Trends in Maternal, Fetal and Infant Mortality in the United States, 2000-2023: Accounting for and Incorporating Reporting Changes

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Key Points

Question: How have trends in maternal, fetal and infant mortality in the US changed since 2000?

Findings: Maternal mortality remained relatively constant from 2000 to 2020 until it spiked to an all-time high in 2021, then returned to 2020 levels in 2022. Mortality in most demographic groups increased in 2020-2022 relative to 2011-2019, demonstrating that the pandemic led to worse outcomes for most mothers. Fetal and infant deaths largely decreased during the same period.

Meaning: Maternal health is difficult to track due to changes in reporting practices, but public health emergencies such as COVID-19 can have large negative impacts.

Abstract

Importance: Accurately measuring maternal mortality trends has been challenging due to changes in data collection. This work disambiguates trends from the effects of introducing the pregnancy checkbox on death certificates and also analyzes closely-related fetal and infant mortality.

Objective: To describe trends in maternal, fetal and infant deaths since 2000, including the impact of the COVID-19 pandemic.

Design, Setting, and Participants: A national population-level epidemiological analysis during 2000-2023 was conducted, using the US Centers for Disease Control and Prevention Wide-Ranging Online Data for Epidemiologic Research (WONDER) database on underlying causes of death in the US to identify maternal, infant and fetal deaths. Study population was restricted to mothers aged 15-44 years for all definitions of maternal mortality.

Main Outcomes and Measures: Longitudinal study (2000-2023) reporting crude rates per 100,000 population for adjusted maternal mortality and per 1,000 population for fetal and infant mortality at the national level and by United States Census Bureau-designated main census regions, age groups, and race and ethnicity.

Results: Adjusted maternal death rates remained consistently between 6.75 to 10.24 per 100,000 live births from 2000 until 2021, when it peaked at 18.86; the rate dropped to 10.23 in 2022. Native American/Alaska Native women death rates increased the most during the COVID-19 period, almost tripling from 2011-2019 (10.7 per 100,000 live births) to 2020-2022 (27.5 per 100,000 live births). Non-Hispanic Black women death rates were highest across time—approximately triple the rate of Non-Hispanic White women in each time period. Infant death rates per 1,000 live births dropped from 6.93 in 2000 to 5.44 in 2020, increasing slightly to 2018 levels in 2021-2023. Fetal death rates per 1,000 live births decreased from 6.28 in 2005 to 5.53 in 2022.

Conclusion and Relevance: Most groups saw increases from 2011-2019 to 2020-2022, demonstrating that the pandemic led to worse outcomes for most mothers. The adjusted maternal mortality rate almost doubled from 2020 to 2021, reaching the highest point across our study period. Infant mortality slightly increased in 2020-2023. The findings demonstrate the relevance of public health emergencies to maternal health outcomes.

Introduction

In the United States, contributors to maternal mortality include the relatively high cost of healthcare, systemic racism and bias, and lack of guaranteed maternity leave and universal health coverage.[1–3] Studying trends in maternal mortality in the US has proven challenging due to issues with data reporting. In particular, the staggered introduction of the "pregnancy checkbox" on death certificates across different states caused inconsistencies in the reporting of maternal deaths, showing large increases in maternal deaths over time concurrent to when the checkboxes were introduced.[4,5] The Center for Disease Control (CDC) have attempted to adjust for the effect of the checkbox by evaluating codes unlikely to be affected, publishing an extensive report that includes predicted maternal death counts without the introduction of the checkbox revision.[6] However, more recent studies have shown conflicting results, with some making a strong claim that maternal mortality has increased for all groups over time, while others contend that this result is an artifact of the staggered implementation of the pregnancy checkbox on death certificates.[7,8,9]

While there have been analyses to isolate the mortality codes affected by the introduction of the pregnancy checkbox, none have directly modelled its effect on maternal mortality rates. Additionally, most analyses studying maternal mortality pre-date the COVID-19 pandemic, summarizing trends up to 2018 or 2019.[4,10] While the pandemic has impacted health outcomes across all specialties,[11] there is evidence suggesting specific implications for pregnant women; pregnant women infected with SARS-CoV-2 were nearly 8 times as likely to die as their uninfected peers and 4 times as likely to require intensive care.[12] Alongside risk of infection, there were fewer in-person prenatal visits and growth ultrasounds during COVID-19, which has been associated with an increased risk of undetected fetal growth restriction, which in turn have been associated with adverse pregnancy and perinatal outcomes.[13] While the rate of fetal deaths have remained stable or decreased in recent years,[14,15] racial and ethnic disparities mirror those in maternal mortality, with the worst outcomes occurring in non-Hispanic Black women and mothers in the South.[15,16] Similarly, infant mortality has also consistently decreased in the last century, but remained highest in Southern and non-Hispanic Black mothers.[17] Contrary to impacts on maternal health, there is little evidence to date that COVID-19 has led to worse fetal and infant outcomes. Evidence from the first

months of the pandemic period (March to July 2020) showed that neonatal deaths during this period were due to prematurity rather than infection.[18] Data from Alabama that compared early pandemic (March-December 2020) and delta variant (July-September 2021) periods against a baseline period (2016-2019) showed that there was no change in stillbirth or neonatal mortality rates during the COVID-19 periods.[19]

