemic, through September 30, 2021, by age, gender and race/ethnicity. LEL generally rises with age, even though life expectancy lost per decedent falls, because the proportion of the population dying of COVID rises rapidly with age (see Figure 1 and Table 2). At all but advanced ages, men have higher LEL than women, Whites have the lowest LEL, and Hispanics have the highest LEL, with Blacks next highest LEL at younger ages, but both groups trade places with Asians at higher ages. The jump in LEL at age 65 reflects our shifting from NCHS to Medicare data as the source for life expectancy.

In Figure 4, Panel B, we present LEL ratios by calendar quarter for Black, Hispanic, and Asian to White, focusing on ages 20-59, for which the ratios are higher (see Figure 3). The highest ratios are early in the pandemic, especially for men. All ratios diminish over time, with some dropping below 1 in 3Q 2021.

In Figure 5, we compare our estimates of LEL due to COVID using the cohort-based method to estimates using the period-based method, which assumes that the U.S. population will continue to suffer COVID related mortality in the future at the same rate as in 2020. In Panel A, the period-based estimate starts high and declines with age. This reflects the assumption that younger individuals will face 2020 rates for COVID mortality throughout their lifetime. In contrast, the cohort-based estimate starts low and rises with age, reflecting the higher mortality rates for the elderly. Panel B shows the ratio of the period-based to the cohort-based estimate, using both a raw scale (left-hand graph) and a logarithmic scale (right-hand graph). This ratio exceeds 1,000 for younger ages, falls steadily with age but remains substantial at all ages; this is easier to see using the logarithmic scale.

Regional and National Estimates of COVID PFR and LEL

Table 2 shows PFR LEL in years by age, gender, and race/ethnicity, separately for the three Midwest areas and nationally. Consistent with Figures 1, PFR rises rapidly with age. Consistent with Figure 4, LEL rises rapidly with age for the non-elderly, but more gradually thereafter and declines at advanced ages. The average LEL for the three Midwest areas across all ages is 0.025 years, or about 9 days (10 days for men; 8 days for women). Overall LEL is larger for Blacks (0.034 years, or 12 days) and Hispanics (0.033 years, or 12 days). Hispanics have lower overall PFR than Whites, but die of COVID at younger ages and have much higher mean YLL (20 years versus 11 for Whites). The average decedent in the three Midwest areas loses around 13 years of life expectancy; somewhat more for men and less for women.

Table 2 compares estimates for our primary study regions to national estimates. National estimates are all somewhat higher than for the three Midwest areas, national LEL to date is 0.029 years (11 days). However, overall national patterns by age, gender, and race/ethnicity are very similar to those in the Midwest areas, suggesting that the more detailed analyses that we conducted for the Midwest areas are likely to be representative of national trends.

DISCUSSION

Our estimates of life expectancy loss due to COVID to date are nearly two orders of magnitude lower than previously published estimates, which assumed that 2020 mortality rates would continue indefinitely. (Aburto et al., 2021; Andrasfay and Goldman, 2021; Arias et al., 2021; Dugoff et al., 2020; Woolf et al., 2021a). For example, Andrasfay and Goldman estimate national life expectancy loss during 2020 of 1.13 years overall, 2.10 years for Blacks, and 3.05

years for Hispanics. In contrast, our national estimate through September 30, 2021 is average LEL of 10.6 days (12.0 days for men; 9.1 days for women).

Our cohort-based approach to estimating LEL illustrates the greater impact of the pandemic on older Americans. For example, in the three Midwest areas, 30-34 year-olds suffered average LEL of 2.2 days, while persons aged 85-89 lost an average of 41 days. In contrast, period-based LEL estimates suggest a greater impact on younger individuals. Differences based on gender and race/ethnicity are seen with either approach, but the cohort-based approach is more suitable for decomposing those differences by age. The high Hispanic/White and Black/White ratios that we find for the non-elderly suggest workplace exposure as a likely cause (Do and Frank, 2021). In contrast, there is no evidence for several other potential causes, including disparities in case fatality rates, mortality once hospitalized, or age-adjusted comorbidities (Do and Frank, 2021; Mackey et al., 2021), and the lower ratios for the elderly suggest a modest role for transmission within multigenerational households.

