American Journal of Epidemiology

Vol. 193, No. 2
https://doi.org/10.1093/aje/kwad186
Advance Access publication:
September 15, 2023

Original Contribution

Demographic and Geographic Characterization of Excess Mortality During the COVID-19 Pandemic in Baltimore City, Maryland, March 2020 to March 2021

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Initially submitted October 4, 2022; accepted for publication September 12, 2023.

Estimates of excess mortality can provide insight into direct and indirect impacts of the coronavirus disease 2019 (COVID-19) pandemic beyond deaths specifically attributed to COVID-19. We analyzed death certificate data from Baltimore City, Maryland, from March 1, 2020, to March 31, 2021, and found that 1,725 individuals (95% confidence interval: 1,495, 1,954) died in excess of what was expected from all-cause mortality trends in 2016–2019; 1,050 (61%) excess deaths were attributed to COVID-19. Observed mortality was 23%–32% higher than expected among individuals aged 50 years and older. Non-White residents of Baltimore City also experienced 2 to 3 times higher rates of excess mortality than White residents (e.g., 37.4 vs. 10.7 excess deaths per 10,000 population among Black residents vs. White residents). There was little to no observed excess mortality among residents of hospice, long-term care, and nursing home facilities, despite accounting for nearly 30% (312/1,050) of recorded COVID-19 deaths. There was significant geographic variation in excess mortality within the city, largely following racial population distributions. These results demonstrate the substantial and unequal impact of the COVID-19 pandemic on Baltimore City residents and the importance of building robust, timely surveillance systems to track disparities and inform targeted strategies to remediate the impact of future epidemics.

Baltimore; COVID-19; disparities; excess mortality

Abbreviations: CI, confidence interval; COVID-19, coronavirus disease 2019; ICD, *International Classification of Diseases*; MR, mortality ratio.

The coronavirus disease 2019 (COVID-19) pandemic significantly shifted patterns of mortality in the United States. In addition to deaths directly attributed to COVID-19, all-cause mortality may have increased due to indirect effects of the pandemic, including limited access to health and social services, effects of social distancing, and economic changes (1). Additionally, COVID-19-related morbidity and mortality may have been underreported, particularly early in the pandemic before confirmatory testing was readily available (2–6).

One method to estimate the total impact of an epidemic is to estimate all-cause excess mortality, defined as the number of persons who have died from all causes in excess of the expected number of deaths for a given population, place, and time. The US Centers for Disease Control and Prevention estimated 299,028 excess deaths in the United States from January to October 2020, one-third of which were not directly attributable to COVID-19 (7). Excess mortality in the United States in this period was higher for Black, Asian, and Hispanic populations compared with White non-Hispanic populations (8), highlighting the disproportional impact of the pandemic among racial/ethnic minorities. Excess mortality can therefore provide a measure of the cumulative effect of the pandemic on mortality overall, as well as among vulnerable populations.

While there are several estimates of excess mortality at the subnational level, there are to date few estimates of excess mortality during the COVID-19 pandemic at the city or county level, at which most public health interventions are formulated and implemented (7, 9–11). Even fewer studies have investigated patterns of excess mortality at this administrative level in substantial detail, including

demographic trends and racial and ethnic disparities (12, 13). Excess mortality estimates at the city or county level can help identify within-state geographic heterogeneities in mortality and allow for a refined understanding of how the pandemic has shifted local mortality trends across different sociodemographic groups. An investigation of excess mortality, with a specific focus on demographic disparities, is therefore warranted, to better understand the total impact of the pandemic and to identify populations for prioritization of prevention and care services at fine spatial scales. In this analysis, we applied previously used methodology to estimate excess mortality at the city level for Baltimore, Maryland.

Baltimore City is an urban county (and city) in one of the 10 largest metropolitan areas in the United States, with a high proportion of Black residents (62.3% in 2020), high poverty (19.3% of population living below the federal poverty threshold), and documented racial discrimination and health disparities (14, 15). Baltimore City reported its first confirmed case of COVID-19 on March 12, 2020. As of February 20, 2023, Baltimore City has reported a cumulative 148,393 COVID-19 cases and 1,916 associated deaths (16, 17). While Baltimore City had lower reported COVID-19 incidence and mortality compared with other semiurban, mid/low–socioeconomic status counties, population-adjusted incidence of reported COVID-19 cases in Baltimore City was highest among Hispanic and Black populations, likely contributing to increased population level mortality among these groups despite no observed racial/ethnic disparities in case fatality rates (16). The historical and extant racial, social, and economic inequity in Baltimore City may have also concentrated the ancillary impacts of the pandemic, such as unemployment and reduced access to health services, in vulnerable or marginalized populations, with unclear effects on mortality (18, 19). Baltimore City therefore provides an ideal case study for examining the broader impact of the pandemic beyond reported cases and deaths, particularly among racial and ethnic minorities at the city level, through excess mortality. In this analysis, we sought to estimate the total impact of the first year of the COVID-19 pandemic on mortality in Baltimore City, including identification of populations that experienced disproportionally high mortality, in order to improve public health response in Baltimore and other areas with similar sociodemographic composition.