Given the availability of new data, this study analyzes and compares long-term trends in maternal, fetal and infant deaths, including the years affected by the pregnancy checkbox roll-out and the years following the COVID-19 outbreak for as long as the data are available. There are two main aims to this work: (1) to disentangle the true trends in maternal mortality from the impacts of changes in data collection and (2) describing the impact of the COVID-19 pandemic on maternal, fetal and infant deaths. We use methods from existing literature to parse out the effect of the pregnancy checkbox to extract true trends in maternal mortality over time. Additionally, we are the first to explicitly model the effect of the staggered implementation of pregnancy checkbox on maternal mortality by state. We also contribute to the literature on fetal and infant deaths by examining a continuous, multi-decade trend that includes data beyond the Delta wave.

Methods

We followed the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) reporting guidelines for cross-sectional studies[20]. For ethics, we used the Health Research Authority decision tools. Our study was considered research, and according to the NHS Research Ethics Committee review tool[21], we did not need NHS Research Ethics Committee review or informed consent, as we only used (1) publicly available, (2) anonymized, and (3) aggregated data outside of clinical settings. Per the Brown University Human Subjects Self-Determination Tool, our study did not involve human subjects and therefore did not require review by the Brown University Institutional Review Board.

Data

We used data from the National Vital Statistics Service (NVSS) which is publicly available data collected and maintained by the Center for Disease Control (CDC), a US national agency that monitors and provides guidance on matters of public health interest. Data from the multiple causes of mortality, fetal deaths and live births tables were extracted and linked using CDC WONDER, the extraction interface. The extraction tool provides data at aggregate-level, suppressing low numbers (less than ten) within any specified grouping and imposes limitations on spatiotemporal granularities to prevent re-identification of individuals.

For infant deaths, we extracted all-cause deaths for the population aged less than one year. For fetal deaths, we extracted data directly from the recorded fetal deaths table, which reports fetal deaths at 20 weeks gestation or more and does not include induced terminations of pregnancy.[22] For maternal deaths, we studied four different definitions for the purpose of separating out the true trends from the effects of the checkbox, informed by results from Joseph et al.[4] The first definition is a traditional definition of *maternal mortality*—deaths within 42 days postpartum—comprised of codes A34, O00-O94 and O98-O99 as the underlying cause of death. The second definition is the remainder of deaths in the pregnancy-related deaths period (between 43 days and 365 days postpartum) which we call *late maternal mortality*,

identified using codes O96-O97. The third definition separates out maternal deaths from unspecified causes from the first definition using codes O26.8, O95 and O99, which we call *unspecified maternal mortality*. Joseph et al.[4] demonstrated that the late maternal death codes and the unspecified maternal death codes (definitions 2 and 3) increased as a result of the death certificate revision, while other codes remained constant during 2003-2017. Accordingly, the final definition examines maternal mortality without the unspecified maternal death codes, which we call *maternal mortality excluding cause unspecified.* We treat this last definition as a proxy for the true trends, absent the effects of the pregnancy checkbox implementation. In addition to specifying these codes, we limit the extraction to deaths in females aged 15-44 (a conservative and plausible age range for when most pregnancies would occur).

Statistical Analysis

We reported crude mortality rates indexed by live births (per 100,000 live births for maternal and per 1,000 live births for fetal and infant mortalities). Where reported, data from 2022 are provisional, and data from 2023 are births and deaths from the first half of the year (January to June) doubled to approximate the yearly counts. We were unable to report age-weighted rates for all definitions due to low counts, but included the age-weighted rates for maternal mortality excluding cause unspecified to demonstrate that age-weighted trends are similar to crude rates.

