The Impact of the Pregnancy Checkbox and Misclassification on Maternal Mortality Trends in the United States, 1999–2017

Analytical and Epidemiological Studies

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Contents

Text Figures

Contents—Con.

Detailed Tables

Appendix Figures

Contents—Con.

Contents—Con.

Appendix Tables

Acknowledgments

The Impact of the Pregnancy Checkbox and Misclassification on Maternal Mortality Trends in the United States, 1999–2017

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Abstract

Background

National maternal mortality rates (MMRs) using mortality data from the National Vital Statistics System have not been reported since 2007 due to the staggered implementation of the 2003 U.S. Standard Certificate of Death between 2003 and 2017, which added a checkbox to determine pregnancy status at the time of death. This report evaluates the impact of the staggered implementation of the pregnancy checkbox and potential outcome misclassification on MMRs and related trends from 1999 through 2017.

Methods

Log-binomial regression models were used to examine the impact of the staggered implementation of the pregnancy checkbox by states over time and to predict MMRs under two alternative scenarios: (1) assuming that no states had the checkbox at any point, and (2) assuming that all states had the checkbox from 1999 through 2017. The impact of the checkbox and related trends over time were examined by age, race and Hispanic origin, state of occurrence, and causes of maternal death. Sensitivity analyses examined the impact of outcome misclassification.

Results

The implementation of the checkbox was associated with an increased identification of maternal deaths. Averaging over the period 2003–2017, the checkbox resulted in an MMR increase of 9.6 deaths per 100,000 live births (95% confidence interval: 8.6–10.6). The average impact of the checkbox adoption was greater for women aged 40 and over, non-Hispanic black women, and for certain causes of death. Accounting for the checkbox, predicted MMRs did not change significantly from 1999 through 2017, although trends varied by subgroup (age, race and Hispanic origin, cause of death).

Conclusions

Estimated trends suggest that the observed increases in MMRs from 1999 through 2017 reported in the literature were largely due to the staggered implementation of the checkbox. Potential misclassification of pregnancy status using the pregnancy checkbox likely also contributed, which disproportionately inflated MMRs among women aged 40 and over.

Keywords: death certificate • epidemiologic methods • maternal death • National Vital Statistics System

Introduction

Maternal mortality is a critical indicator of population health in both the United States and internationally (1–3). Monitoring maternal mortality over time is important to evaluate progress in improving maternal health in the United States, to make international comparisons, and to examine differences and inequities by demographic subgroup (3). Substantial disparities in maternal mortality exist by race and Hispanic origin and age in the United States (4–6). Maternal and pregnancy-related mortality rates for non-Hispanic black women are approximately three times the rates for non-Hispanic white women, while women aged 40 and over have the highest maternal mortality rates compared with other age groups (4,6,7).

The National Vital Statistics System (NVSS) is the official source for U.S. maternal mortality statistics used in international, state, and demographic comparisons. NVSS is used to tabulate the number of maternal deaths, defined by the World Health Organization (WHO) as the "death of a woman while pregnant or within 42 days of termination of pregnancy, irrespective of the duration and site of the pregnancy, from any cause related to or aggravated by the pregnancy or its management but not from accidental or incidental causes" (3). Of note, this is different from the Centers for Disease Control and Prevention definition of pregnancy-related deaths, defined as the death of a woman while pregnant or within 1 year of pregnancy termination—regardless of the duration or site of the pregnancy—from any cause related to or aggravated by the pregnancy or its

management, but not from accidental or incidental causes; and from pregnancy-associated deaths, defined as all deaths during pregnancy or within 1 year of pregnancy, regardless of cause.

Examinations of maternal deaths prior to 2000 suggested substantial underreporting of maternal deaths in NVSS (8–12). To improve identification of maternal deaths, a pregnancy question was added to the 2003 revision of the U.S. Standard Certificate of Death. This pregnancy question includes a series of checkboxes to determine whether female decedents were currently or recently pregnant (within 42 days, or 43 days to 1 year). Jurisdictions adopted this revision at different times between 2003 and 2017, making it difficult to estimate national-level trends in maternal mortality over this time period (13,14). Subsequently, national maternal mortality rates (MMRs) have not been reported since 2007. Studies have suggested that the pregnancy checkbox resulted in the identification of more maternal or pregnancy-associated deaths (8,15). A companion report examines the impact of the pregnancy checkbox by recoding cause of death without consideration of the checkbox, using data on maternal deaths from 2015 through 2016 (15). Findings suggest that the number of maternal deaths was approximately three times higher when using information from the checkbox compared with the recoded data without considering the checkbox (15). Differences were seen in the magnitude of the impact of the checkbox by maternal age, race and Hispanic origin, and cause of death. Specifically, among women aged 40 and over, the number of maternal deaths reported with the checkbox was more than 14 times higher than the number reported without using information from the checkbox. That companion report offers additional detail about the coding of maternal deaths and differences in the impact of the checkbox by cause of death.

Given the substantial impact of the checkbox on the identification of maternal deaths, estimating trends in maternal mortality considering its staggered implementation across the United States has proved challenging. Several studies have attempted to account for the checkbox in examinations of recent trends in maternal mortality. MacDorman et al. examined trends from 2000 through 2014 and reported that MMRs (maternal deaths per 100,000 live births) increased by nearly 30%, from 18.8 in 2000 to 23.8 in 2014; however, these estimates excluded California and Texas, and correction factors (to account for changes in measurement associated with the checkbox) were calculated based on 24 states and the District of Columbia (14). Joseph et al. suggested that most of the increase in MMRs from 1993 through 2014 was due to the implementation of the checkbox and that increases were limited to nonspecific causes of maternal death (16). Davis et al. reported that 90% of the increase from 1998–2002 through 2008–2012 was due to the implementation of the pregnancy checkbox, comparing a subset of 23 states that adopted the checkbox with a group of 11 states that had not (17). Another study suggested that only 31% of the increase in MMRs from 1997

through 2012 was attributable to the 2003 death certificate revision (18) but was limited to the 36 states that had adopted the revision by 2012. Because prior studies examining the impact of the pregnancy checkbox have typically looked at subsets of states (4,14,17), the impact of the checkbox on national trends since 1999 remains unclear; 2017 is the first year that all states have adopted the 2003 revision of the certificate, allowing for examination of national-level data.

Although pregnancy checkboxes have been found to identify a greater percentage of deaths during or following pregnancy (8,19), some reports suggest that approximately 14% of pregnancy-associated deaths had no verifiable evidence of pregnancy (20). Therefore, misclassification of pregnancy status on death certificates may have contributed to biased trend estimates (19,21,22). An examination of Texas MMRs reported increases from 2006 through 2015, but the extent to which the increase was driven by overreporting of maternal deaths was unclear, particularly among women aged 40 and over (23). A review of 147 maternal deaths in Texas suggested that approximately one-half of obstetric-coded deaths had no evidence of pregnancy within 42 days of death, with 67% of the deaths among women aged 35 and over showing no evidence of pregnancy (24). Davis et al. also suggested that a high degree of misclassification of pregnancy status among women aged 40 and over may explain the increasing trends seen among this age group. The impact of potential misclassification of pregnancy status on MMRs among all states incorporating the pregnancy checkbox has not been explored.

The objectives of this analysis were to (1) quantify the impact of the staggered implementation of the pregnancy checkbox on MMRs overall and by maternal age, race and Hispanic origin, cause of death, and state; (2) estimate trends in MMRs from 1999 through 2017, accounting for the checkbox, overall and by maternal age, race and Hispanic origin, and cause of death; and (3) examine the impact of potential misclassification of pregnancy status on the death certificate on trends in MMRs from 1999 through 2017.

Methods

Data

Data on maternal deaths and births were drawn from NVSS for the years 1999 through 2017. Maternal deaths for each year were identified using International Classification of Diseases, 10th Revision (ICD–10) underlying-cause codes A34, O00–O95, and O98–O99, consistent with the WHO definition. Late maternal deaths (those occurring more than 42 days following pregnancy) were identified using the underlying-cause codes O96 and O97, and analyzed separately. Denominators for maternal mortality rates were calculated from NVSS birth data for 1999 through 2017 (25). Maternal deaths and corresponding numbers of live births were aggregated by year, state of occurrence, race and

Hispanic origin (non-Hispanic white, non-Hispanic black, Hispanic, non-Hispanic other), and age group (under 15, 15–19, 20–24, 25–29, 30–34, 35–39, 40 and over). State of occurrence, rather than residence, was used because the death certificate information (and consequently, the pregnancy checkbox) is collected using the certificate issued by state of occurrence.

Causes of maternal death

Prior studies suggested that the impact of the pregnancy checkbox varied by cause of death (4,16). Subsequently, analyses examined the impact of the checkbox and related trends over time by various causes (and groups of causes) of maternal deaths:

- O00–O07: Pregnancy with abortive outcomes
- O10–O16: Edema, proteinuria and hypertensive disorders in pregnancy, childbirth and the puerperium
- O20–O29: Other maternal disorders predominantly related to pregnancy
- O26.6: Liver disorders in pregnancy, childbirth and the puerperium
- O26.8: Other specified pregnancy-related conditions
- O30–O48: Maternal care related to the fetus and amniotic cavity and possible delivery problems
- O60–O75: Complications of labor and delivery
- O85–O92: Complications predominantly related to the puerperium
- O95–O99: Other obstetric conditions not elsewhere classified (including late maternal deaths)
- O95, O98–O99: Other obstetric conditions not elsewhere classified (excluding late maternal deaths)
- O96–O97: Late maternal deaths
- O99.3: Mental disorders and diseases of the nervous system complicating pregnancy, childbirth and the puerperium
- O99.4: Diseases of the circulatory system complicating pregnancy, childbirth and the puerperium
- O99.5: Diseases of the respiratory system complicating pregnancy, childbirth and the puerperium
- O99.8: Other specified diseases and conditions complicating pregnancy, childbirth and the puerperium
- Direct causes (26)
- Indirect causes (26)
- O26.8, O95, O99.8: Nonspecific causes
- A34, O00–O92: Alternative grouping of direct causes (4)
- O98–O99: Alternative grouping of indirect causes (4)
- A34, O00–O95: Alternative grouping of direct causes (15)

Statistical Analysis

Objective 1: Quantify the impact of the staggered implementation of the pregnancy checkbox on MMRs

A regression-discontinuity approach was used to examine the impact of adopting the pregnancy checkbox on maternal mortality rates overall, by demographic group, and by cause of death. Regression-discontinuity designs can be used to examine the causal effects of a given intervention when the exposure to that intervention is based on a specific threshold (27). Assuming that observations immediately below and above the threshold are otherwise similar, the difference at the threshold corresponds to the causal effect estimate of that intervention (27–29). By examining MMRs immediately prior to and after the implementation of the checkbox, the impact of the checkbox on MMRs can be estimated.