METHODS

Data source

Death certificate data for Baltimore City from January 1, 2016, through March 31, 2021, were drawn from the Maryland Department of Health Vital Statistics Administration. Our analysis was restricted to Baltimore City residents using the recorded county of residence in the death certificate.

Each death certificate record included a unique identifying record number, age at date of death, sex (data collected as male vs. female), race and ethnicity, zip code of decedent's residence, date of death, place of death (e.g., at home, in hospice facility), and primary and contributing causes of death. Causes of death were coded using the World Health Organization *International Classification of Diseases*, *Tenth Revision* (ICD-10), for which ICD-10 code U07.1 and U07.2 were used to designate COVID-19 as a primary or contributing cause of death. Duplicate records (e.g., from deaths undergoing autopsy generating multiple records) were merged to retain the most recent and complete data for each decedent.

As established by previous investigations, we defined COVID-19 deaths as any deaths listing COVID-19 as either a primary or contributing cause of death (7, 20). We additionally classified deaths into categories of non–COVID-19 primary causes of death: respiratory disease other than COVID-19, circulatory disease, malignant neoplasms, Alzheimer disease and dementia, other selected causes (diabetes, renal failure, sepsis), or external causes (e.g., drug poisoning; see Web Table 1, available at https://doi.org/10.1093/aje/kwad186, for ICD-10 codes). Race and ethnicity were categorized using the standard US Census definitions as non-Hispanic White, non-Hispanic Black, non-Hispanic Asian, Hispanic, non-Hispanic American Indian/Alaska Native, or other.

Calculation of excess mortality

Weekly counts of all-cause deaths from January 1, 2016, to March 31, 2021, were tabulated according to age, sex, race/ethnicity, place of death, and cause of death (all-cause, COVID-19, and other causes listed above), and zip code of residence at the time of death.

Excess deaths were defined as the number of persons who died in excess of what is expected for a given time period and each stratum listed above (e.g., cause of death or age group). To determine the weekly expected number of from March 1, 2020, to March 31, 2021, we fitted an overdispersed Poisson model that accounted for seasonal trends using the excessmort package (21) for R (R Foundation for Statistical Computing, Vienna, Austria). Since the Baltimore City population declined through the baseline period, time-varying population offsets were taken from 2016–2019 1-year American Community Survey reports and from the 2020 decennial census city population totals, accessed using the tidycensus R package (22). The 2020 population estimate was used as the population size for 2021 weekly calculations. These models were used to estimate the mean expected weekly number of deaths overall and for each stratum of interest (cause of death, location of death, and demographic characteristics). The 95% confidence intervals (CIs) of the expected number of deaths were then calculated for each weekly estimate of expected deaths. This method has been used previously to characterize excess mortality during the COVID-19 pandemic, including for national estimates in the United States and other high-income countries, and has been validated against other common methods using simulations and available historical data (23, 24).

Weekly all-cause and cause-specific excess mortality was computed as the difference between the observed count of deaths from March 1, 2020, to March 31, 2021, and the expected deaths estimated for that same calendar week and stratum. Confidence intervals in weekly excess mortality

Table 1. All-Cause Excess Mortality Estimates According to Selected Demographic Characteristics, Baltimore City, Maryland, March 1, 2020, to March 31, 2021