As a robustness check on our use of maternal mortality excluding cause unspecified as a proxy for true trends, we used staggered difference-in-differences (DiD) to estimate the effect of the implementation of pregnancy checkbox in 50 states, using the Callaway & Sant'Anna estimator (Supplement) on two outcomes separately (1) maternal mortality and (2) maternal mortality excluding cause unspecified.[23] Based on previous literature, we expected to find a large effect on (1) maternal mortality, and a smaller and possibly insignificant effect on (2) maternal mortality excluding cause unspecified. We used the year of checkbox implementation on death certificates in a given state as the treatment provided by NVSS, using not-yet-treated states in each year as the comparison group (Supplement).[23,24] We reported average effects across different lengths after the implementation and counterfactual trends estimated

using the average treatment effect per calendar year or overall average effect where year estimates were unreliable (i.e. outside of the checkbox rollout or where year estimates were negative at the tails of the treatment period). Inference was conducted using bootstrapping.[23]

Geographically, we examined trends at the national level, as well as by census region when the data were available at that granularity. We also computed rates separately across demographic groups including five-year age groups and race and ethnic groups. We calculated the 95% confidence interval for each rate using Byar's method.[25,26]

Results

Temporal trends

Maternal deaths

Crude rates. The rate of maternal mortality excluding cause unspecified per 100,000 live births—our proxy definition for true trends—remained consistently between 6.75 to 10.24 per 100,000 live births until 2021, when it peaked at 18.86 (95% CI: 17.48-20.32; **Figure 1**A). In 2022, the rate dropped back down to 10.23 (95% CI: 9.22-11.32). In comparison, all other definitions of maternal deaths per 100,000 live births—which include codes affected by the checkbox implementation on death certificates—increased steadily from the start of the time period until 2020: maternal mortality from 9.66 in 2000 to 23.42 in 2020, late maternal mortality from 0.37 in 2001 to 11.57 in 2020 and unspecified maternal mortality from 1.63 in 2000 to 13.18 in 2020. We were unable to report age-weighted rates for all definitions due to low counts; **eFigure 1** in the Supplement shows rates of age-weighted maternal mortality excluding cause unspecified by year, which shows a similar trend to that of crude rates.

Staggered DiD estimates. Implementation of the pregnancy checkbox on death certificates was associated with significant increases in maternal mortality for the first five years after implementation (**Figure 2**A). In comparison, there was no significant effect in maternal mortality excluding cause unspecified in the first four years after implementation (**Figure 2**A). The overall average treatment effect on the treated (ATT) was 6.78 (95% CI: 1.47-12.09) per 100,000 live births for maternal mortality and 1.82 (95% CI: -0.74-4.38) per 100,000 live births for maternal mortality excluding cause unspecified. We estimate that the checkbox accounted for 66% (95% CI: 14% to 117%) of the observed change in maternal mortality from 2000 to 2019, i.e. the true change was only +3.5 (95% CI: -1.8 to +8.8) per 100,000 live births. The counterfactual trends for both definitions are reasonably constant before the COVID-19 period (**Figure 2**B). The observed trend for maternal mortality excluding cause unspecified follows the counterfactual trend line more closely than the observed trend for all maternal mortality (**Figure 2**B).

Infant and fetal deaths

The rate of infant deaths per 1,000 live births dropped from 6.93 (95% CI: 6.85-7.01) in 2000 to 5.44 (95% CI: 5.36-5.51) in 2020 (**Figure 1**B). There was an increase over the last three years to 5.64 (95% CI: 5.57-5.72) in 2023. Fetal deaths decreased marginally from 6.23 (95% CI: 6.16-6.31) to 5.53 (95% CI: 5.45-5.60) from 2005 to 2022.

Demographic trends

Maternal deaths

Across all time periods, Non-Hispanic Black women had the highest observed rate of maternal mortality excluding cause unspecified across all race and ethnic groups. Before COVID-19, the rate per 100,000 live births was quadruple that of Non-Hispanic White women: 20.65 (95% CI: 19.52-21.84) vs 5.00 (95% CI: 4.71-5.30) in 2001-2010 and 20.51 (95% CI: 19.29-21.79) vs 5.94 (95% CI: 5.59-6.30) in 2011-2019. In 2020-2022, Non-Hispanic Black women saw a 38.42% increase from the previous period to 28.40 (95% CI: 25.81-31.18) while Non-Hispanic White women saw a 68.54% increase to 10.00 (95% CI: 9.19-10.87).

From 2011-2019 to the COVID-19 period (2020-2022), rates increased significantly for all age groups (except women aged 15-19), women in the Northeast, and across all race and ethnic groups (**Figure 3**). Geographically, women in the South saw the greatest increase from 10.27 (95% CI: 9.74-10.82) to 17.75 (95% CI: 16.52-19.04; **Figure 3**B). Native American/Alaska Native women had the largest increase of all demographic subgroups from 10.70 (95% CI: 7.64-14.57) to 27.47 (95% CI: 18.39-39.45; **Figure 2**C).

Infant deaths

Infant deaths decreased significantly across all time periods for all census regions (**Figure 4**A). All race and ethnic groups saw a constant or decreasing rate of infant deaths (**Figure 4**B).