First, a variable was created by subtracting the year that states revised their certificates (30) from the year of death. This variable represents time since revision year, equal to zero in the year that the state revised. This variable represents the threshold value used in a regression-discontinuity analysis—states and other factors related to maternal mortality are assumed to be otherwise similar immediately before and after the revision, the major difference being the addition of the pregnancy checkbox. To examine the impact of the checkbox visually, MMRs were plotted against the "time since revision" variable using fractional polynomial prediction plots in Stata 14 SE (College Station, Tex.), which allows for nonlinear trends. Plots were limited to show trends within plus or minus 4 years of the revision, with the discontinuity between the lines pre- and postrevision (when "time since revision" is equal to zero) representing the impact of the checkbox on MMRs. Four years before and after the implementation of the checkbox are shown to visually inspect any potential temporal trends prior to or following the checkbox.

Frequency-weighted log-binomial regression models with robust standard errors were implemented using Stata 14 SE to examine whether the impact of the checkbox differed by various demographic characteristics. These models also were used to estimate trends over time, accounting for the staggered adoption of the pregnancy checkbox by states from 2003 through 2017. MMRs were modeled as a function of revision status, state of occurrence, year, age group, and race and Hispanic origin. Additionally, interactions between revision status and state, age group, and race and Hispanic origin were included to allow for the impact of the checkbox to vary by these factors. Interactions between year and state of occurrence, age group, and race and Hispanic origin allowed temporal trends to vary by these factors. Finally, models including indicators for whether a given state had a pregnancy question prior to the checkbox implementation (Alabama, Florida, Illinois, Indiana, Iowa, Kentucky, Louisiana, Maryland, Minnesota, Mississippi, Missouri, Nebraska,

New Jersey, New Mexico, New York City, New York State, North Dakota, Texas, and Virginia), and for when coding was centralized at the National Center for Health Statistics (NCHS) in 2011, also were explored to assess whether MMRs and the impact of the revision varied by these factors. California was not included in the set of states with pregnancy questions prior to the checkbox implementation, because it uses a question that is inconsistent with the 2003 standard certificate, asking about pregnancy status in the past 12 months.

Average marginal effects were used to estimate the change in the MMRs associated with the revision overall, and by age group, race and Hispanic origin, state of occurrence, cause-of-death grouping, and whether the state had a pregnancy question on the death certificate prior to the revision. All analyses were conducted using Stata 14 SE, and no adjustments were made for multiple comparisons.

Objective 2: Estimate trends in MMRs from 1999 through 2017, accounting for the checkbox

To examine trends from 1999 through 2017, maternal mortality rates were predicted based on two scenarios: (1) assuming that no states had adopted the checkbox and (2) assuming that all states had implemented the checkbox throughout the entire study period. Observed and predicted trends were estimated overall and by age group, race and Hispanic origin, state of occurrence, and cause-of-death group. Average marginal effects were used to estimate the linear time trends overall and by group, adjusted for the factors included in the models (e.g., age, race and Hispanic origin, state, revision status). These average marginal effects represent the estimated annual absolute change in the MMRs under the two scenarios described previously, controlling for sociodemographic factors such as age, race and Hispanic origin, and state.

Objective 3: Examine the impact of potential misclassification of pregnancy status on the death certificate on MMR trends from 1999 through 2017

Several additional analyses were conducted to examine the potential impact of misclassification (31,32) of pregnancy status on MMRs and related trends (see Appendix I for more details). Prior studies have suggested that the pregnancy checkbox resulted in many deaths being classified as maternal (or pregnancy-associated) when there was no evidence of pregnancy, with false-positive rates as high as 50% (13,17–24,33–35). Other studies have described substantial false-negative rates (failure to identify pregnancy on death certificates) both before and after the implementation of the checkbox (8,12,22,34,36,37).

Accounting for a certain percentage of death certificates where a pregnancy checkbox may have been selected in error

To determine a plausible range for the error rate, the percentage of records where one of the pregnancy checkboxes was selected (either currently pregnant, pregnant within 42 days, or pregnant 43 days to 1 year) among women of ages where pregnancy would be implausible (age 10 years and under or 55 and over) was calculated by state of occurrence. There was variability by state in the percentage of records where this occurred, with the largest percentages in North Dakota, California, New Jersey, Oklahoma, Michigan, New York State (excluding New York City), Kentucky, Tennessee, Utah, the District of Columbia, New Hampshire, Rhode Island, and Texas (ranging from 0.05% to 0.34%; see Table I).

Models were run assuming that 0.25%, 0.50%, or 1.00% of death certificates for female decedents had a pregnancy checkbox selected in error (currently pregnant or pregnant within 42 days). These percentages were used to adjust the observed numbers of maternal deaths. For each state, age, and racial or Hispanic-origin group, these percentages (expressed as proportions) were multiplied by the total number of deaths among females aged 15–44 in that group to estimate the number of overall death records that may have a checkbox marked in error. These numbers were subtracted from the observed numbers of maternal deaths in each stratum (among states and years where the checkbox applied), and the models were refit. Because more deaths occur among older women, this adjustment had a disproportionate impact on MMRs among older age groups, even assuming a constant error rate of 0.25%, 0.50%, or 1.00%.

Adjusting for outcome misclassification

Additionally, MMRs were corrected for potential outcome misclassification based on prior validation studies examining the accuracy of death record data in identifying maternal deaths, conducted before the implementation of the checkbox (8,9,11,12,38) and after (13,17–24,33–35). These studies have provided a range of values for the sensitivity (Se) of death certificate data (the proportion of true maternal deaths captured in death certificate data), predictive value positive (PVP; the proportion of maternal deaths determined using death certificate data that are true maternal deaths), or false-positive rates (the proportion of maternal deaths determined using death certificate data that are not maternal deaths).

A data visualization tool (available from: https://www.cdc.gov/nchs/maternal-mortality/dashboard/) was developed to explore the impact of potential misclassification on MMR trends overall and by demographic group, allowing users to vary Se and false-positive rates within plausible ranges (0.4–1.0 for Se, 0.00–0.75 for false-positive rates). The following formula was used to adjust the predicted MMRs

based on Se and PVP values (where PVP is equal to 1–false-positive rate; see Appendix I for more detail):

$$\text{\# Maternal Deaths}_{adj} = \frac{\text{\# Maternal Deaths}_{obs} \bullet PVP}{Se} \quad (1)$$

Because the Se and PVP values differed before and after the implementation of the checkbox, values defined for the period prior to the checkbox implementation were applied to the predicted MMRs assuming that no states adopted the checkbox, while values defined for the period after the checkbox implementation were applied to the predicted MMRs assuming that all states had adopted the checkbox throughout 1999–2017.

Falsification test: Nonmaternal causes of death

Finally, the impact of the checkbox was examined for several nonmaternal causes of death, including unintentional injuries, suicide, homicide, drug overdose, and unknown or ill-specified (R99). These are not maternal causes of death according to the WHO definition, and so, should not necessarily have changed because of the adoption of the checkbox. However, in some cases, deaths due to these causes may be coded as a maternal death due to ICD–10 coding rules relating to what information appears on the death certificate and where it appears (15,39,40). To explore whether changes in these nonmaternal causes were a result of the implementation of the checkbox, two sets of models were run.

First, the percentage of overall deaths among women of reproductive age (15–44 years) due to these causes was modeled using the same frequency-weighted log-binomial models described previously. The estimated impact of the checkbox refers to the change in the percentage of deaths among women of reproductive age due to these five causes. Second, as a falsification test, these same models were run for females under age 10 or 55–59, where there should be no impact of the checkbox because it does not apply to these age groups in determining the underlying cause-of-death code. If changes in the percentages of deaths among these groups occurred due to these causes, then it would suggest that there are factors confounding the estimates of the impact of the pregnancy checkbox (e.g., the adoption of electronic death registration systems, or other data quality improvements that may have occurred at the same time as the adoption of the revised standard certificate). Finally, if there were declines in the percentages of deaths due to these external causes (and unknown or ill-specified causes) among women of reproductive age associated with the implementation of the checkbox, then it could suggest that the coding changes instituted with the implementation of the checkbox resulted in a certain percentage of these deaths being assigned a maternal cause of death.

Results

The Impact of the Implementation of the Pregnancy Checkbox on MMRs

Overall, the addition of the pregnancy checkbox on the 2003 standard death certificate, which was implemented in staggered fashion across the United States from 2003 through 2017, was associated with an average increase of 9.6 maternal deaths per 100,000 live births (95% confidence interval [CI]: 8.6–10.6). Figure 1 shows the trends in MMRs prior to and immediately after the implementation of the checkbox.

The average impact of the revision varied by maternal age, race and Hispanic origin, and state of occurrence. For females aged 15–34, the implementation of the checkbox resulted in an increase in the age-specific MMRs ranging from 3.7 (95% CI: 1.7–5.7) among teenagers (ages 15–19) to 6.0 (95% CI: 3.9–8.0) among women (ages 30–34) (Table 1; Figures 2 and 3). For women aged 35–39, MMRs increased by 13.9 (95% CI: 9.7–18.0). The impact of the checkbox on MMRs among women over 40 was much larger than for other age groups, with an increase of 145.3 (95% CI: 127.6–163.1). By race and Hispanic origin, the checkbox was associated with increases of 6.2 (95% CI: 4.3–8.1) among Hispanic women, 7.1 (95% CI: 4.2–10.0) among non-Hispanic women of other races, 8.6 (95% CI: 7.5–9.7) among non-Hispanic white women, and 19.6 (95% CI: 15.3–24.0) among non-Hispanic black women (Table 1; Figure 4).

The impact of the checkbox was smaller among states that had a question about pregnancy status prior to the adoption of the revised standard certificate (8.1, 95% CI: 6.8–9.4) than among states that did not have a pregnancy question (9.8, 95% CI: 8.7–10.9). Additionally, the impact of the revision was larger after the coding of cause of death was centralized at NCHS in 2011 (10.9, 95% CI: 9.5–12.2) compared with before (9.0, 95% CI: 8.0–10.0).