Characteristic	No.	No. of Observed Deaths	Expected Deaths		Excess Mortality		Excess Mortality/10,000		Mortality Ratio[a]	
			No.	95% CI	No.	95% CI	No.	95% CI	No.	95% CI
Overall	609,032	8,496	6,771	6,542, 7,001	1,725	1,495, 1,954	28.1	24.3, 31.8	1.25	1.21, 1.30
Age, years										
0–17	125,823	91	97	76, 117	−6	−26, 15	−0.4	−2.0, 1.2	0.94	0.77, 1.20
18–29	120,716	278	248	215, 280	30	−2, 63	2.4	−0.2, 5.0	1.12	0.99, 1.29
30–39	97,760	401	285	251, 318	116	83, 150	12.1	8.6, 15.6	1.41	1.26, 1.60
40–49	66,953	505	423	380, 467	82	38, 125	12.1	5.6, 18.5	1.19	1.08, 1.33
50–64	115,359	2,208	1,799	1,698, 1,900	409	308, 510	35.1	26.4, 43.7	1.23	1.16, 1.30
65–74	48,941	1,820	1,376	1,292, 1,459	444	361, 528	95.0	77.2, 112.8	1.32	1.25, 1.41
75–84	23,464	1,551	1,224	1,152, 1,296	327	255, 399	145.1	113.2, 177.0	1.27	1.20, 1.35
≥85	10,316	1,640	1,315	1,236, 1,394	325	246, 404	327.9	248.4, 407.4	1.25	1.18, 1.33
Unknown		2								
Sex										
Female	322,984	3,968	3,149	3,010, 3,288	819	680, 958	25.2	20.9, 29.4	1.26	1.21, 1.32
Male	286,048	4,528	3,622	3,482, 3,762	906	766, 1,046	31.3	26.5, 36.2	1.25	1.20, 1.30
Unknown		0								
Race/ethnicity										
NH Black	379,571	6,226	4,788	4,610, 4,966	1,438	1,260, 1,616	37.4	32.8, 42.0	1.30	1.25, 1.35
NH White	167,430	2,019	1,838	1,745, 1,930	181	89, 274	10.7	5.3, 16.2	1.10	1.05, 1.16
NH Asian	15,693	58	30	19, 40	28	18, 39	18.7	11.7, 25.8	1.96	1.44, 3.06
NH American Indian/Alaska Native	1,732	13	6	1, 10	7	3, 12	40.9	14.6, 67.2	2.30	1.25, 14.38
Other race	41,533	8	6	1, 11	2	−3, 7	0.6	−1.4, 2.7	1.23	0.70, 5.35
Hispanic	32,183	131	58	43, 73	73	58, 88	23.4	18.5, 28.2	2.25	1.79, 3.04
Unknown		45								

Abbreviations: CI, confidence interval; NH, non-Hispanic.
[a] Mortality ratio = observed/expected deaths in each stratum.

were calculated by comparing the number of observed deaths with the 2.5th and 97.5th percentile of expected deaths.

We estimated the cumulative number of excess deaths as well as the population-adjusted excess mortality rate using 2020 decennial census data. Mortality ratios (MRs) with 95% confidence intervals were calculated by taking the ratio of the number of expected and observed deaths; percent increases in deaths were calculated as $100 \times (1 - \text{MR})\%$. We also quantified the proportion of excess mortality attributable to COVID-19 as the primary or underlying cause of death. All analyses were completed using R, version 4.0.3 (R Foundation for Statistical Computing). The Johns Hopkins Bloomberg School of Public Health institutional review board reviewed the project and deemed it to be nonhuman subjects research because it is considered public health practice.

RESULTS

All-cause excess mortality

From March 1, 2020, to March 31, 2021, 8,496 deaths were recorded among the 585,708 residents of Baltimore City, of which 1,725 deaths (95% CI: 1,495, 1,954) were in excess of expected mortality based on death certificate data from 2016–2019. This represents a 25% increase over the expected number of deaths estimated from the prior four years (Table 1). Weekly excess mortality was highest from April to June 2020 and from November 2020 to January 2021 (Figure 1). Excess mortality rates were highest in predominately Black and historically disadvantaged neighborhoods (Figure 2).

All-cause excess mortality was observed in most age groups, with the highest absolute burden occurring among persons aged 65–74 years (444 excess deaths, 95% CI: 361,