Discussion

Maternal mortality excluding cause unspecified—which are composed of underlying causes of death codes not affected by the implementation of the pregnancy checkbox on death certificates[4]—has remained relatively consistent over the pre-pandemic period, while all other maternal mortality definitions saw an increase. Accounting for the checkbox implementation, counterfactual trends show that both maternal mortality and maternal mortality excluding cause unspecified were reasonably constant before COVID-19. In 2021, the rate nearly doubled from the previous year, reaching the highest point since the start of the millennium. This may be explained by the Delta wave, which was declared a variant of concern by the CDC in May 2021 and associated with a higher risk of adverse maternal outcomes in France and Switzerland compared to pre-Delta or Omicron periods.[27] The US Government Accountability Office (GAO) found that 25% of maternal deaths in 2020 and 2021 were related to COVID-19.[28] Another contributing factor could have been relaxation of social distancing requirements in this period, which may have led to increased social mixing and COVID-19 infection rates, leading to a higher incidence of pregnancy complications. Maternal mortality rates returned to 2020 levels in 2022. Further investigation on the differences in antenatal and postpartum care across the pandemic years may provide more information on interventions that could reduce adverse maternal outcomes in future pandemics.

While a few demographic groups saw modest increases over time in maternal mortality excluding cause unspecified from 2001-2010 to 2011-2019, we note that in the DiD analysis we found that the yearly adjusted maternal mortality rates were slightly inflated compared to the predicted counterfactuals in 2011-2019 (**Figure 2**B). Thus, it is conceivable that the modest increases over time by demographic group may be due to the checkbox implementation. We were unable to derive counterfactuals for demographic groups due to low counts at those granularities.

Most groups saw an increase from 2011-2019 to 2020-2022, which demonstrates that the pandemic led to worse outcomes for most mothers. The South saw increases between all time periods. Non-Hispanic Black women had the highest mortality in all three periods, which may be due to systemic bias and racism

that affect socioeconomic determinants of health and, more specifically, systemic discrimination within the US healthcare system.[3,29–31] Native American/Alaska Native women saw the largest increase during the COVID-19 period, with the rate more than doubling from 2011-2019 to 2020-2022. These results may indicate the need for targeted interventions by racial and ethnic groups and regions.

The only region that did not see a statistically significant increase during the pandemic period was the Northeast. Further research is necessary to determine whether this was due to random variation or could be explained by better implementation of and compliance with public health guidelines, availability of healthcare staff in the region, or other social and environmental factors.

In contrast to Fleszar et al.[7], we show that pre-pandemic levels of maternal mortality remained flat across regions and race and ethnic groups. The difference in results are likely due to the fact that we use direct counts after accounting for the effects of pregnancy checkbox rollout, while their Bayesian modeling approach is driven by priors that borrow strength across states, groups, and time, without an explicit control for the checkbox effect.[8]

All four definitions of maternal mortality follow a similar pattern from 2016. This indicates that the checkbox implementation is no longer falsely inflating trends over time, and the standard definition for maternal mortality may be used to track trends starting in 2016 and beyond.

Infant deaths decreased consistently over the last two decades, with a slight rise from 2020 to 2023. In contrast, fetal deaths declined from 2021 to 2022. Infant deaths were the highest among non-Hispanic Black infants across all-time periods, which could be attributed to systemic racism; Ramos et al. demonstrated that increase in the Systemic Racism Index was associated with an increase the Non-Hispanic Black to Non-Hispanic White infant mortality rate ratio at the county level.[32] Fetal and infant deaths should be monitored further as more up-to-date data are released, to check for any persisting effects of the COVID-19 pandemic.

Limitations

There are several limitations to the study. Firstly, because fetal deaths were only available from 2005 to 2022, we could not perform the equivalent time period comparisons. However, preliminary evidence from the last three available years demonstrates that the trend in fetal deaths may be more similar to infant deaths than maternal deaths. Secondly, because the study focuses on rare events, it was difficult to get adequate numbers at the granularity necessary to observe trends over time at multiple levels of aggregation (e.g. state by year, age-race combination by year). Thirdly, while we aimed to separate the effects of the checkbox, it is still an incomplete audit of the data quality; it is unclear by what mechanism the checkbox questions are driving up unspecified maternal deaths. Fourthly, there are alternative data sources which use different approaches to estimate mortality, which may show differing trends.[33] Finally, this study does not evaluate the underlying causes of maternal deaths. Joseph et al.[4] examined several underlying causes such as diabetes, liver disease and chronic hypertension, which all showed different trends over time. A future study could further examine and compare these underlying causes separately.