We also demonstrate that SES alone explains only a fraction of the race/ethnicity differences. Finally, we estimate the impact of COVID mortality on the Asian American population, which period-based approaches cannot because they rely on national data which does not treat Asians as a separate group.

COVID mortality is continuing, so our PFR and LEL estimates understate the eventual toll of COVID. However, our estimates are readily extended to cover a longer time period; we plan to provide quarterly updates on the *Fight COVID Milwaukee* website (https://fightcovidmilwaukee.org). Our estimates of COVID mortality are not directly comparable to those based on all-cause excess mortality during the pandemic period (e.g., Woolf et al., 2021b; Polyakova et al. 2021; Miller et al., 2021; Chan et al., 2021; Murphy et al., 2021), but our approach is readily adaptable to estimating all-cause LEL.

Our PFR and LEL measures are calculated at the individual-level and can be aggregated to study outcomes of interest for groups defined by any combination of demographic and social characteristics. Thus, we are able to examine the difference in LEL between white and Hispanic men or between Hispanic women and men in particular age ranges. We also note that this method allows for more accurate comparison to other time-limited events, such as wars, prior pandemics, or other natural or man-made disasters.

Our results are broadly consistent with prior work using the cohort approach (Goldstein and Lee, 2020; Bach, 2021; Wilson, 2021). However, these studies did not examine population subgroups, and either use a hypothetical number of deaths (Goldstein and Lee, 2020) or have limited data on life expectancy and fatality rates (Bach, 2021; Wilson, 2021). Thus, ours is the first detailed examination of the COVID pandemic using the cohort-based approach, which is generally seen as more appropriate for a time-limited event, as the pandemic appears likely to be (Goldstein and Wachter, 2006).

We acknowledge several limitations. First, our estimate is retrospective – we examine PFR and LEL to date, which will increase over time. However, our estimate does not rely on predicting the future course of the pandemic – an exercise that has proven challenging for many scientists and politicians. Second, we rely on data for three Midwest areas for SES-adjusted estimates of the impact of age, gender and race/ethnicity on LEL, which may not reflect national experience. Indeed, LEL for these areas is somewhat below national estimates. However, our estimates of the impact of age, gender and race/ethnicity are similar for the three areas and nationally. Third, we likely overestimate mean YLL and this LEL for two reasons. First, we lack data about decedent comorbidities, and thus cannot estimate how comorbidities affect LEL. Studies from the U.K. and Hungary (Hanlon et al., 2020; Ferenci, 2021) provide evidence that adjusting for comorbidities would reduce mean YLL by 1-2 years. We likely also overestimate mean YLL because nursing home residents suffered a disproportionate number of COVID deaths, but had much lower life expectancy than non-residents of similar age (Kelly et al., 2010). Finally, death certificates do not always collect race/ethnicity data in a consistent fashion.

Despite these limitations, we believe that this study offers an important contribution to the COVID literature. We point out the magnitude of the overestimates of LEL from period-based methods, and we provide much more granular insight into the disparate impacts of the pandemic on population subgroups. We believe that future research should use similar methods, and more robust datasets covering different and/or broader geographic areas to examine this unique event. In particular, our methods allow critical examination of the impact of social determinants of health on the mortality impact of the pandemic, within and across population subgroups and at different time points in the pandemic.