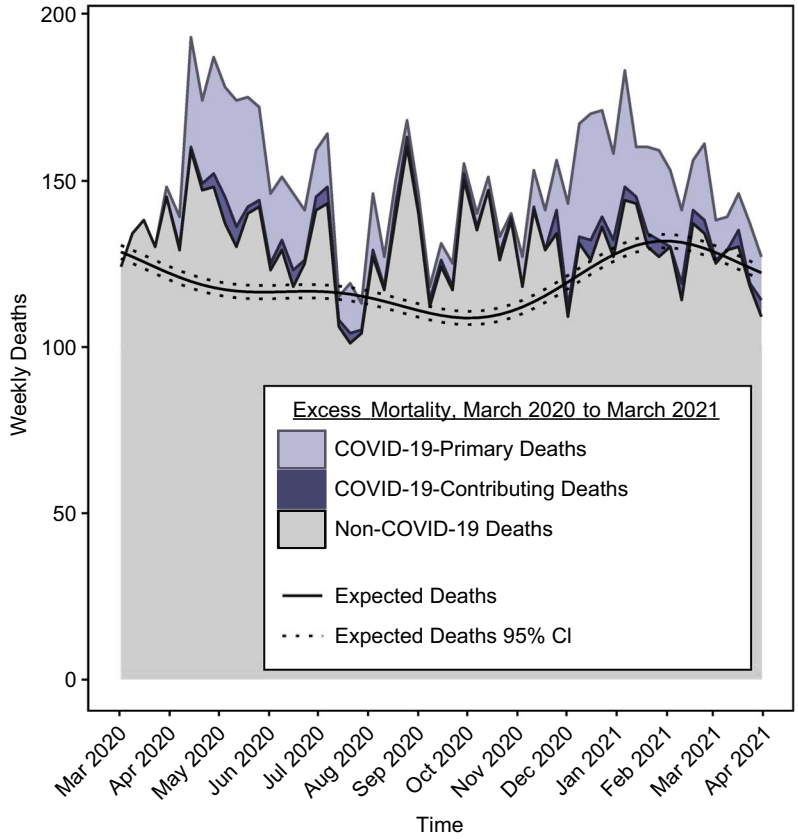

Figure 1. Excess all-cause mortality by week from March 1, 2020, to March 31, 2021, in Baltimore City, Maryland.

528) and the highest excess mortality rate among persons aged 85 or older (327.9 excess deaths per 10,000, 95% CI: 248.4, 407.4; Table 1). Compared with expected deaths based on 2016–2019 data, residents aged 30–39 years experienced the highest relative increase in mortality (MR = 1.41, 95% CI: 1.26, 1.60), followed by those aged 65–74

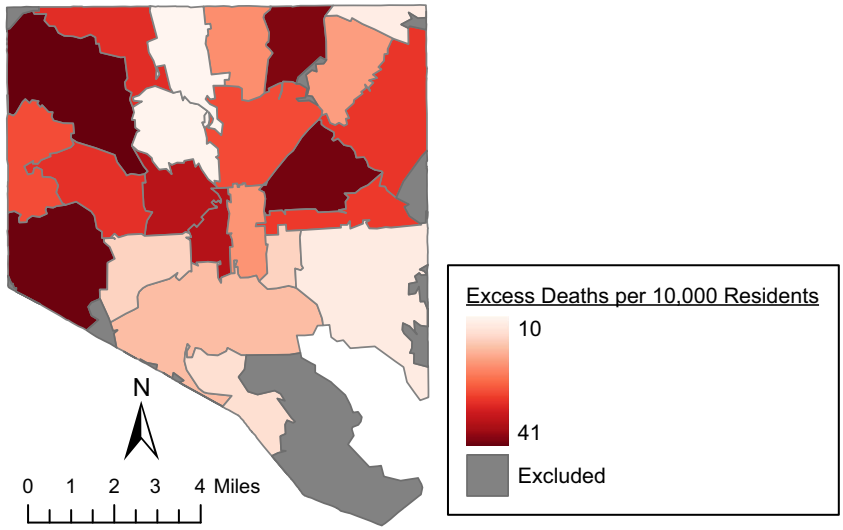

Figure 2. All-cause excess mortality per 10,000 population by zip code in Baltimore City, Maryland, from March 1, 2020, to March 31, 2021. Zip codes with populations of <3,500 are excluded in mapping due to small sample size.

Table 2. Excess Mortality, According to Primary Cause Other Than COVID-19 and Place of Death, Baltimore City, Maryland, March 1, 2020, to March 31, 2021

Primary Cause and Place of Death	No. of Observed Deaths	Expected Deaths		Excess Mortality		Mortality Ratio[a]	
		No.	95% CI	No.	95% CI	No.	95% CI
Primary cause of death (non–COVID-19)	7,587						
Circulatory	2,362	2,035	1,927, 2,143	327	219, 435	1.16	1.10, 1.23
External[b]	1,491	1,187	1,104, 1,269	304	222, 387	1.26	1.18, 1.35
Cancer	1,325	1,330	1,243, 1,417	−5	−92, 82	1.00	0.94, 1.07
Diabetes, renal, sepsis	544	478	435, 521	66	23, 109	1.14	1.04, 1.25
Dementia	456	394	353, 435	62	21, 103	1.16	1.05, 1.29
Respiratory[c]	451	453	411, 494	−2	−43, 40	1.00	0.91, 1.10
Other natural	958	885	827, 944	73	14, 131	1.08	1.01, 1.16
Place of death[d]							
Home	2,794	1,776	1,670, 1,883	1,018	911, 1,124	1.57	1.48, 1.67
Inpatient	2,245	1,775	1,681, 1,869	470	376, 564	1.26	1.20, 1.34
Hospice	1,001	1,053	976, 1,131	−52	−130, 25	0.95	0.89, 1.03
Nursing home/LTCF	877	806	745, 868	71	9, 132	1.09	1.01, 1.18
ER/outpatient	830	758	703, 814	72	16, 127	1.09	1.02, 1.18
Other	749	585	516, 654	164	95, 233	1.28	1.15, 1.45