Conclusions

It is difficult to track trends in maternal mortality in the US due to changes over time in data coding and collection. All measures of maternal mortality indicated a marked rise in 2021, demonstrating the relevance of public health emergencies to maternal health outcomes. Any future initiatives on pandemic preparedness planning should consider provisions for childbirth and antenatal and postpartum care to limit preventable maternal deaths. With the exception of 2021, and accounting for changes in reporting, maternal mortality remained flat over the last two decades. By contrast, fetal and infant mortality has been decreasing across this period, though there is a worrying rise in the last three years in infant mortality. Redoubled efforts, including careful measurement of the problem, are needed to improve maternal and child health.

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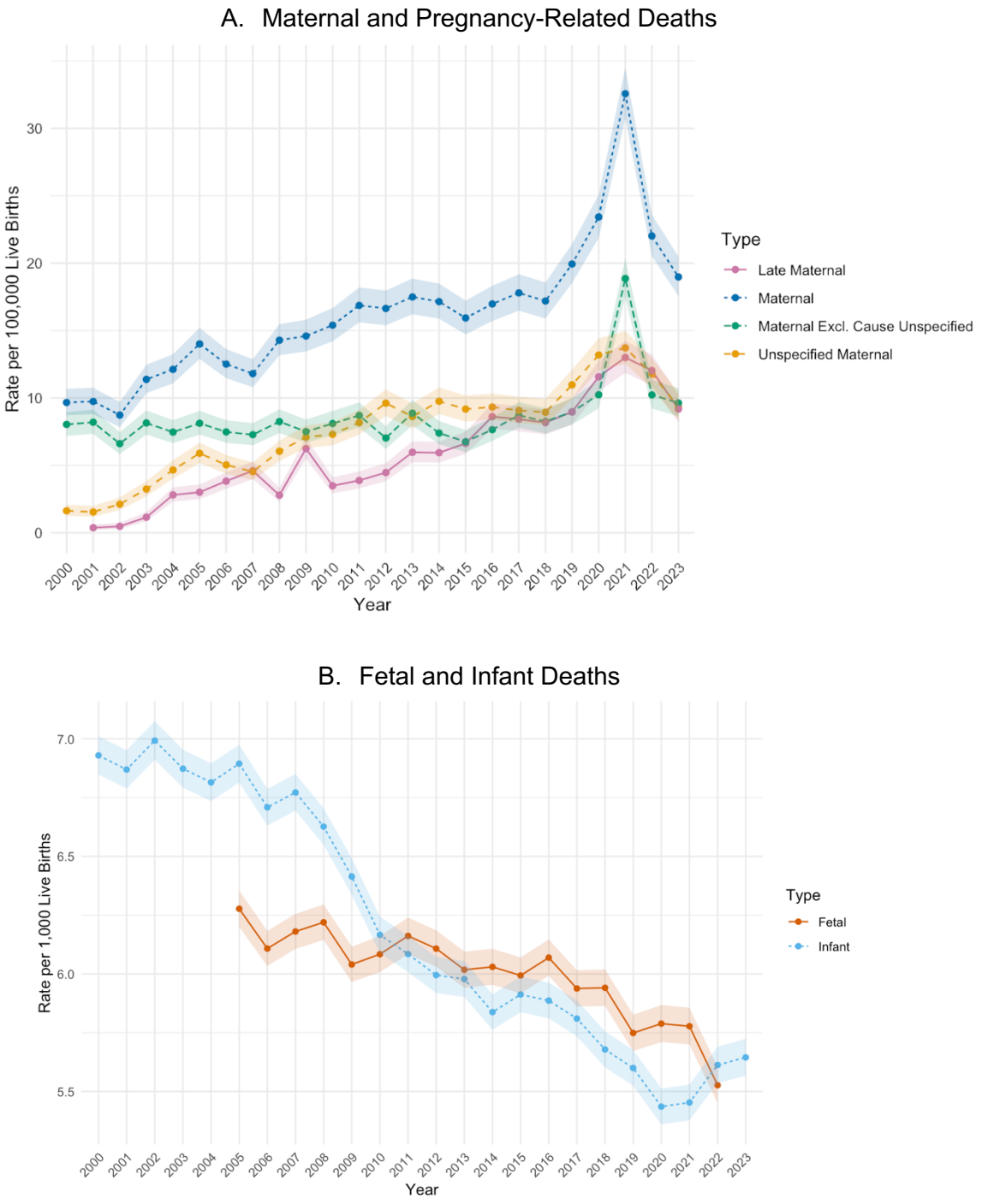
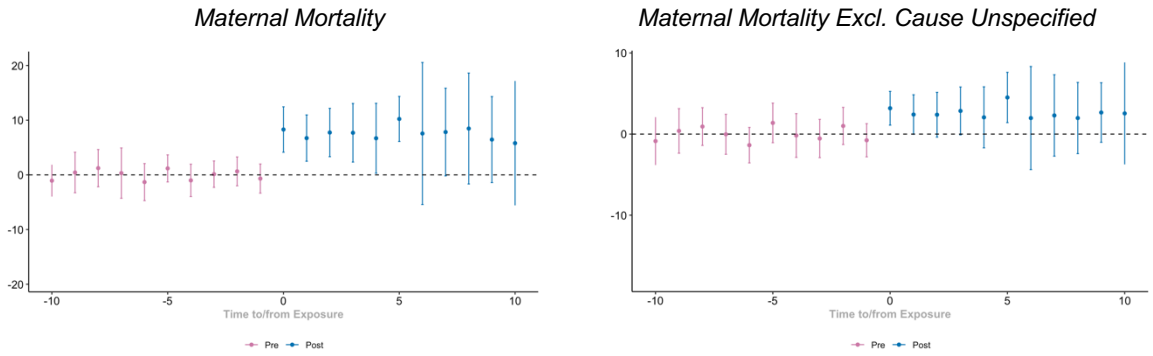
Figure 1. Rates of Maternal, Fetal and Infant Deaths by Year, 2000-2023