Differences by state of occurrence were seen in the impact of the checkbox, with most states exhibiting increases in MMRs, except Maryland, where the MMR declined (Figure 5; Table II). The point estimates for Mississippi, Hawaii, Wisconsin, Nebraska, Pennsylvania, Nevada, and Rhode Island also indicated that MMRs declined as a result of the checkbox, but the CIs around these estimated changes were wide, and the 95% CI bounds were compatible with the possibility that MMRs increased or did not change as a result of the checkbox. The largest increases in MMRs as a result of the checkbox were seen in Louisiana, Oklahoma, Michigan, Alabama, Idaho, Indiana, Ohio, Tennessee, South Carolina, Illinois, New Jersey, and Arkansas (all increased by more than 15 maternal deaths per 100,000 live births). Wyoming, North Dakota, and Delaware also exhibited increases of 15 or more, but the CIs around these estimates were wide due to the small number of events in these states, and the 95%

Figure 1. Average change in maternal mortality rates associated with the pregnancy checkbox implementation: United States, 2003–2017

NOTE: Figure was generated using fractional polynomial prediction plots in Stata 14 SE, with shaded areas corresponding to 95% confidence intervals.
SOURCE: NCHS, National Vital Statistics System.
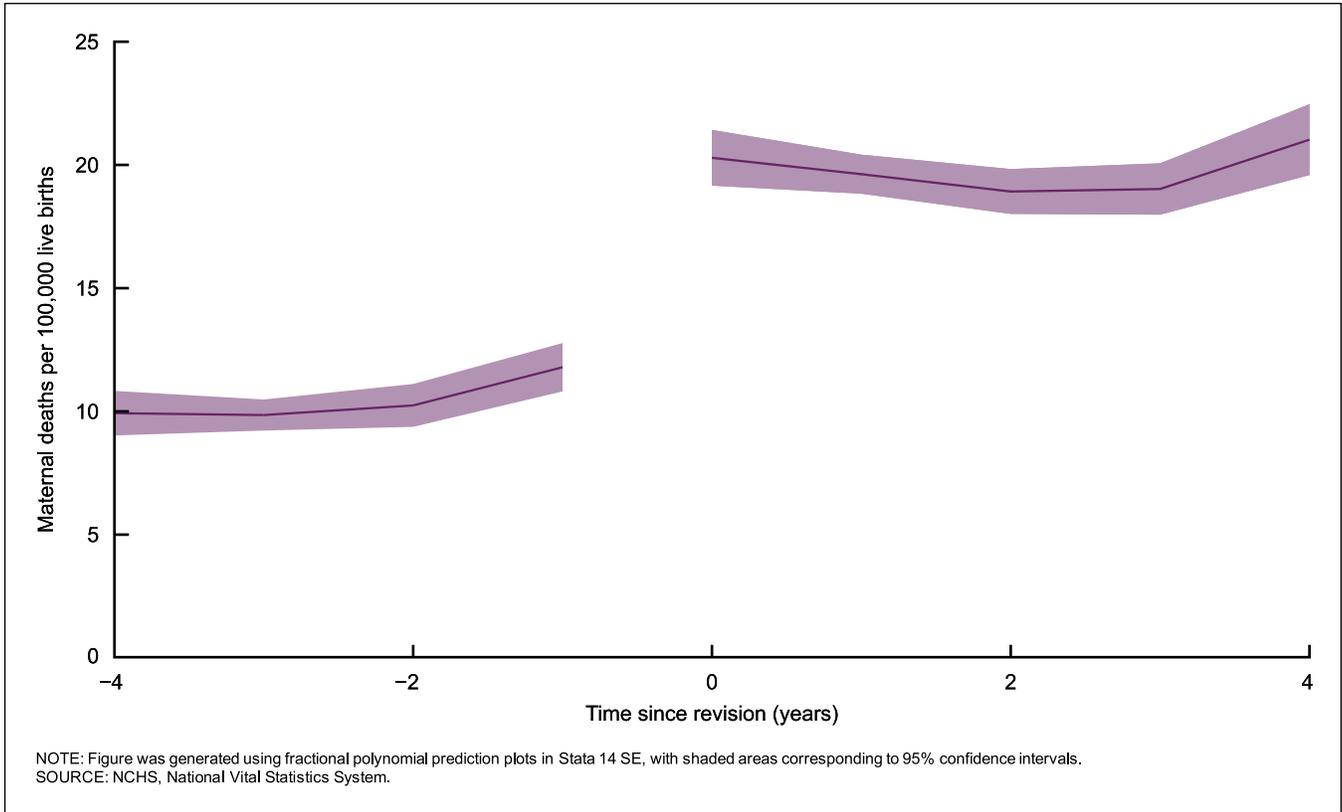
Figure 2. Average change in maternal mortality rates associated with the pregnancy checkbox implementation, by age: United States, 2003–2017

SOURCE: NCHS, National Vital Statistics System.
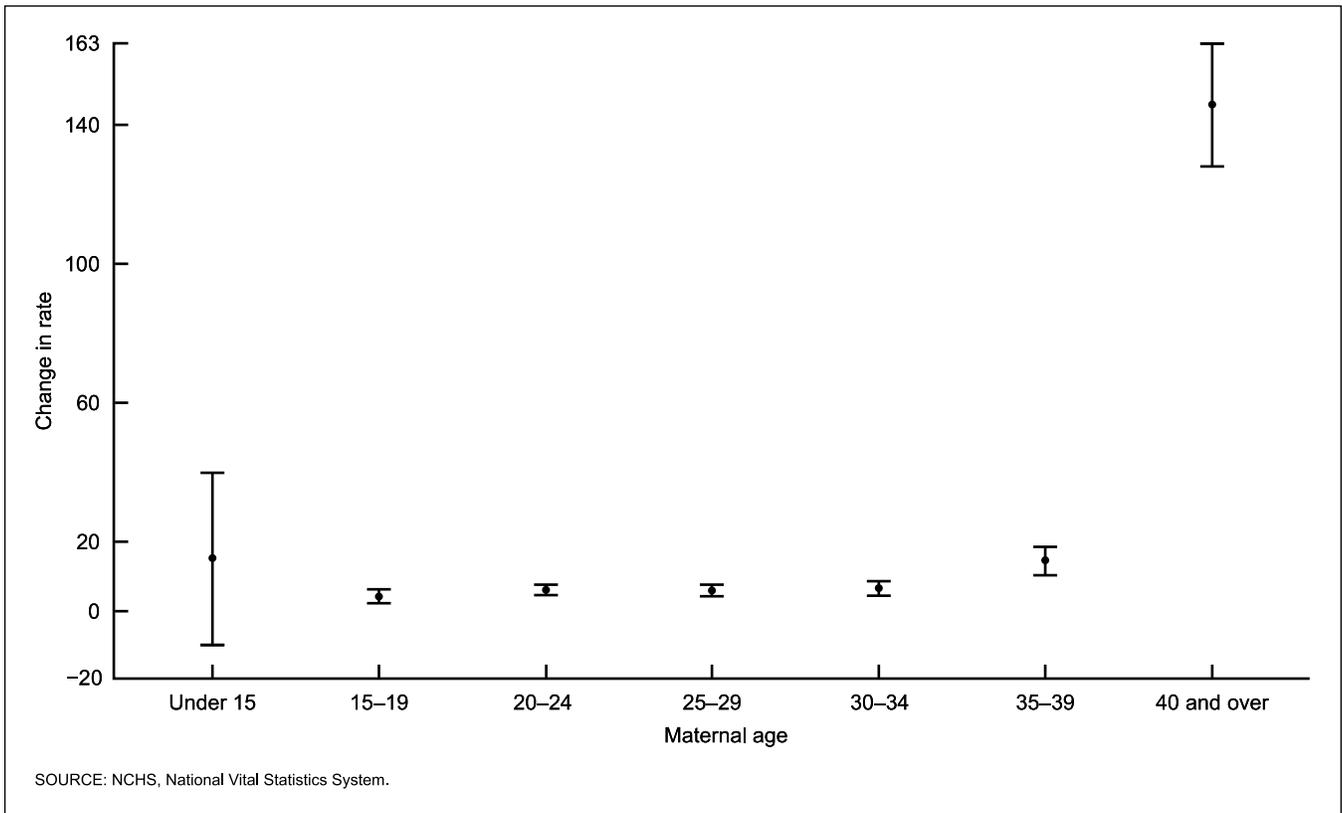
Figure 3. Average change in maternal mortality rates associated with the pregnancy checkbox implementation among females aged 15–39, by age: United States, 2003–2017

SOURCE: NCHS, National Vital Statistics System.
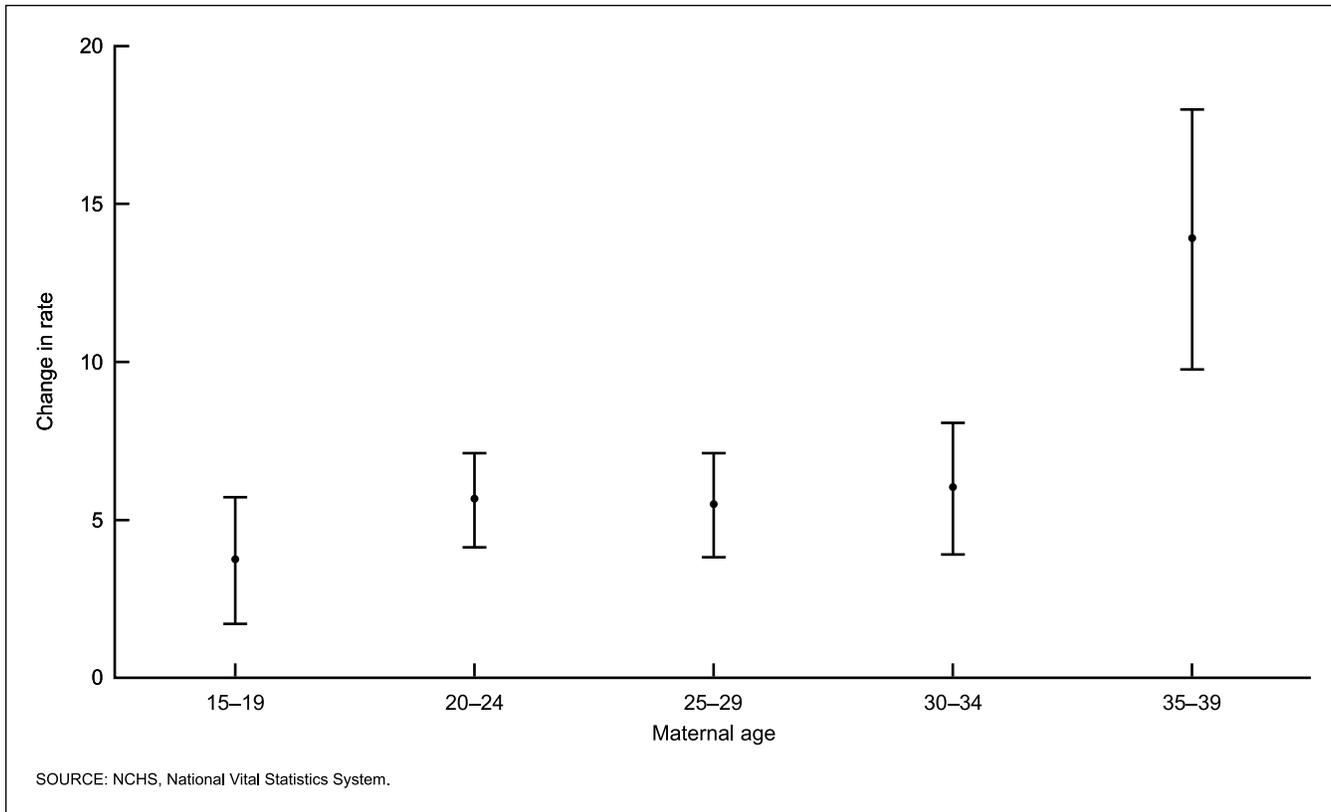
Figure 4. Average change in maternal mortality rates associated with the pregnancy checkbox implementation, by race and Hispanic origin: United States, 2003–2017