Abbreviations: CI, confidence interval; COVID-19, coronavirus disease 2019; ER, emergency room; LTCF, long-term care facility.
[a] Mortality ratio = observed/expected deaths in each stratum.
[b] External causes of death include drug overdose, homicide, motor vehicle accident, suicide, alcohol poisoning, and other injury.
[c] Excluding COVID-19 as primary cause of death.
[d] Place of death refers to location of death, regardless of residence (e.g., a nursing home resident who dies in a nursing home would have place of death recorded as nursing home/LTCF, not home).

(MR = 1.32, 95% CI: 1.25, 1.41), indicating that while the total number of excess deaths in younger populations was low, the relative increase in mortality risk was still high. Excess mortality was similar in absolute and relative magnitude between males and females.

Adjusted for population, we observed a statistically significantly higher excess mortality rate among Black residents (37.4 excess deaths per 10,000, 95% CI: 32.8, 42.0), more than 3 times the rate among White residents (10.7 deaths per 10,000, 95% CI: 5.3, 16.2). The greatest relative increases in all-cause mortality were observed among Hispanic (MR = 2.25, 95% CI: 1.79, 3.04), American Indian (MR = 2.30, 95% CI: 1.25, 14.38), and non-Hispanic Asian (MR = 1.96, 95% CI: 1.44, 3.06) residents, although small numbers of expected and observed deaths in these groups led to large uncertainty intervals.

We detected the greatest excess all-cause mortality in deaths occurring at home (1,018 excess deaths, 95% CI: 911, 1,124) and in inpatient care facilities (470 excess deaths, 95% CI: 376, 564; Table 2). There was little to no excess all-cause mortality occurring in hospice facilities, nursing homes or long-term care facilities, or emergency room and outpatient care facilities, despite these facilities accounting for more than one-third of reported COVID-19 deaths (Table 3).

Cause-specific excess mortality

The percentage of excess mortality that was attributed to COVID-19 on death certificates can provide information on drivers of excess mortality and reporting rates. COVID-19 was attributed as an underlying or contributing cause of death in 1,050 death certificates from March 1, 2020, to March 31, 2021, or 61% of all-cause excess deaths overall in this time period (Table 3). There were noticeable increases in excess mortality that were not fully attributable to COVID-19 from March to April 2020 and from August to November 2020 (Figure 1).

The proportion of excess mortality attributed to COVID-19 varied widely by age. In younger age categories (18–39 years of age), only 12% of all-cause excess deaths were attributed to COVID-19, compared with nearly two-thirds (65%) among persons aged 40 years or older.

The number of deaths attributed to COVID-19 exceeded the number of all-cause excess deaths among White residents (percentage attributable to COVID-19, 110%). In all other race and ethnicity categories, percentages ranging from 25% to 56% of all-cause excess deaths were attributable to COVID-19. There were also substantial differences in the proportion attributed to COVID-19 by place of death: Just 7% of excess mortality that occurred at home was attributed to COVID-19, while more COVID-19 deaths

Table 3. Excess Mortality Attributable to COVID-19, According to Decedent Demographic Characteristics, Cause of Death, and Place of Death, Baltimore City, Maryland, March 1, 2020, to March 31, 2021

Characteristic	No. of COVID-19 Deaths	No. of Excess Deaths	Attributable Excess Fraction, %[a]
Overall	1,050	1,725	61
Age, years			
0–17	0	−6	
18–29	6	30	20
30–39	11	116	10
40–49	41	82	50
50–64	216	409	53
65–74	250	444	56
75–84	266	327	81
≥85	260	325	80
Unknown	0		
Sex			
Female	530	819	65
Male	520	906	57
Unknown	0		
Race/ethnicity			
NH Black	807	1,438	56
NH White	199	181	110
NH Asian	7	28	25
NH American Indian/ Alaska Native	4	7	54
Other race	0	2	0
Hispanic	31	73	43
Unknown race/ ethnicity	2		
Primary cause of death			
Circulatory	52	327	16
Other external	11	304	4
Cancer	11	−5	
Diabetes, renal, sepsis	12	66	18
Dementia	22	62	36
Respiratory	5	−2	
Other natural	28	73	39
Place of death			
Home	68	1,018	7
Inpatient	601	470	128
Hospice	126	−52	
Nursing home/ LTCF	186	71	264
ER/outpatient	44	72	61
Other	25	164	15

Abbreviations: COVID-19, coronavirus disease 2019; ER, emergency room; LTCF, long-term care facility; NH, non-Hispanic.