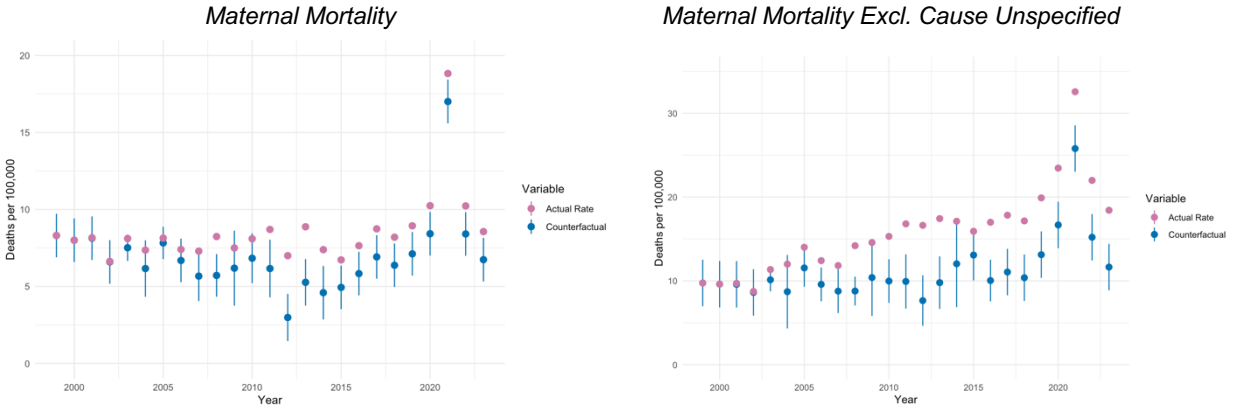
The 2022 count is provisional. The 2023 count is provisional and partial; deaths in the first half of 2023 were doubled to approximate the yearly mortality. The 95% confidence intervals are shaded around each line. **(A)** Maternal deaths are identified using underlying cause of death codes A34, O00-O94 and O98-O99. Late maternal deaths are identified using codes O96-O97. Unspecified maternal deaths are identified using codes O26.8, O95 and O99. Late maternal mortality is censored for 2000 due to low counts (<10). **(B)** Infant deaths include all-cause deaths for the population aged <1 year. Fetal deaths include deaths at 20 weeks gestation or more and do not include induced terminations of pregnancy. Fetal mortality was only available for 2005-2022.

Figure 2. Effect of Pregnancy Checkbox on Cause of Death Coding

(A) Average Treatment Effect of Maternal Mortality Checkbox by Length of Exposure



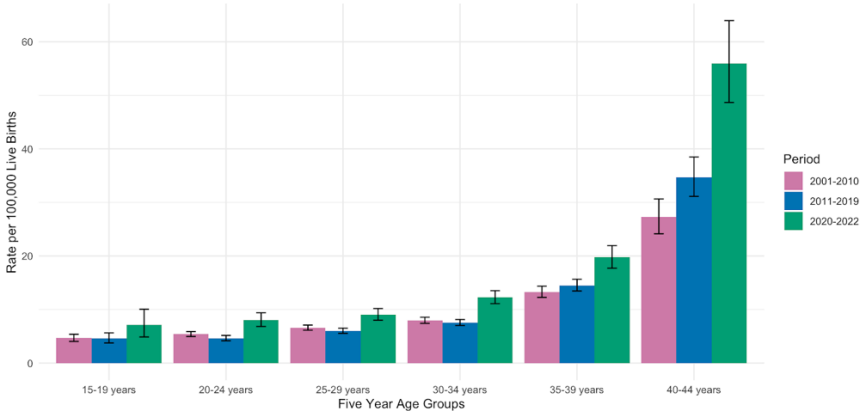
(B) Counterfactual Mortality by Years Pre/Post State Checkbox Introduction