SOURCE: NCHS, National Vital Statistics System.
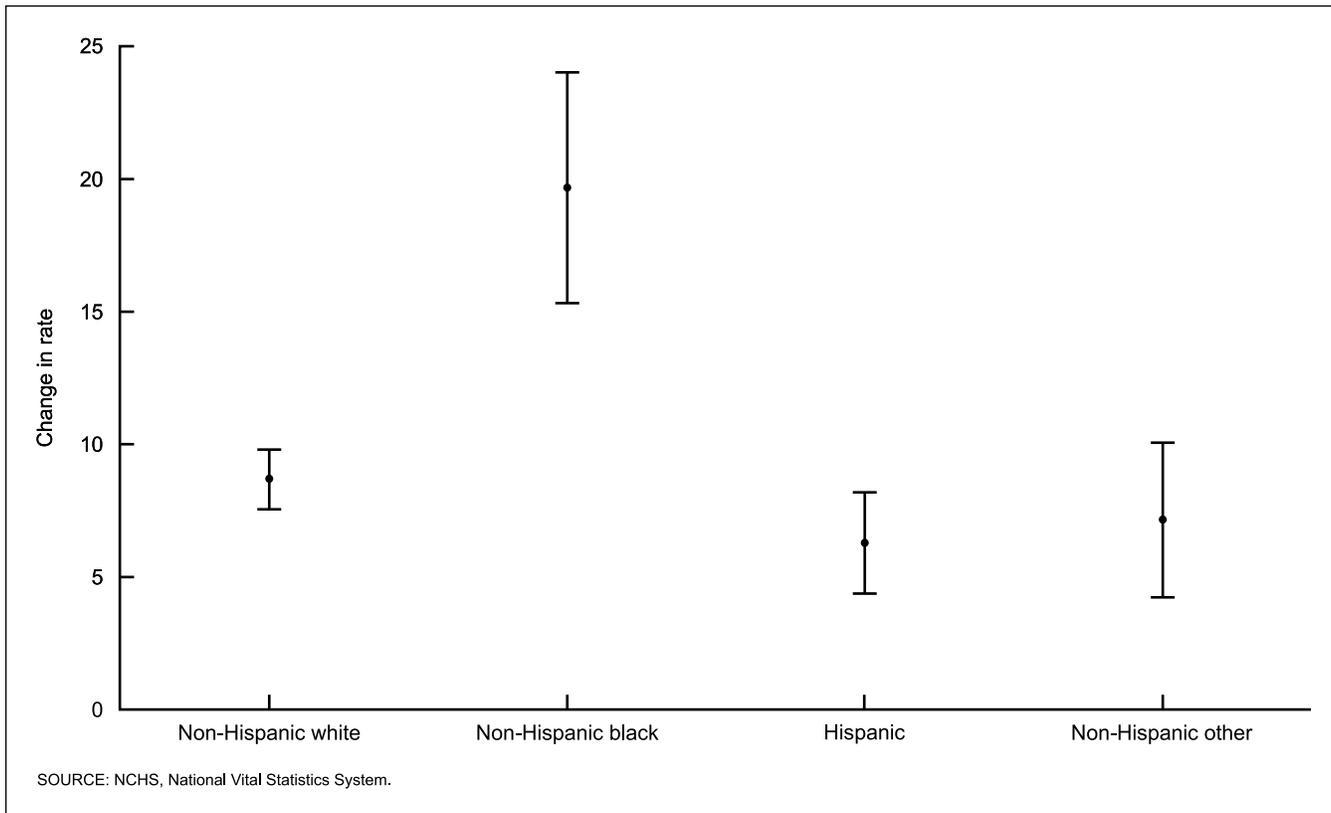
Figure 5. Average change in maternal mortality rates associated with the pregnancy checkbox implementation, by state of occurrence: United States, 2003–2017

NOTE: Wyoming was excluded as the estimate was highly unstable (95% confidence interval: −22.48–191.33).
SOURCE: NCHS, National Vital Statistics System.
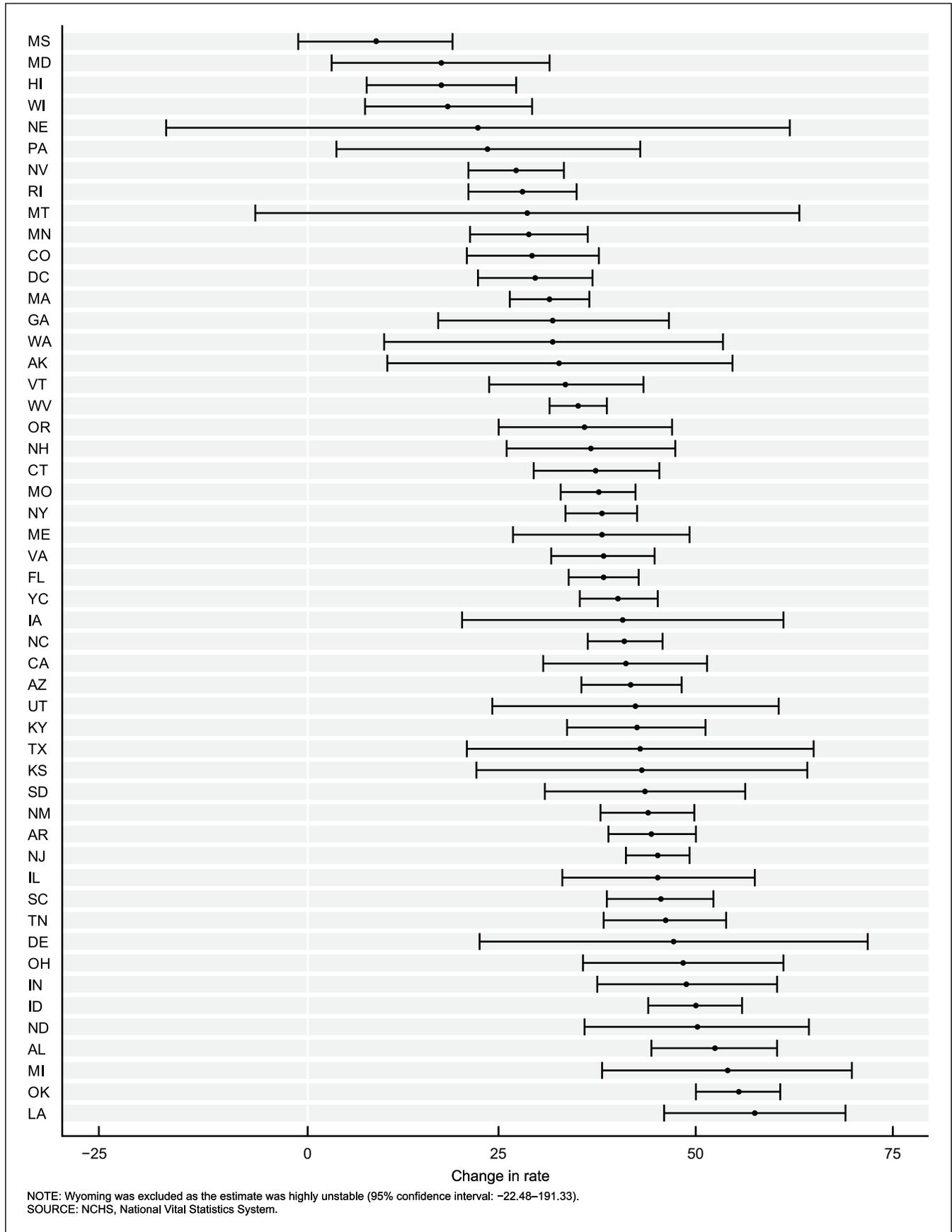
CI bounds were compatible with the possibility that MMRs either declined or did not change as a result of the checkbox.

Observed and Predicted MMR Trends From 1999 Through 2017, Accounting for the Checkbox

Figure 6 illustrates the overall trends in the observed MMRs and in the predicted MMRs, assuming that no states had adopted the checkbox during this time period, and in the predicted MMRs, assuming that all states had adopted the checkbox during this time period. Both with and without the checkbox, no significant change in the MMRs was observed in adjusted models (−0.03, 95% CI: −0.09–0.03, p = 0.307; 0.04, 95% CI: −0.07–0.15, p = 0.459, respectively). Without the checkbox, estimated MMRs were 10.3 maternal deaths per 100,000 live births in 1999 and 12.8 in 2017 (Table IV). Assuming that all states had adopted the checkbox in 1999, estimated MMRs were 21.2 in 1999 and 23.5 in 2017. Of note, unadjusted trend estimates accounting only for revision status by state showed an average annual increase in MMRs both without the checkbox (0.12, 95% CI: 0.06–0.18, p < 0.001) and with the checkbox (0.22, 95% CI: 0.12–0.32, p < 0.001).

Figures 7–13 show trends by age group. No significant changes in predicted MMRs were seen with or without the checkbox for the youngest groups (under 15 and 15–19) (Table 2; Figures 7 and 8). Without the checkbox, predicted MMRs declined for women aged 20–24 (−0.1 per year, 95% CI: −0.2 − −0.0, p = 0.001; see Figure 9) and 30–34 (−0.2 per year, 95% CI: −0.3 − −0.1, p = 0.002; see Figure 11). Predicted MMRs did not change significantly for women aged 25–29 (−0.1 per year, 95% CI: −0.2–0.0, p = 0.057; see Figure 10) or 35–39 (−0.1 per year, 95% CI: −0.3–0.1, p = 0.425; see Figure 12) and increased for women aged 40 and over (2.5, 95% CI: 1.8–3.3, p < 0.001; see Figure 13). Assuming that all states had adopted the checkbox, trends were similar, declining for women aged 20–24 (−0.2 per year, 95% CI: −0.4 − −0.1, p = 0.008) and 30–34 (−0.3 per year, 95% CI: −0.5 − −0.1, p = 0.013). Predicted MMRs assuming that all states had adopted the checkbox did not change significantly for women aged 25–29 (−0.1 per year, 95% CI: −0.3–0.0, p = 0.116) and 35–39 (−0.1 per year, 95% CI: −0.5–0.3, p = 0.552) but increased for women aged 40 and over (7.7, 95% CI: 6.1–9.4, p < 0.001).

By race and Hispanic origin, predicted MMRs increased for non-Hispanic white women by 0.1 per year from 1999 through 2017 (95% CI: 0.1–0.2, p < 0.001) assuming no checkbox, and by 0.3 per year (95% CI: 0.2–0.5, p < 0.001) assuming all states had adopted the checkbox (Table 2; Figure 14). Trends declined for non-Hispanic black women, assuming that no states had adopted the checkbox (−0.3, 95% CI: −0.6 − −0.1, p = 0.004). Assuming that all states had adopted the checkbox, predicted MMRs among non-Hispanic black women declined by −0.4 per year (95% CI: −0.9–0.0), but this trend was not statistically significant (p = 0.072).