[a] Attributable fractions are not calculated for categories with negative excess deaths.

than excess mortality were reported in long-term care facilities, hospices, and inpatient care facilities.

Most non–COVID-19 primary causes of death exhibited relatively small excess mortality in weekly deaths (Table 2; Figure 3); very few of these deaths had COVID-19 listed as a contributing cause. Excess non–COVID-19 respiratory deaths occurred sporadically through 2020, but respiratory deaths in winter 2020–2021 were well below the number expected (Figure 3A). There were statistically significant increases in mortality among several other primary causes of death, including circulatory deaths; diabetes-, renal-, and sepsis-related deaths; dementia, and other external and natural causes (Table 2). The greatest relative increase was for other external deaths (MR = 1.26, 95% CI: 1.18, 1.35), a category that includes drug overdoses, which were consistently elevated throughout the time period (Figure 3F).

DISCUSSION

In this analysis, we estimated an excess of 1,725 deaths from March 1, 2020, to March 31, 2021, among Baltimore City, Maryland, residents, highlighting the impact that the COVID-19 pandemic has had on mortality in the city. While 1,050 (61%) of these excess deaths were attributed to COVID-19 as a primary or contributing cause of death, the remaining 39% may be attributed a combination of underreported COVID-19 deaths and increased deaths due to other causes during the pandemic (10). This is consistent with national analyses, which found that 66% of excess mortality through October 2020 was attributable to COVID-19 (7). Notably, statewide estimates of excess mortality in Maryland found that 77% of excess deaths were attributable to COVID-19; these within-state heterogeneities highlight the importance of estimating excess mortality at the city or county level (11). The largest increase in excess mortality in Baltimore City was observed in March to April 2020, early in the COVID-19 pandemic. There was likely underreporting of COVID-19 as a cause of death in this period, perhaps due to lack of available testing or delayed guidance for attributing COVID-19 as a cause of death (5, 25). Nationally, all-cause excess mortality peaked in early January 2021; excess mortality was high in Baltimore City in this period, too, but did not reach the same levels as spring 2020 (20).

Underreporting of COVID-19 deaths, particularly early in the pandemic when testing was not widely available, has been previously documented (2–6). Moreover, the ICD-10 diagnosis code for COVID-19 was not formally released in the United States until April 1, 2020 (26), which may have contributed to misattribution of COVID-19-associated deaths (2–6). In Baltimore City, there was a rapid rise in excess mortality in March 2020, which was not attributed to COVID-19, suggestive of underdiagnosis. By April 2020, these excess deaths were largely attributed to COVID-19, corresponding with release of the ICD-10 code used to define a COVID-19 death in this analysis as well as greater availability of confirmatory testing.

We also noted a substantial peak in excess mortality in August and September 2020, where a large proportion of deaths were not attributable to COVID-19 and occurred at home. These deaths followed a peak in COVID-19 cases in Baltimore City in July and may indicate further underreporting (e.g., due to delayed care seeking or limited availability of medical services) of COVID-19 mortality. The low proportion of cases attributable to COVID-19 may be related to other causes of death, such as the observed increase in excess mortality due to other external causes of death, including drug overdose, in the same period. These peaks in non–COVID-19 attributable mortality may also be due to limited access to health and social services, secondary effects of social distancing, and economic changes driving increases in non–COVID-19 causes of death. Other studies similarly have identified increases in injuries and self-harm during the pandemic (27). Although our data precluded us from elucidating potential causes related to increases in self-harm and overdose deaths, other studies in the United States have suggested an increase in the burden of mental health and substance abuse during the pandemic, particularly among members of non-White racial and ethnic groups (28–30).

There were notable racial and ethnic disparities in excess mortality, demonstrating the substantial and unequal impact of the COVID-19 pandemic on mortality among Baltimore City residents, particularly non-Hispanic Black residents and Hispanic residents. The disproportionate impact of the COVID-19 pandemic among historically marginalized racial and ethnic groups in the United States has been well documented (31). Prior studies have suggested that racial inequities in COVID-19 mortality rates stem from unequal infection risk among these groups, rather than increased case fatality rates (32). We also found in our analysis that fewer excess deaths among non-White residents were directly attributed to COVID-19 in death certificate data, indicating that there may have been differential underreporting of COVID-19 deaths, reductions in mortality due to other causes of death among White residents, or increases in other causes of death among non-White residents.