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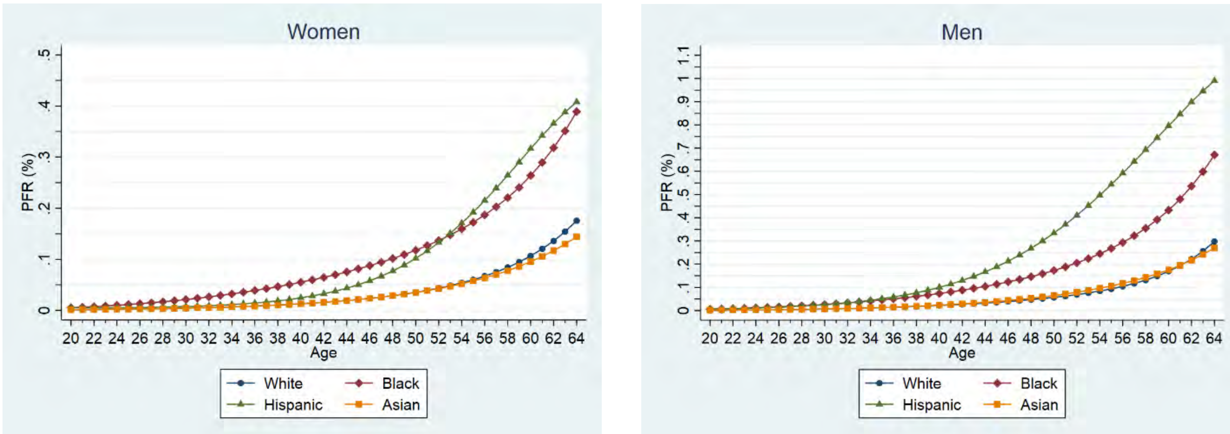
Panel A: PFR for Ages 20-64



Panel B: PFR for Ages 65-95

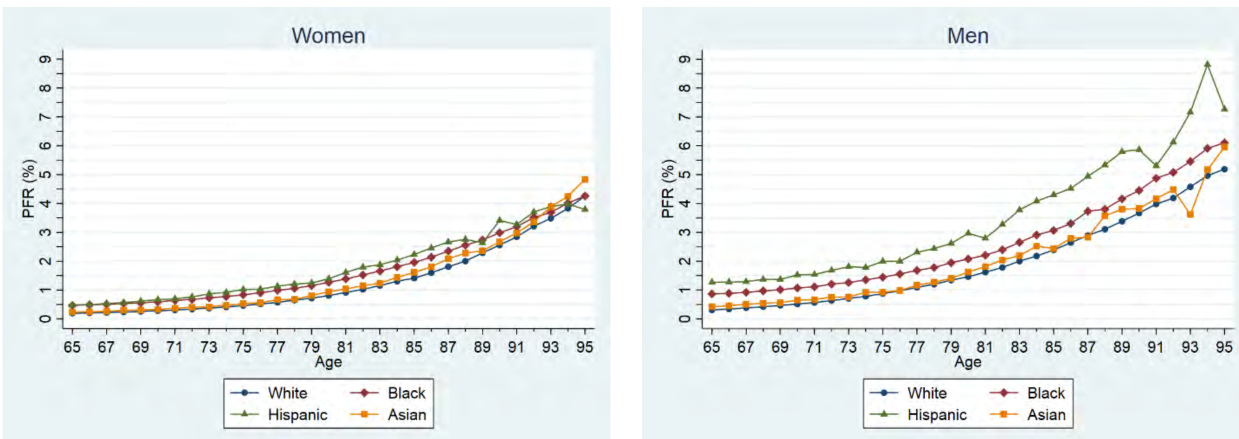


Figure 1. Estimated PFRs by Age, Gender, and Race/Ethnicity: Three Midwest Areas

Figure shows estimated COVID PFRs, modeled using eqn. (5) by age and race/ethnicity, pooled across the three Midwest areas, for women (left-hand graph) and men (right-hand graph) averaged across SDI quintiles. Panel A shows ages 20-95; Panel B shows ages 20-64. For ages 20-64, the male and female graphs use different y-axis scales. PFR by race/ethnicity is estimated within the appropriate subsamples.