Figure 6. Observed and predicted maternal mortality rates: United States, 1999–2017

NOTE: Models were adjusted for age group, race and Hispanic origin, and state of occurrence, and included interactions between these factors and year as well as revision status.
SOURCE: NCHS, National Vital Statistics System.
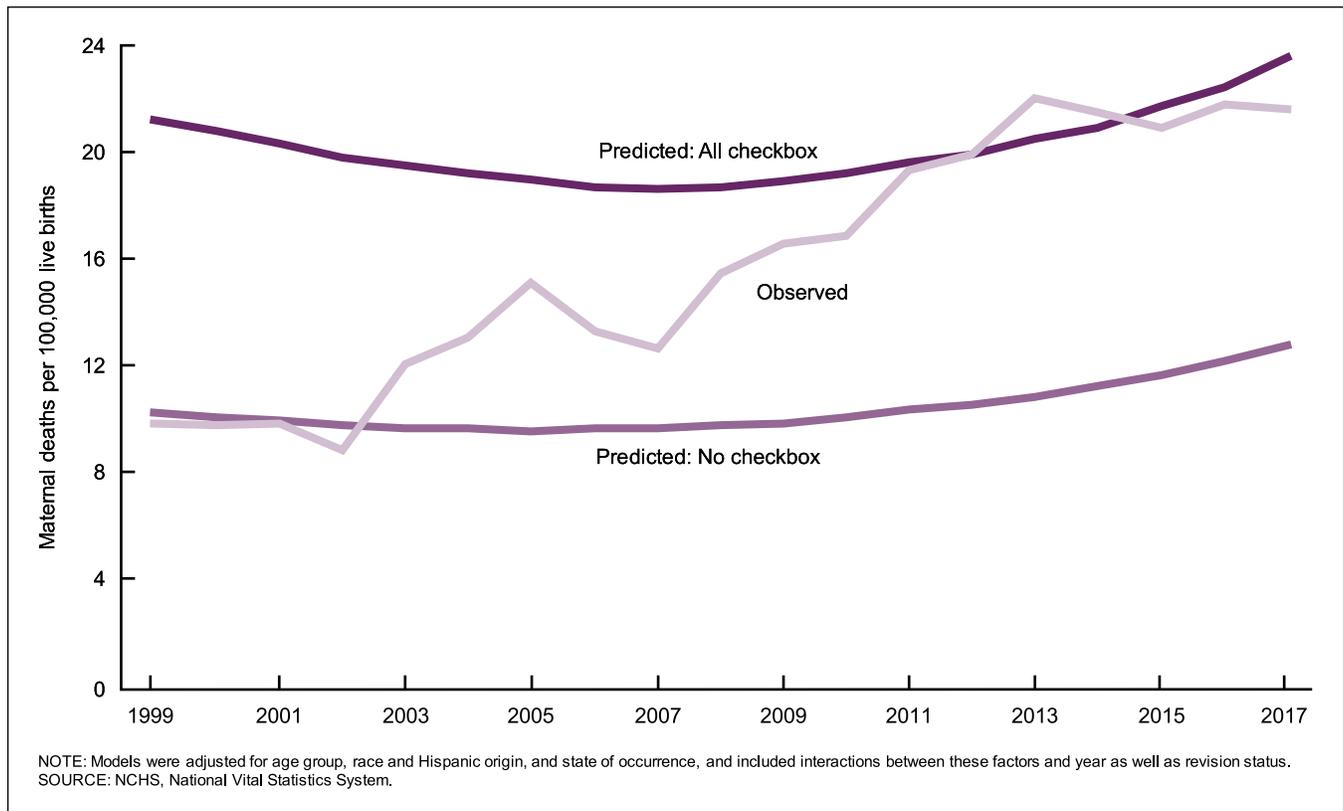
Figure 7. Observed and predicted maternal mortality rates among females under age 15: United States, 1999–2017

Predicted: All checkbox

Predicted: No checkbox

Observed[1]

[1]Observed rates suppressed when the number of deaths is fewer than 20 (all years).
NOTE: Models were adjusted for age group, race and Hispanic origin, and state of occurrence, and included interactions between these factors and year as well as revision status.
SOURCE: NCHS, National Vital Statistics System.
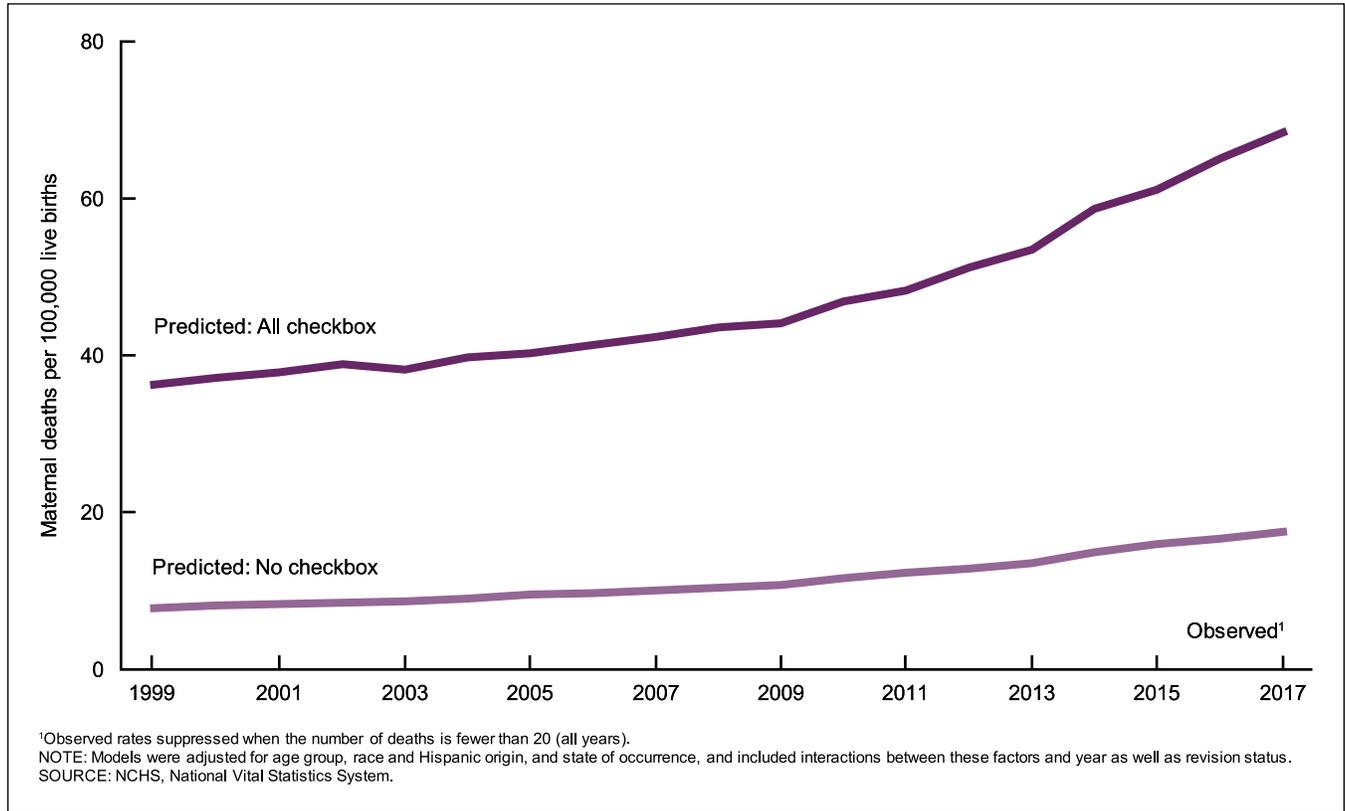
Figure 8. Observed and predicted maternal mortality rates among females aged 15–19: United States, 1999–2017

Predicted: All checkbox

Observed[1]

Predicted: No checkbox

[1]Observed rates suppressed when the number of deaths is fewer than 20 (in 2000).
NOTE: Models were adjusted for age group, race and Hispanic origin, and state of occurrence, and included interactions between these factors and year as well as revision status.
SOURCE: NCHS, National Vital Statistics System.
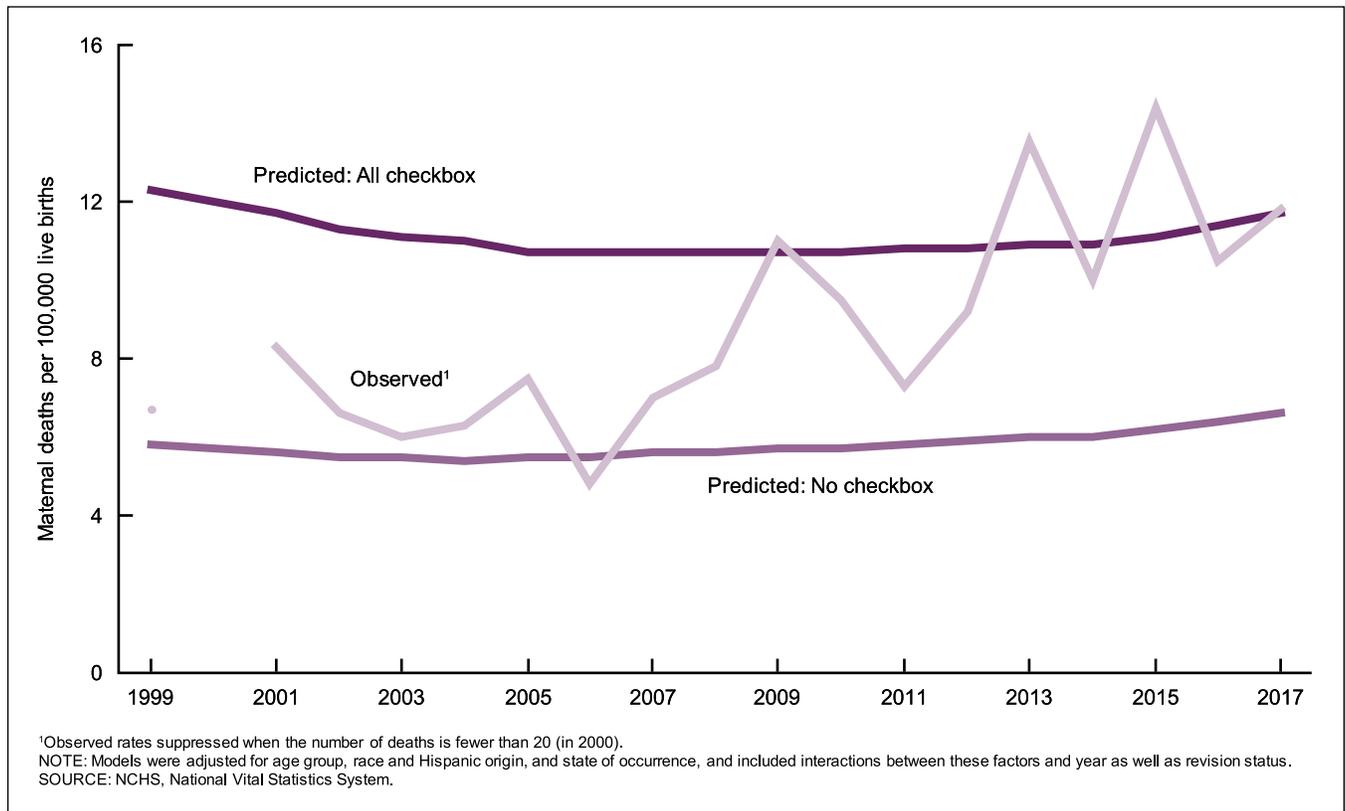
Figure 9. Observed and predicted maternal mortality rates among women aged 20–24: United States, 1999–2017