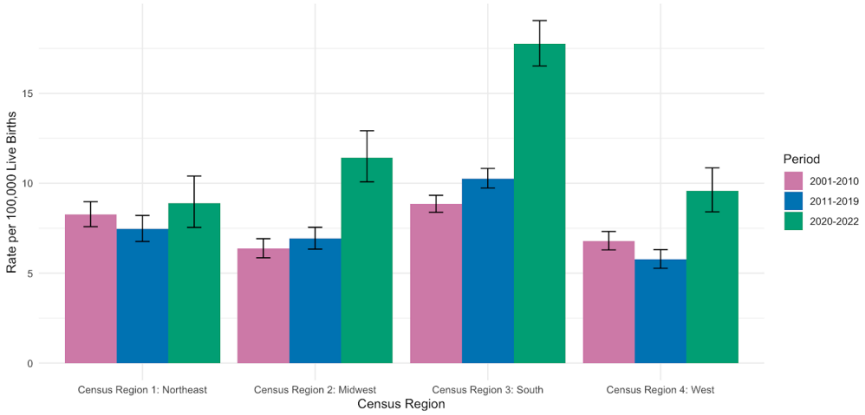
Difference-in-difference results using the year of checkbox implementation on death certificates in a given state as the treatment and not-yet-treated states in each year as the comparison group (see Supplement for technical specifications). Maternal deaths are identified using underlying cause of death codes A34, O00-O94 and O98-O99. Maternal mortality excluding cause unspecified are maternal deaths (identified using underlying cause of death codes A34, O00-O94 and O98-O99) excluding unspecified maternal deaths (O26.8, O95 and O99). **(A)** Years were limited to 10 years pre- and post-checkbox implementation due to sparse numbers in the treated (pre) or untreated (post) group in the tails **(B)** The actual 2022 count is provisional. The actual 2023 count is provisional and partial; deaths in the first half of 2023 were doubled to approximate the yearly mortality.

Figure 3. Rates of Maternal Mortality Excluding Cause Unspecified by Demographic Subgroups, 2001-2022