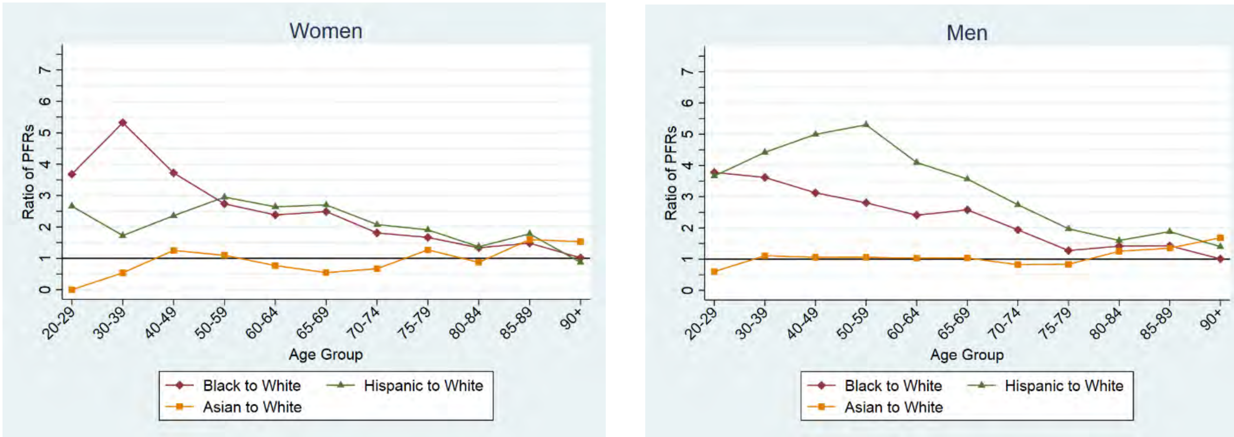
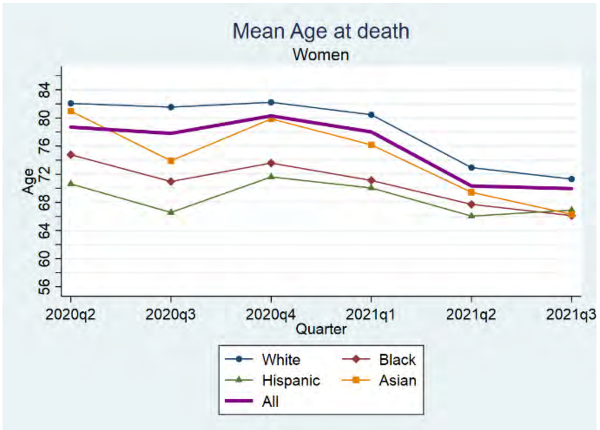


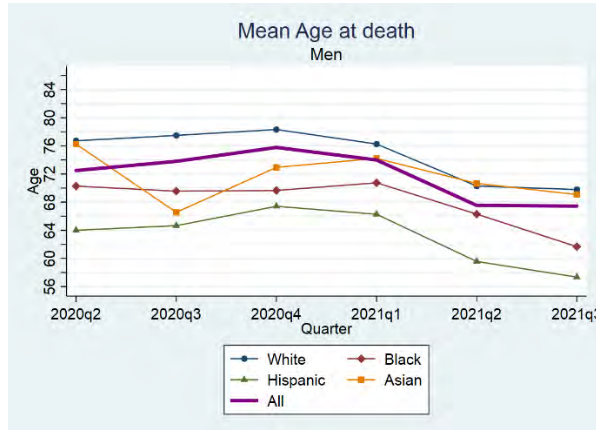
Figure 2. Ratios of Black, Hispanic, and Asian to White PFR by Age

Figure shows ratio of COVID PFRs for Blacks, Hispanics, and Asians relative to Whites, pooled across the three Midwest areas, for women (left-hand graph) and men (right-hand graph), for ages 20-95.