NOTE: Models were adjusted for age group, race and Hispanic origin, and state of occurrence, and included interactions between these factors and year as well as revision status.
SOURCE: NCHS, National Vital Statistics System.
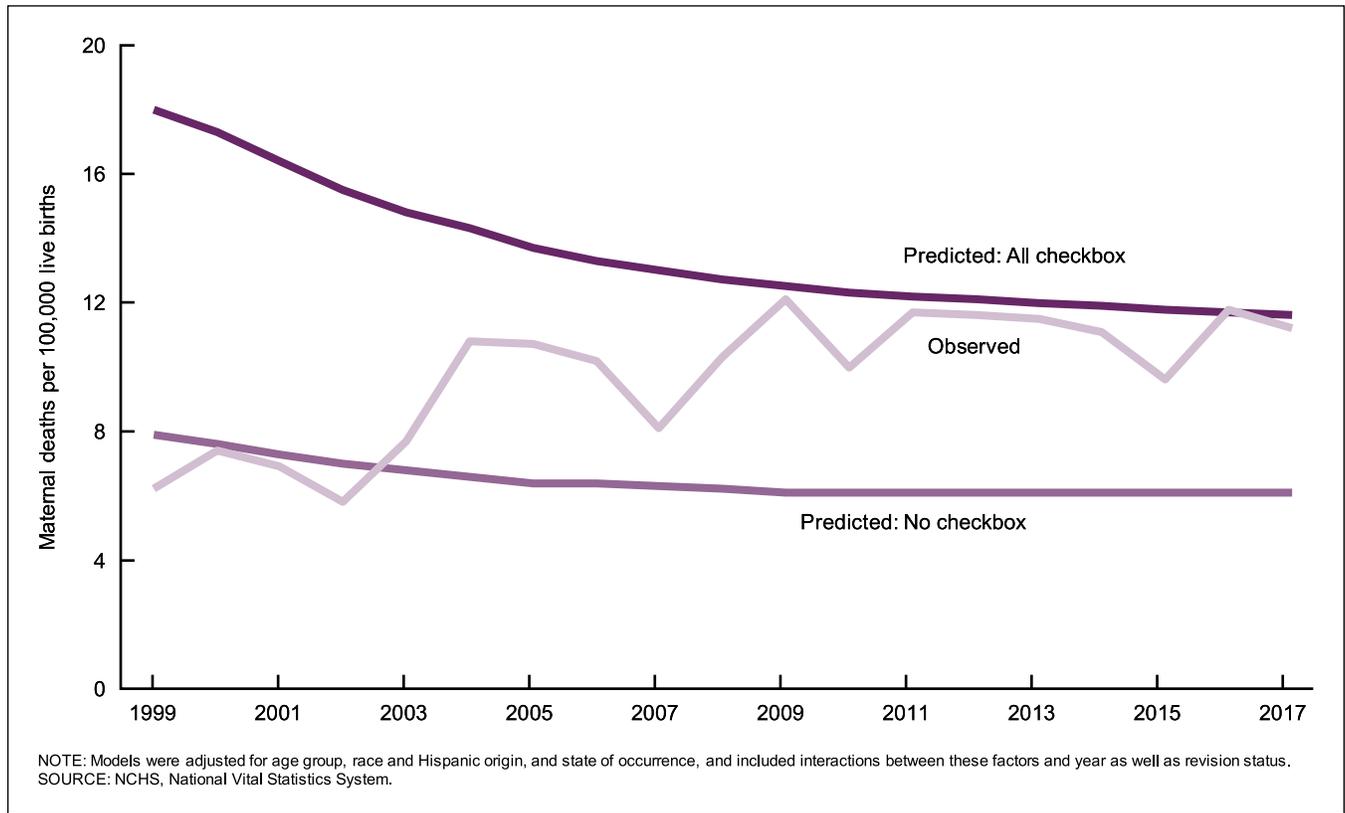
Figure 10. Observed and predicted maternal mortality rates among women aged 25–29: United States, 1999–2017

NOTE: Models were adjusted for age group, race and Hispanic origin, and state of occurrence, and included interactions between these factors and year as well as revision status.
SOURCE: NCHS, National Vital Statistics System.
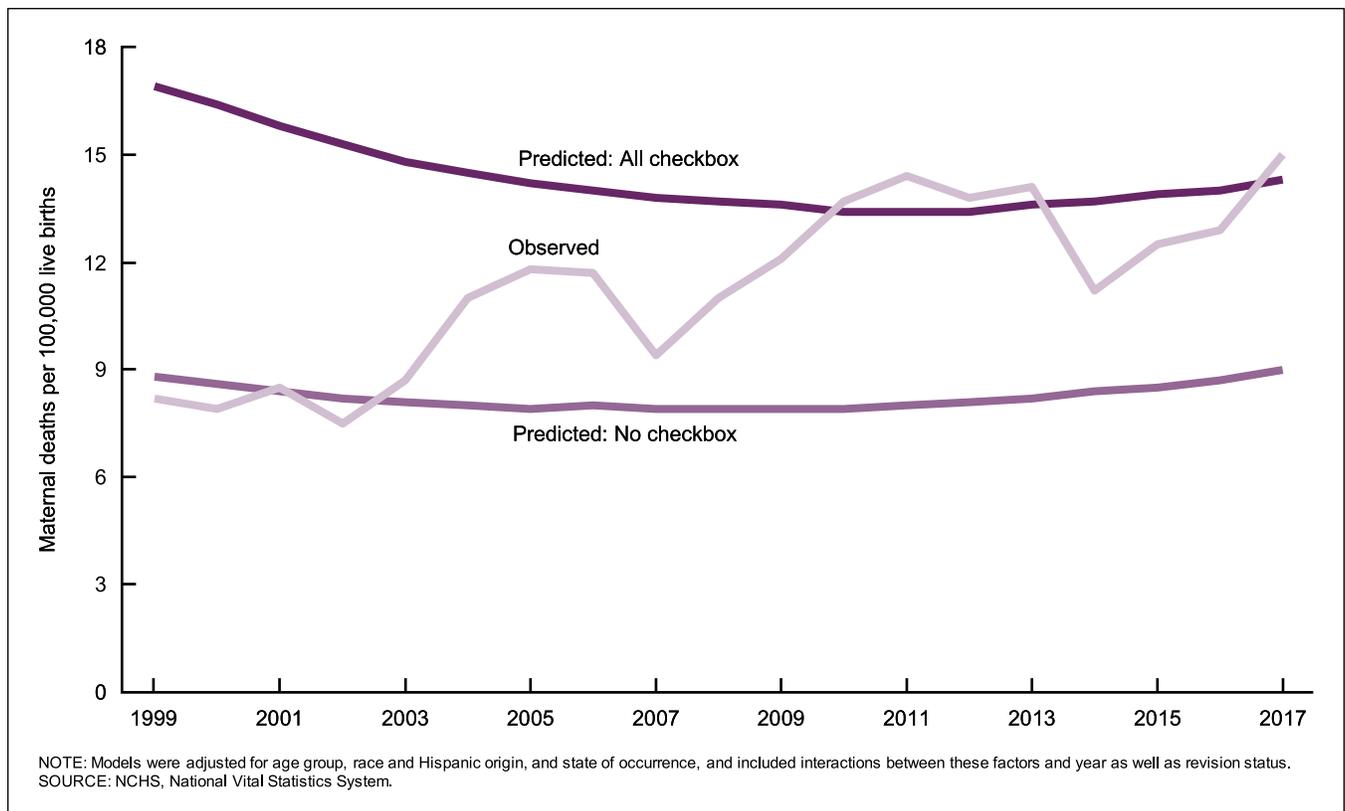
Figure 11. Observed and predicted maternal mortality rates among women aged 30–34: United States, 1999–2017

NOTE: Models were adjusted for age group, race and Hispanic origin, and state of occurrence, and included interactions between these factors and year as well as revision status.
SOURCE: NCHS, National Vital Statistics System.
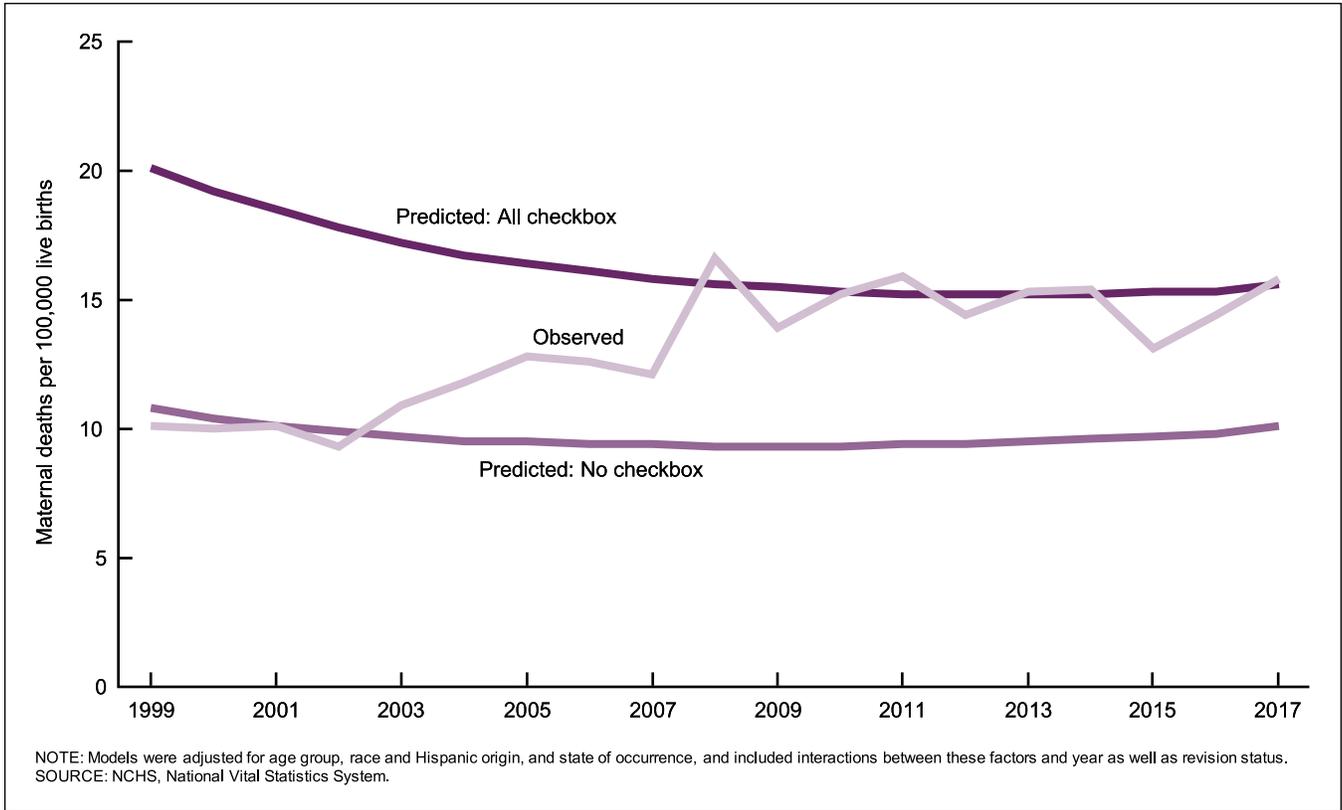
Figure 12. Observed and predicted maternal mortality rates among women aged 35–39: United States, 1999–2017