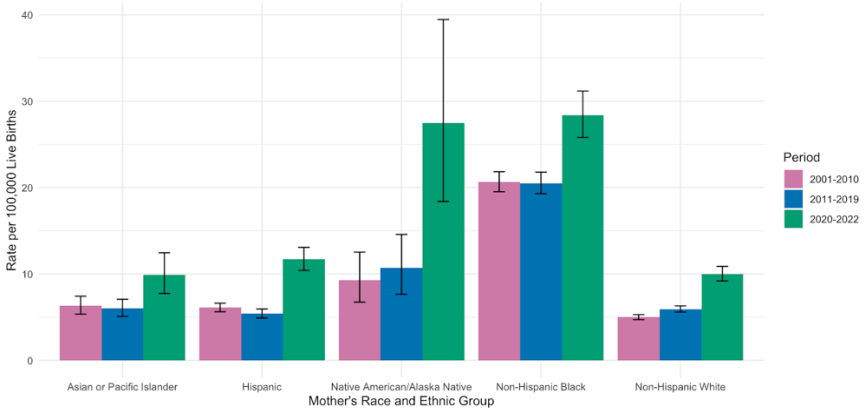
(A) By Five Year Age Groups



(B) By United States Census Bureau-designated Main Census Regions



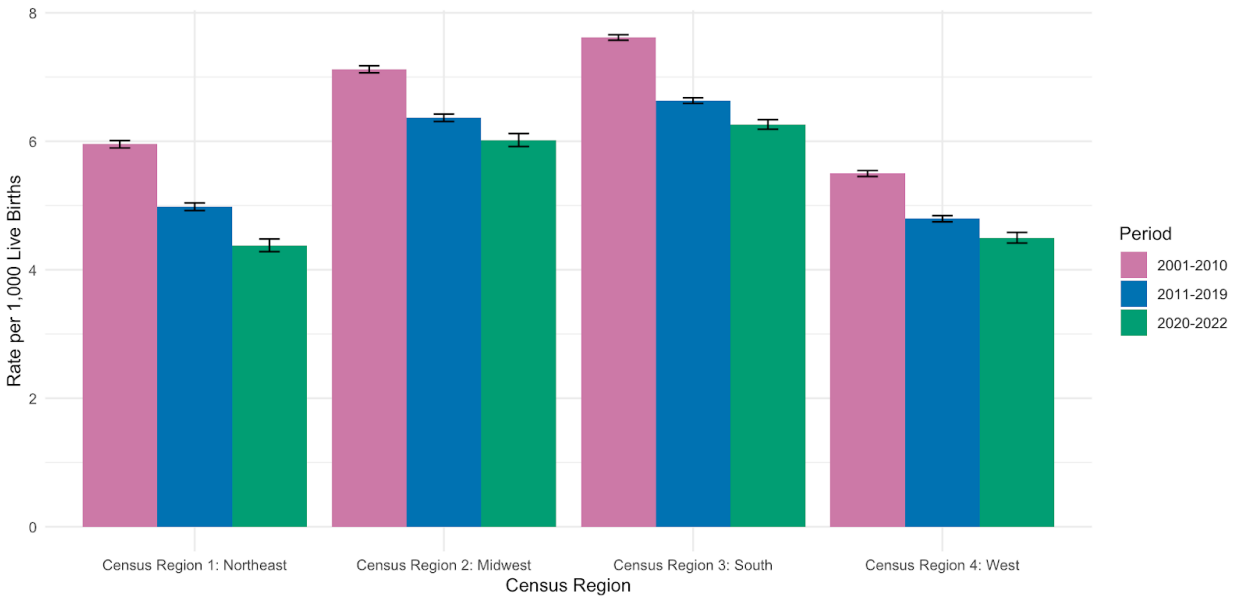
(C) By Mother's Race and Ethnic Groups



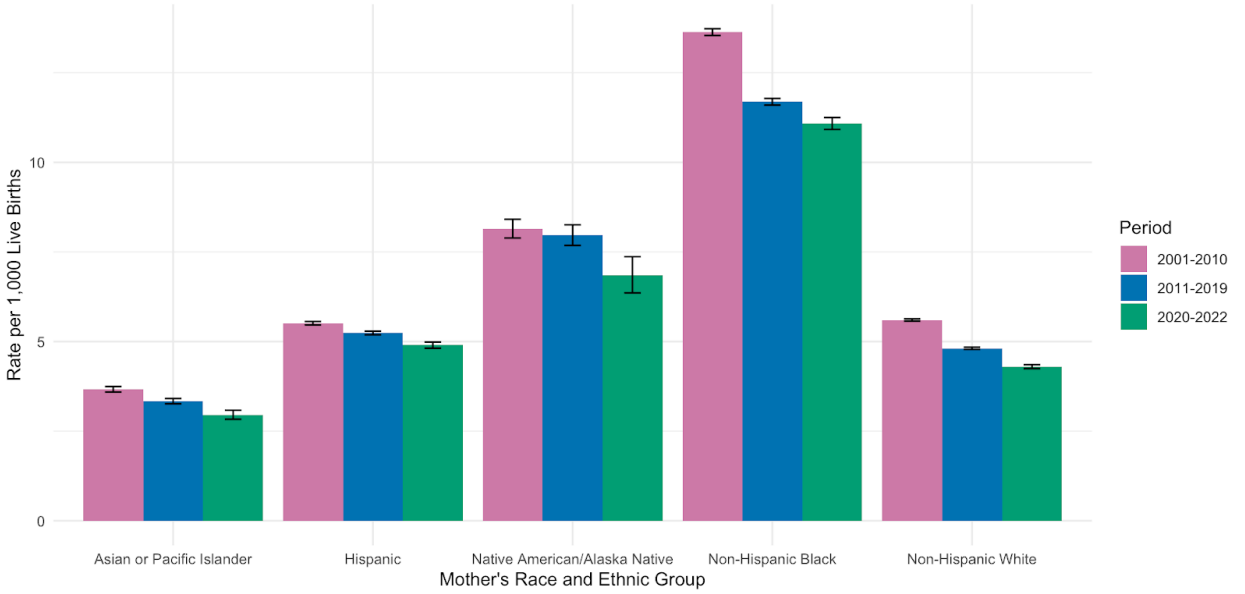
Maternal mortality excluding cause unspecified are maternal deaths (identified using underlying cause of death codes A34, O00-O94 and O98-O99) excluding unspecified maternal deaths (O26.8, O95 and O99). The 95% confidence intervals are shown in black. The 2022 count is provisional. Rates are not age-adjusted due to suppression in small groups. See eFigure 1 in Supplementary Materials for age-weighted rates of maternal mortality excluding cause unspecified.

Figure 4. Rates of Infant Deaths by Demographic Subgroups, 2001-2022

(A) By United States Census Bureau-designated Main Census Regions



(B) By Mother's Race and Ethnic Groups



Infant deaths include all-cause deaths for the population aged <1 year. The 95% confidence intervals are shown in black. The 2022 count is provisional.