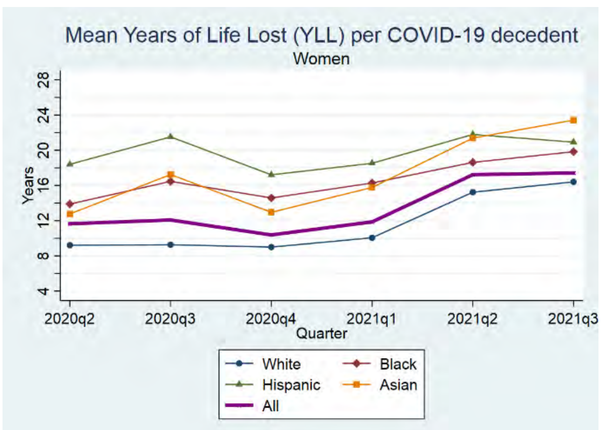
Panel A. Mean Age at Death for women



Panel B. Mean Age at Death for men



Panel C. Mean Years of Life Lost for women



Panel D. Mean Years of Life Lost for men

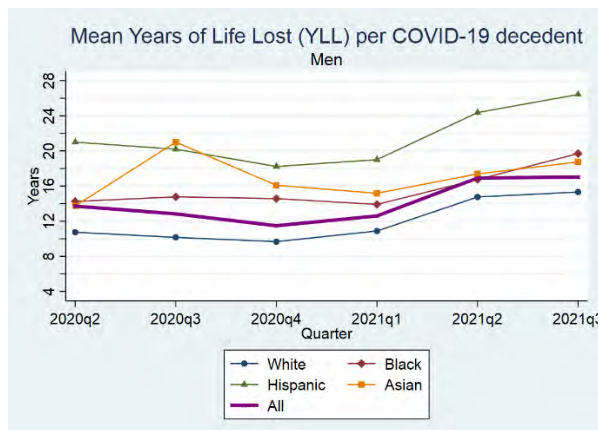
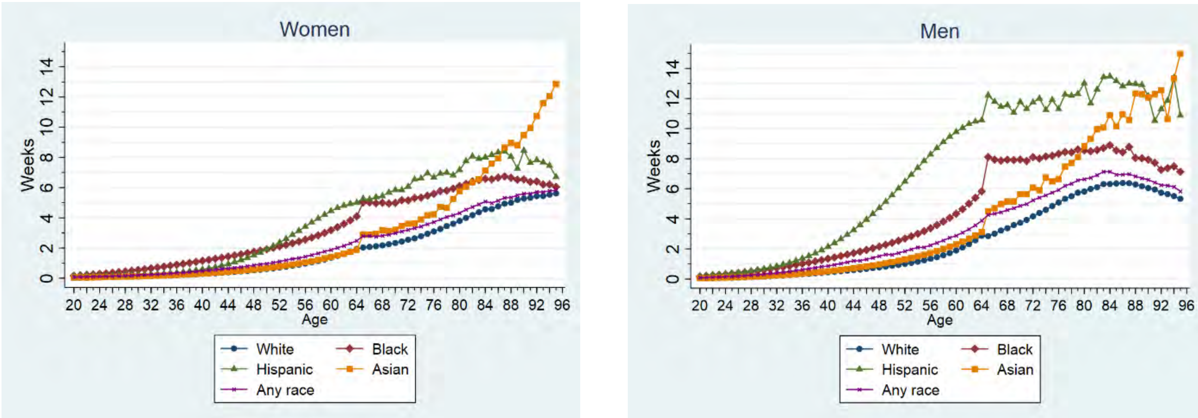


Figure 3. Mean Age and Years of Life Lost at Death by calendar quarter

Figure shows, by calendar quarter, mean age at death (top panels) and mean years of life lost (bottom panels) for COVID-19 decedents by race/ethnicity, separately for women (left hand side) and men (right hand side). Data points for 2Q 2020 covers March-June.