NOTE: Models were adjusted for age group, race and Hispanic origin, and state of occurrence, and included interactions between these factors and year as well as revision status.
SOURCE: NCHS, National Vital Statistics System.
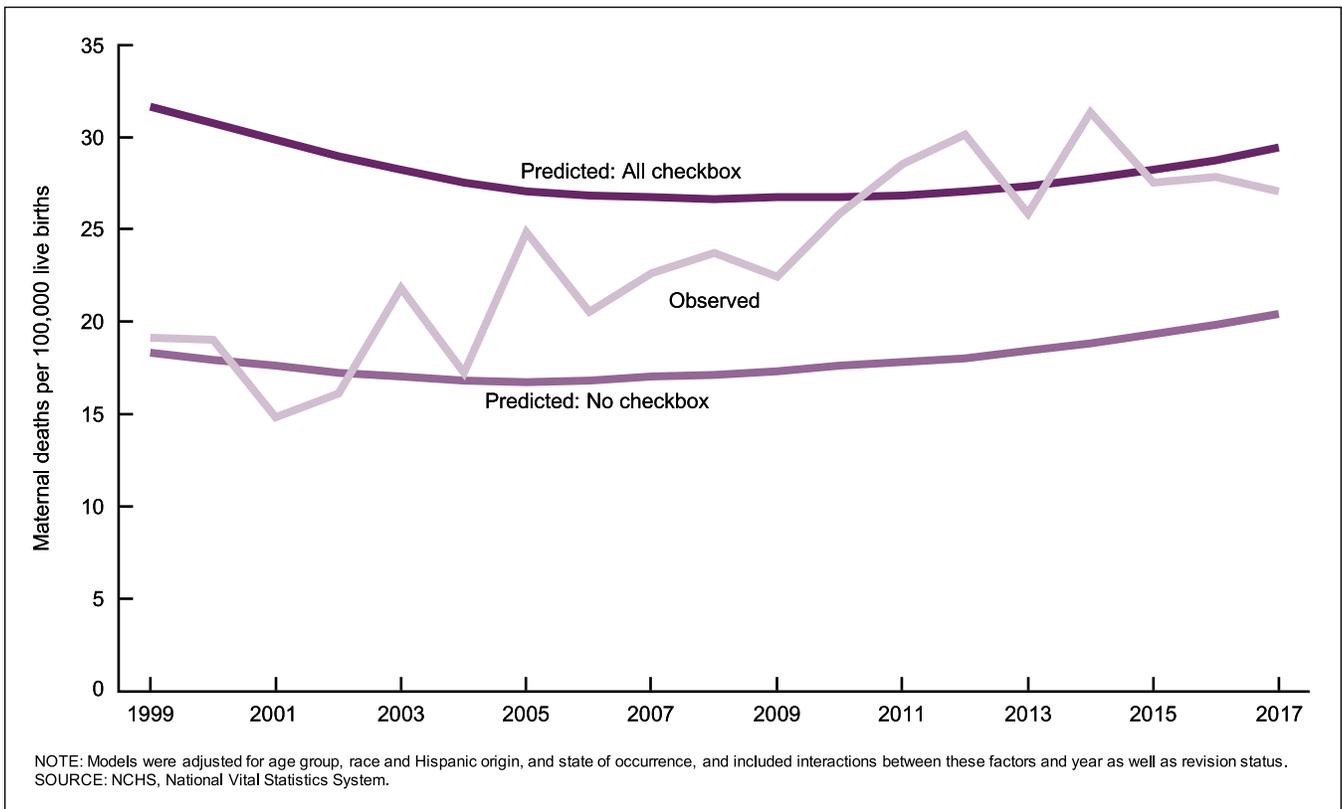
Figure 13. Observed and predicted maternal mortality rates among women aged 40 and over: United States, 1999–2017

NOTE: Models were adjusted for age group, race and Hispanic origin, and state of occurrence, and included interactions between these factors and year as well as revision status.
SOURCE: NCHS, National Vital Statistics System.
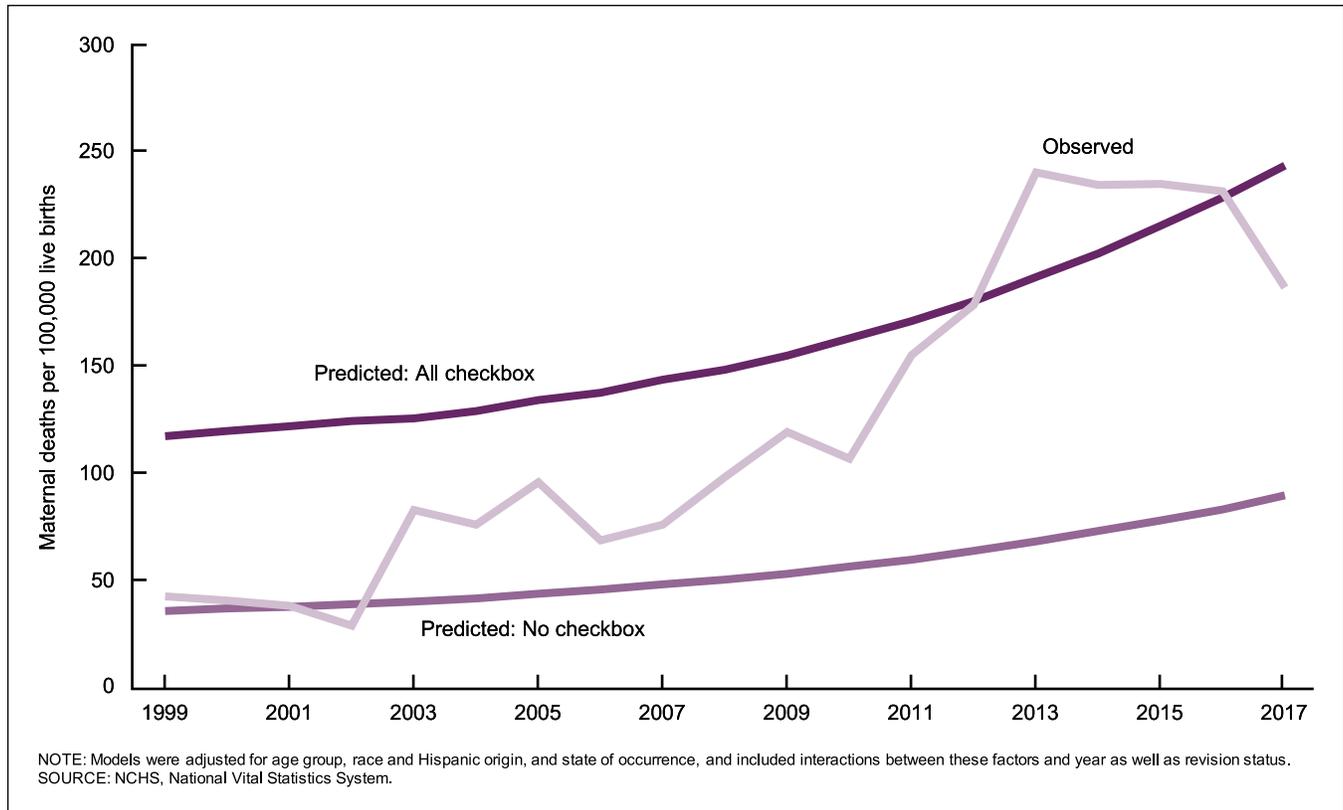
Among Hispanic women, predicted MMRs declined over time, both assuming no checkbox (–0.3, 95% CI: –0.3 – –0.2, $p < 0.001$) and assuming that all states had adopted the checkbox (–0.4, 95% CI: –0.6 – –0.2, $p < 0.001$). Trends among non-Hispanic women of other races did not change significantly with the checkbox (–0.2, 95% CI: –0.4–0.1, $p = 0.280$) or without (–0.1, 95% CI: –0.3–0.0, $p = 0.104$).

Causes of maternal death

The impact of the checkbox varied by maternal cause of death (Table 3). Cause-specific MMRs increased by less than 0.5 deaths per 100,000 live births because of the checkbox for the following causes (or groups of causes): pregnancy with abortive outcomes (O00–O07); edema, proteinuria and hypertensive disorders in pregnancy, childbirth and the puerperium (O10–O16); liver disorders in pregnancy, childbirth and the puerperium (O26.6); maternal care related to the fetus and amniotic cavity and possible delivery problems (O30–O48); complications of labor and delivery (O60–O75); complications predominantly related to the puerperium (O85–O92); mental disorders and diseases of the nervous system complicating pregnancy, childbirth and the puerperium (O99.3); and diseases of the respiratory system complicating pregnancy, childbirth and the puerperium (O99.5).

The impact of the checkbox was largest for indirect or nonspecific causes of death. Maternal deaths due to other obstetric conditions not elsewhere classified (O95–O99) increased by 8.3 (95% CI: 7.6–9.0) as a result of the checkbox, and nonspecific causes (O26.8, O95, O99.8) increased by 5.6 (95% CI: 5.1–6.1). While MMRs for direct causes (26) increased by 5.2 (95% CI: 4.4–6.1) as a result of the checkbox, the impact was driven by the inclusion of a nonspecific cause of death in this category, other specified pregnancy-related conditions (O26.8). Late maternal MMRs increased by 3.5 (95% CI: 3.1–3.9) as a result of the checkbox.

Trends in predicted MMRs both with and without the checkbox varied by cause of death (Table 4; Figures I–XXIII). Predicted MMRs declined significantly from 1999 through 2017 under both scenarios for the following causes of maternal death: direct causes (26) (excluding O26.8, other specified pregnancy-related conditions); pregnancy with abortive outcomes (O00–O07); edema, proteinuria and hypertensive disorders in pregnancy, childbirth and the puerperium (O10–O16); complications of labor and delivery (O60–O75); and complications predominantly related to the puerperium (O85–O92). Predicted MMRs increased under both scenarios for the following causes: other maternal disorders predominantly related to pregnancy (O20–O29), which was driven by the inclusion of other specified pregnancy-related conditions (O26.8) in this group; indirect causes (26); late maternal deaths (O96–O97); and the group of nonspecific causes (O26.8, O95, O99.8).