In Baltimore City, during early roll-out of vaccines, only 19% of Black individuals had been vaccinated as of April 9, 2021, compared with 38% of White residents; these disparities were not due to differential eligibility by age or occupation (33, 34). This suggests that targeted, equity-focused preventive measures against infection, such as vaccines and improved testing and case detection efforts, could reduce future COVID-19 mortality among the most vulnerable populations. In fact, as of February 20, 2023, this vaccination gap has narrowed such that 54.0% of Black Baltimore City residents have now been fully vaccinated compared with 65.2% of White residents, following concerted efforts, including geographically targeted mobile vaccinations campaigns, to reduce infection risk in these populations (33).

Moreover, the concentration of excess mortality in historically marginalized neighborhoods of Baltimore provides additional evidence for the impact of structural determinants of health on pandemic mortality. High-quality, real-time surveillance and analysis can facilitate the timely identification of disparities in disease incidence and mortality and inform the prioritization of public health interventions to prevent deaths in historically vulnerable communities. Although this analysis was unable to explore trends in excess mortality by socioeconomic status alone, measures such as

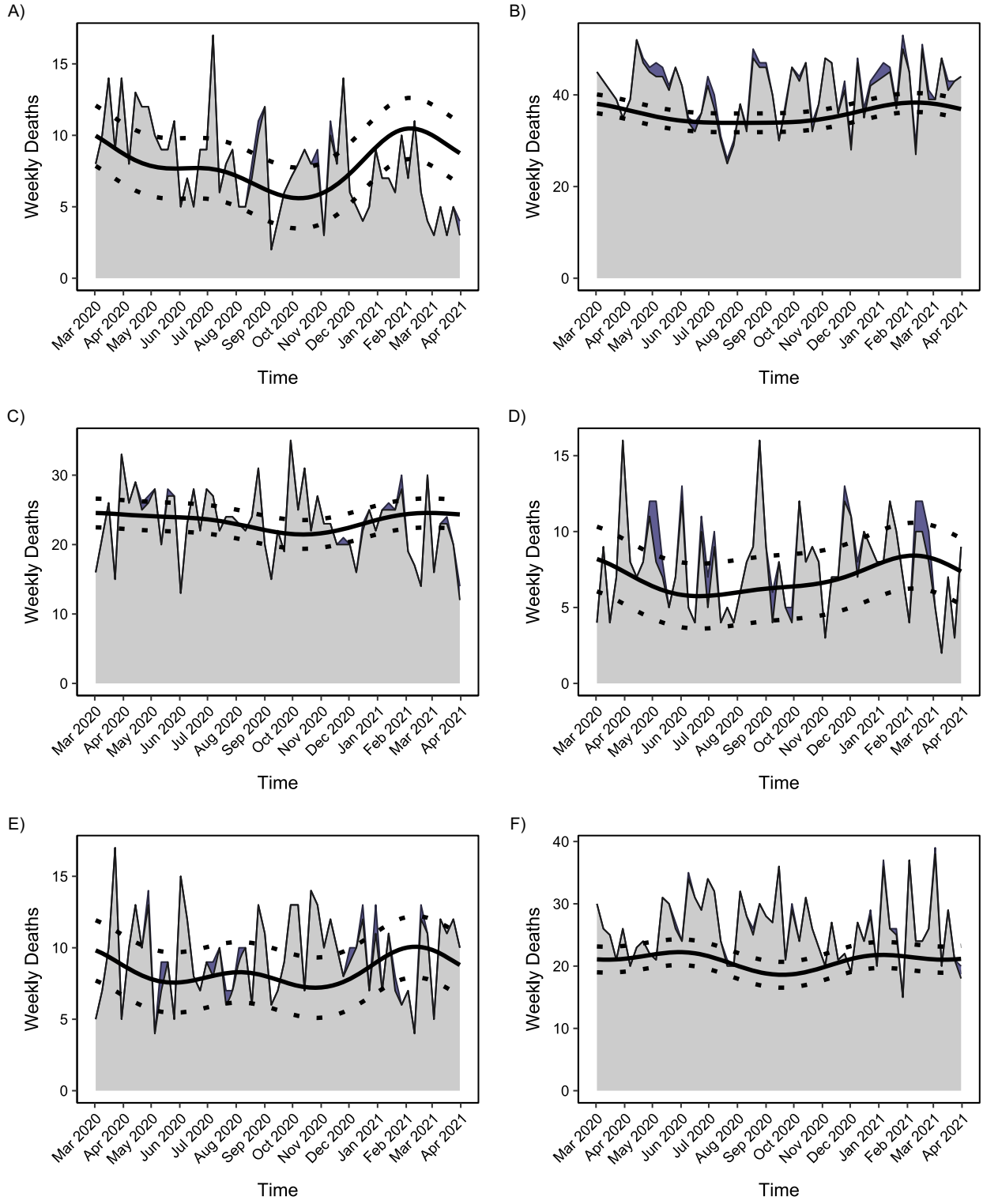

Figure 3. Time series of weekly mortality due to non–coronavirus disease 2019 (COVID-19) causes in Baltimore City, Maryland, March 1, 2020, to March 31, 2021. Shaded regions show the observed, weekly deaths by categories of non–COVID-19 primary cause of death. The purple region represents deaths with COVID-19 included as a contributing cause of death, and the gray region represents deaths without COVID-19 as a contributing cause of death. The solid line represents the expected number of cause-specific deaths by week, and the dashed lines represent the 95% confidence interval of this expectation. Primary cause of death: A) non–COVID-19 respiratory deaths; B) circulatory deaths; C) cancer (malignant neoplasms) deaths; D) Alzheimer and dementia deaths; E) other selected causes of deaths, including diabetes, renal failure, and sepsis; and F) external causes of deaths, including drug overdose, homicide, motor vehicle accident, suicide, alcohol poisoning, and other injury.

ensuring access to testing, treatments, vaccination, and the means to effectively isolate and quarantine will likely be critical in addressing disparities in excess mortality.

Conversely, the number of COVID-19-attributed deaths among White Baltimore City residents exceeded the number of excess deaths in this population, suggesting there were reductions in certain causes of death during the COVID-19 pandemic, likely experienced by privileged and well-resourced groups. For instance, deaths due to influenza and traffic accidents were markedly lower than expected during this time, likely due to the implementation of social distancing measures, including more options for working from home (35), that may have predominately benefitted White and/or wealthier Baltimore residents (36).