Panel A. LEL in Weeks Due to COVID for Ages 20-95



Panel B. Ratios of Black, Hispanic, and Asian to White LEL for Ages 20-59 by calendar quarter

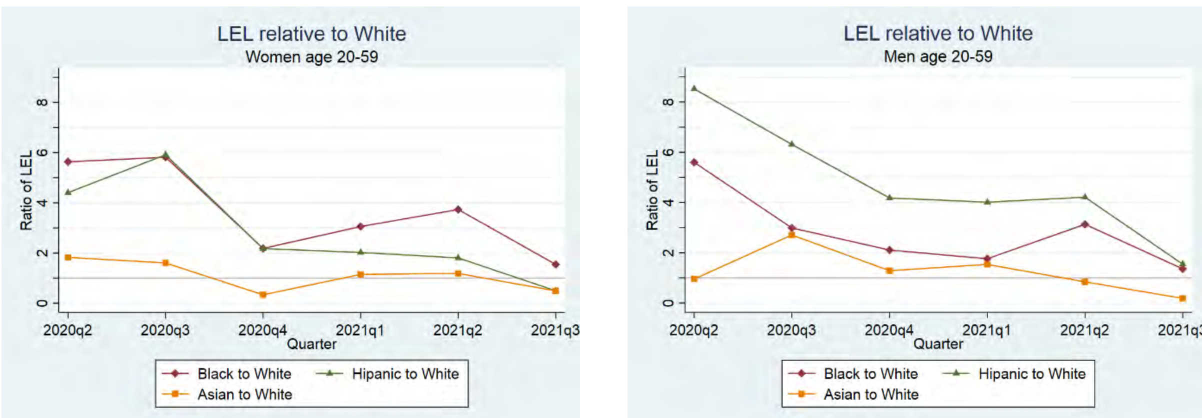
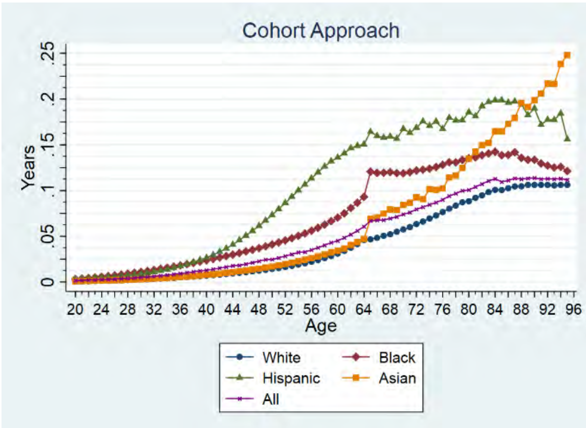
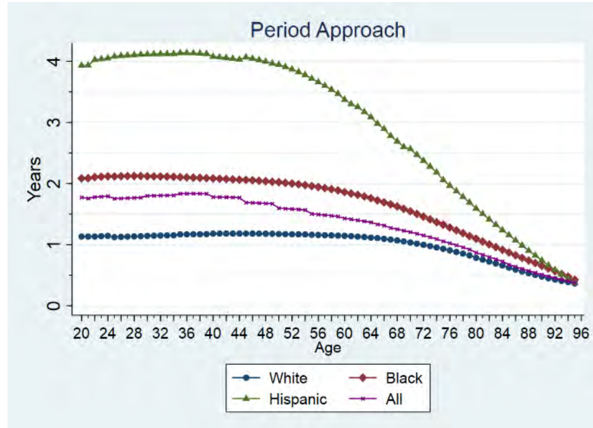


Figure 4. Life Expectancy Loss (LEL) Due to COVID: Three Midwest Areas

Panel A shows modeled LEL in weeks due to COVID by race/ethnicity for ages 20-95. Jump in PFR at age 65 reflects shift in data source for denominator. Individual lines show population-weighted estimates for all persons, whites, Blacks, Hispanics, and Asians. Panel B shows LEL ratios (Black, Hispanic, and Asian relative to White) by calendar quarter for ages 20-59. Both panels show separate figures for women (left hand figures) and men (right hand figures). LEL by race/ethnicity is estimated within the appropriate subsamples.

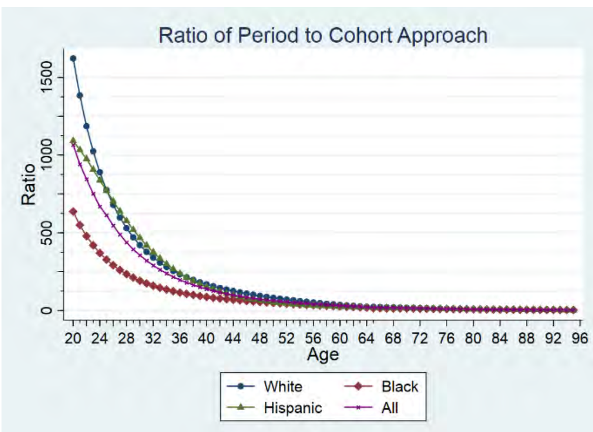
Panel A. LEL: Cohort vs. Period Estimates





Panel B. Ratio of Period to Cohort Life Expectancy Loss

Linear y-axis



Logarithmic y-axis

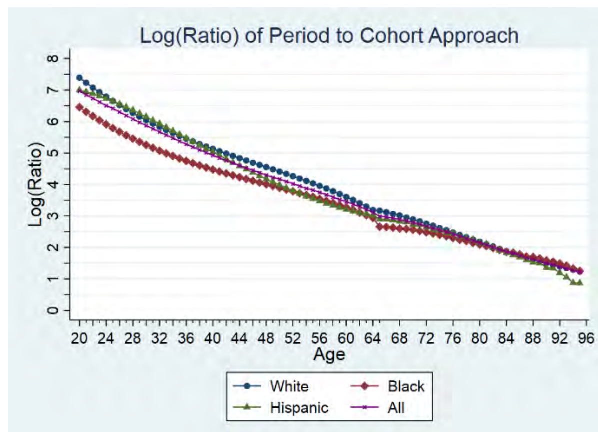


Figure 5. Cohort vs. Period Estimates of Life Expectancy Loss

Panel A. Figure shows LEL due to COVID by race/ethnicity for the three Midwest areas using cohort-based approach using data through September 2021 (left-hand graph); and period life expectancy approach using data for 2020 (right-hand graph). Individual lines show population-weighted estimates for all persons and for whites, Blacks, Hispanics, and Asians (only available for cohort-based approach). **Panel B**. Ratio of period-based to cohort-based estimate, using linear scale (left-hand graph) and logarithmic scale (right-hand graph). Both panels: LEL by race/ethnicity is estimated within the appropriate subsamples.

Table 1. Age-adjusted COVID Population Fatality Rates by Gender, Race/Ethnicity and Socioeconomic Status of Residence Zip Code: Three Midwest Areas

	Age 20-64 (n=7,587,128) Decedents = 5,259	Age 65+ (n=1,988,270) Decedents = 19,404	
	(1)	(2)	(3)
Male	0.00041***	0.0051***	0.0051***
	(0.0000)	(0.00015)	(0.00015)
SES* Status			
SDI* Quintile = 2		0.0028***	
		(0.00025)	
SDI Quintile = 3		0.0038***	
		(0.00023)	
SDI Quintile = 4		0.0032***	
		(0.00022)	
SDI Quintile = 5		0.0047***	
		(0.00024)	
Race/Ethnicity by Gender			
Black Male	0.00100***	0.0060***	0.0080***
	(0.0001)	(0.00045)	(0.00047)
Hispanic Male	0.00210***	0.0132***	0.0152***
	(0.0001)	(0.00076)	(0.00080)
Asian Male	0.00004	0.0027***	0.0029***
	(0.0001)	(0.00082)	(0.00083)
Other Male	0.00044***	0.0164***	0.0161***
	(0.0002)	(0.00216)	(0.00212)
Black Female	0.00069***	0.0036***	0.0050***
	(0.0000)	(0.00031)	(0.00032)
Hispanic Female	0.00059***	0.0058***	0.0069***
	(0.0001)	(0.00055)	(0.00058)
Asian Female	-0.00002	0.0017***	0.0020***
	(0.0000)	(0.00064)	(0.00065)
Other Female	0.00002	0.0081***	0.0082***
	(0.0001)	(0.00151)	(0.00150)

* SES = Socioeconomic status, measured using quintiles of the Graham Social Deprivation Index (SDI).