Similarly, the early and well-resourced interventions in nursing homes, hospice care, and long-term care facilities in Baltimore City worked well to reduce excess mortality in these settings, such that fewer excess deaths occurred than COVID-19-associated deaths in these settings. We note, though, that these interventions may have included earlier or precautionary transfer of sick residents to inpatient care; our data were unable to track excess mortality among residents of these facilities who may have died elsewhere. The high excess mortality occurring at home and among older individuals indicates that many vulnerable individuals living outside of congregate settings may not have benefited as much from these mitigation efforts. That so few deaths occurring at home were attributable to COVID-19 is another indication of possible underreporting of COVID-19 deaths occurring outside of medical establishments, as well as pandemic-associated increases in mortality due to causes other than COVID-19. Programs to proactively reach vulnerable individuals, especially those living outside congregate settings, may help to further combat social isolation and monitor for COVID-19 and other health concerns that may have contributed to excess mortality (37).

There are some methodological limitations associated with this type of analysis. Although our method adjusts for total population by year, the method is unable to account for changes in the specific demographic makeup of the population from 2016 to 2019. However, these changes are small (e.g., 62.5% reporting Black race in 2016 vs 62.6% in 2019) and unlikely to have substantial impact on the conclusions of this work. Additionally, we used only 4 years of historical data to calculate expected mortality. Other studies have used longer time periods, but these data were not available here (7). Nevertheless, our data reflect the most recent trends in mortality in Baltimore City. We present results from only one approach to estimating excess mortality. While other approaches provide more flexibility in weighting and adjusting for missing data, these adjustments are not necessary for our analysis of a single geographic unit. Further, our approach aligns with that used previously by the Centers for Disease Control and Prevention, allowing for comparability of results. Finally, while our results are likely relevant for other urban areas with similar demographics and structural disparities, they may not be generalizable to other settings.

While national estimates of excess mortality exist, our analysis provides unique insight into the factors associated with excess mortality in a city with a lasting legacy of racial discrimination and health disparities (19). Future investigation on certain vulnerable populations and possible determinants of disease burden and mortality that were unavailable here (e.g., whether individuals access services for homelessness, whether individuals were essential or frontline workers, markers of socioeconomic status other than resident zip code) would provide more insight into the drivers of the observed disparities in excess mortality.

ACKNOWLEDGMENTS

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This work was supported by the National Institutes of Health (F32 HL158019 to K.O.R.; T32ES007141 to K.T.A.; T32AI102623 to N.P.M.).

Data were provided through the Maryland Department of Health Vital Statistics Administration, and are available upon request to their organization. All other data are publicly available through referenced sources.

The authors acknowledge the support of the Surveillance and Outbreak Response Team at the Johns Hopkins Bloomberg School of Public Health. The authors thank the Maryland Department of Health Vital Statistics Administration for providing data.

Conflict of interest: none declared.

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