Table shows marginal effects from logit regressions for the three Midwest areas, separately for ages 20-64 and ages 65+. Omitted groups are female, white, live in Indiana, and (for regression (2)) SDI quintile 1 (highest SES). Coefficients on location and age are suppressed. Data on SDI is only available for ages 65+. Standard errors (clustered on person to account for use of one Medicare beneficiary multiple times in the synthetic population for age 65+) are shown in parentheses. We also adjusted for location (Milwaukee County, Cook County, State of Indiana), and for age using a cubic polynomial. *, **, *** indicates statistical significance at the 10%, 5%, and 1% levels, respectively.

Table 2. Life Expectancy, PFR, and Life Expectancy Loss: Three Midwest Area and National Estimates

	Three Midwest Areas				National			
Age	**COVID Decedents**	**COVID PFR (%)**	**Decedent life expectancy**	**Life Expectancy Loss**	**COVID Decedents**	**COVID PFR (%)**	**Decedent life expectancy**	**Life Expectancy Loss**
By age								
0-14	17	0.001	72.48	0.0005	328	0.001	72.40	0.000
15-19	16	0.002	58.29	0.001	300	0.001	59.26	0.001
20-24	31	0.004	56.92	0.002	1,163	0.005	57.19	0.003
25-29	65	0.007	50.97	0.003	2,259	0.01	51.74	0.005
30-34	119	0.013	46.85	0.006	4,135	0.02	47.02	0.008
35-39	200	0.02	42.88	0.010	6,166	0.03	42.98	0.013
40-44	322	0.04	37.77	0.015	9,928	0.05	38.04	0.018
45-49	525	0.07	33.46	0.022	16,476	0.08	33.80	0.027
50-54	779	0.10	29.18	0.029	24,447	0.12	29.40	0.035
55-59	1,198	0.14	24.80	0.036	34,891	0.16	25.09	0.040
60-64	2,020	0.25	20.99	0.053	58,833	0.28	21.24	0.060
65-69	2,443	0.38	17.24	0.065	68,895	0.42	17.47	0.073
70-74	3,031	0.59	13.52	0.080	85,478	0.57	13.97	0.079
75-79	3,289	0.94	10.20	0.096	90,965	1.03	10.77	0.110
80-84	3,310	1.40	7.35	0.103	91,546	1.29	7.92	0.102
85-89	3,333	2.27	4.96	0.112	87,002	2.22	5.67	0.126
90-94	2,660	3.54	3.25	0.115	69,434	3.46	3.90	0.135
95+	1,338	5.24	2.28	0.120	34,926	5.15	2.66	0.137
All ages	**24,696**	**0.19**	**12.76**	**0.025**	**687,172**	**0.21**	**13.71**	**0.029**
By gender								
Men	13,376	0.21	13.28	0.0283	378,268	0.23	14.07	0.033
Women	11,320	0.17	12.14	0.0210	308,904	0.19	13.28	0.025
By race/ethnicity								
White	16,215	0.20	10.67	0.0211	432,199	0.21	11.58	0.024
Black	4,716	0.23	15.24	0.0344	105,691	0.26	15.75	0.041
Hispanic	2,894	0.16	19.97	0.0326	124,925	0.23	19.59	0.045
Asian	569	0.11	15.32	0.0172	24,737	0.15	16.25	0.024
Other	302	0.11	12.76	0.0145	13,755	0.13	17.25	0.023

Left-hand side of table shows for the three Midwest areas: COVID PFR, life expectancy for COVID decedents, life-years lost, and life expectancy loss (in years). Right-hand side shows national data, including national COVID decedents. Decedents are through September 30, 2021 (October 2 for race/ethnicity). Decedents by race/ethnicity sum to slightly less than national totals due to persons with missing race/ethnicity information. For the national data, we assume that the COVID mortality age gradient for the three Midwest areas within each 5-year grouping applies nationally. We compute separate estimates within each age group for men and women and for each race/ethnicity and combine them as needed to generate the rows in the table.