Figure 14. Observed and predicted maternal mortality rates, by race and Hispanic origin: United States, 1999–2017

NOTE: Models were adjusted for age group, race and Hispanic origin, and state of occurrence, and included interactions between these factors and year as well as revision status.
SOURCE: NCHS, National Vital Statistics System.
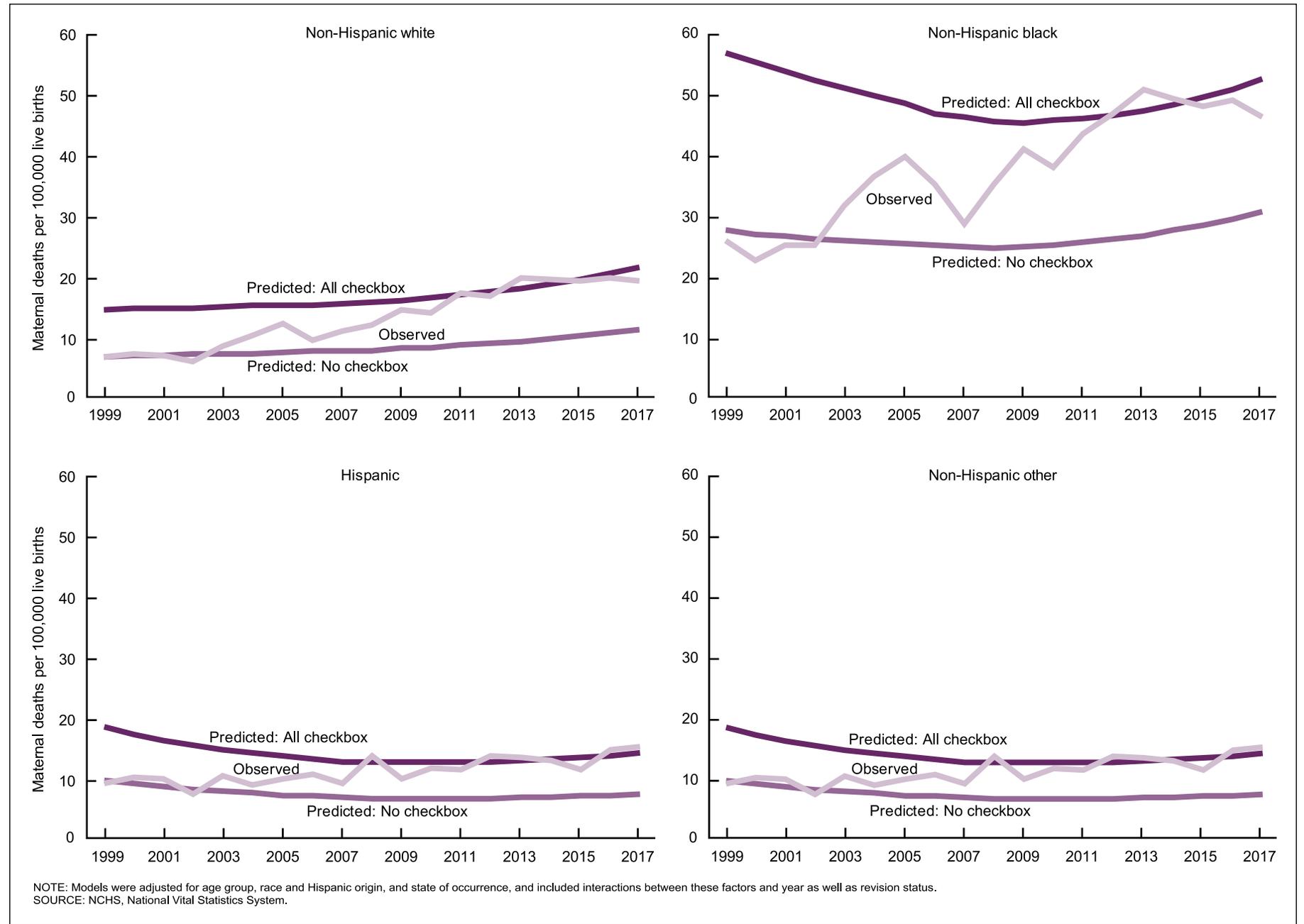
The Impact of Potential Misclassification of Pregnancy Status on the Death Certificate on MMR Trends From 1999 Through 2017

Accounting for a certain percentage of death certificates where a pregnancy checkbox may have been selected in error

Several sensitivity analyses were conducted to examine trends in MMRs over time by subgroup and cause of death, and to explore the impact of potential misclassification. Analyses accounting for varied percentages of false positives (0.25%, 0.50%, 1.00%), resulted in lower predicted MMRs from 1999 through 2017 (assuming that all states adopted the checkbox in 1999; see Figures 15–17).

The impact of the adjustment for this false-positive rate was larger for older age groups and non-Hispanic black and white women (Figures XXIV–XXX).

Adjusting for outcome misclassification

Results of analyses examining the impact of misclassification can be found in Table V and in the data visualization tool (available from: https://www.cdc.gov/nchs/maternal-mortality/dashboard/). For example, assuming that the values for Se before and after the implementation of the checkbox were 0.60 and 0.80, respectively, and the

proportion of records that were false positives was 0.10 and 0.35, respectively, before and after the checkbox, the estimated MMRs in 2017 converged to 19.1–19.2 maternal deaths per 100,000 live births (the observed MMR was 21.6). These values for Se and proportion of false positives are within the range of previously published estimates (8,9,11,13,17–24,33–35, 38).

Examining the predicted MMRs for women aged 40 and over and using the same values described previously, except increasing the proportion of false positives after the checkbox implementation to 0.6 (consistent with the greater degree of misclassification among this age group [17]), the predicted MMRs in 2017 were 133.9 assuming that no states had adopted the checkbox and 121.4 assuming that all states had adopted the checkbox (compared with an observed MMR of 186.1 deaths per 100,000 live births).

Falsification test: Nonmaternal causes death

Finally, as a falsification test, models were run examining the impact of the pregnancy checkbox on several nonmaternal causes of death both among female decedents of reproductive age (15–44) and female decedents to whom the pregnancy checkbox does not apply (under age 10 and 55–59). The percentage of deaths among female decedents aged 15–44 that were due to unintentional injury, suicide, drug overdose, homicide, or unknown or ill-specified causes declined with the implementation of the pregnancy

Figure 15. Observed and predicted maternal mortality rates, adjusted for an error rate of 0.25% in the pregnancy checkbox: United States, 1999–2017

NOTES: Dotted lines represent maternal mortality rates (MMRs) adjusted for fixed error rates, while solid lines depict the original predicted and observed MMRs. Models were adjusted for age group, race and Hispanic origin, and state of occurrence, and included interactions between these factors and year as well as revision status.
SOURCE: NCHS, National Vital Statistics System.
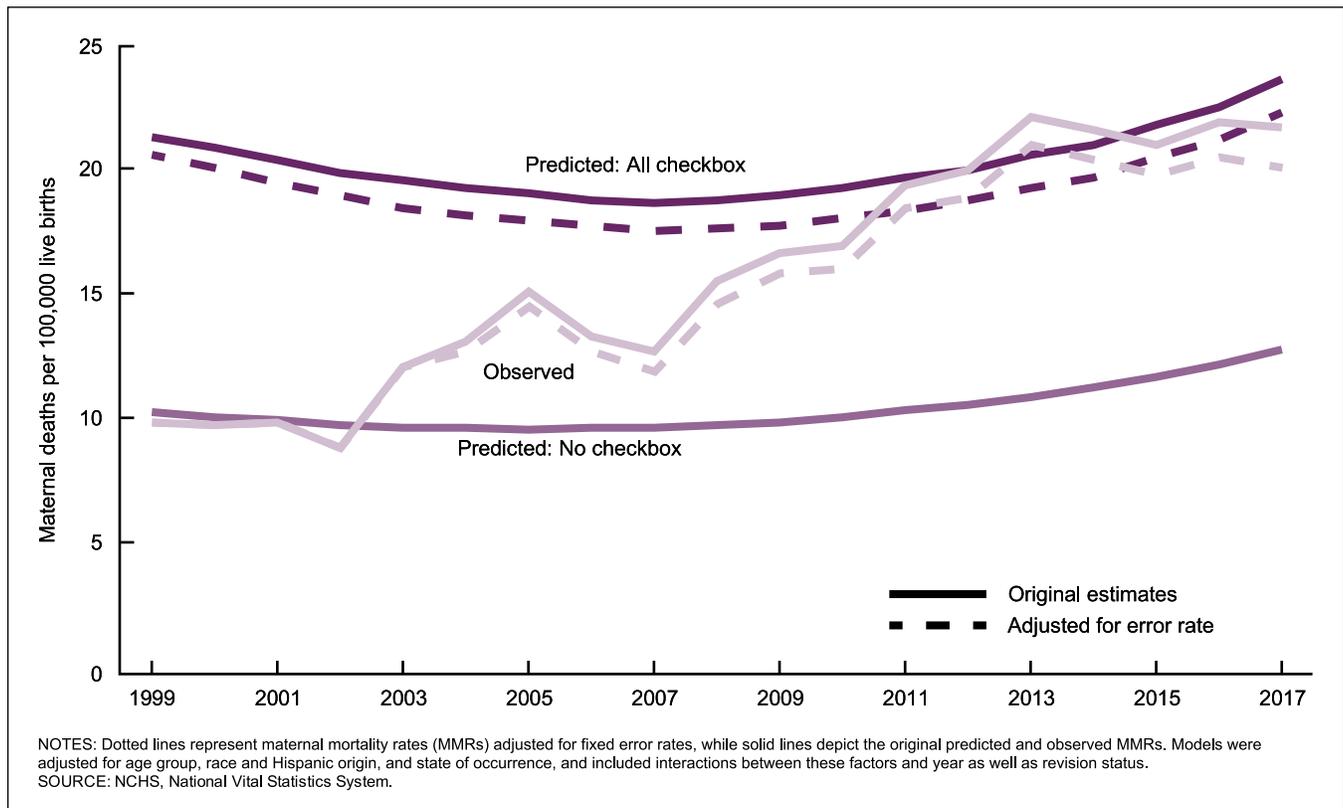
Figure 16. Observed and predicted maternal mortality rates, adjusted for an error rate of 0.50% in the pregnancy checkbox: United States, 1999–2017

NOTES: Dotted lines represent maternal mortality rates (MMRs) adjusted for fixed error rates, while solid lines depict the original predicted and observed MMRs. Models were adjusted for age group, race and Hispanic origin, and state of occurrence, and included interactions between these factors and year as well as revision status.
SOURCE: NCHS, National Vital Statistics System.
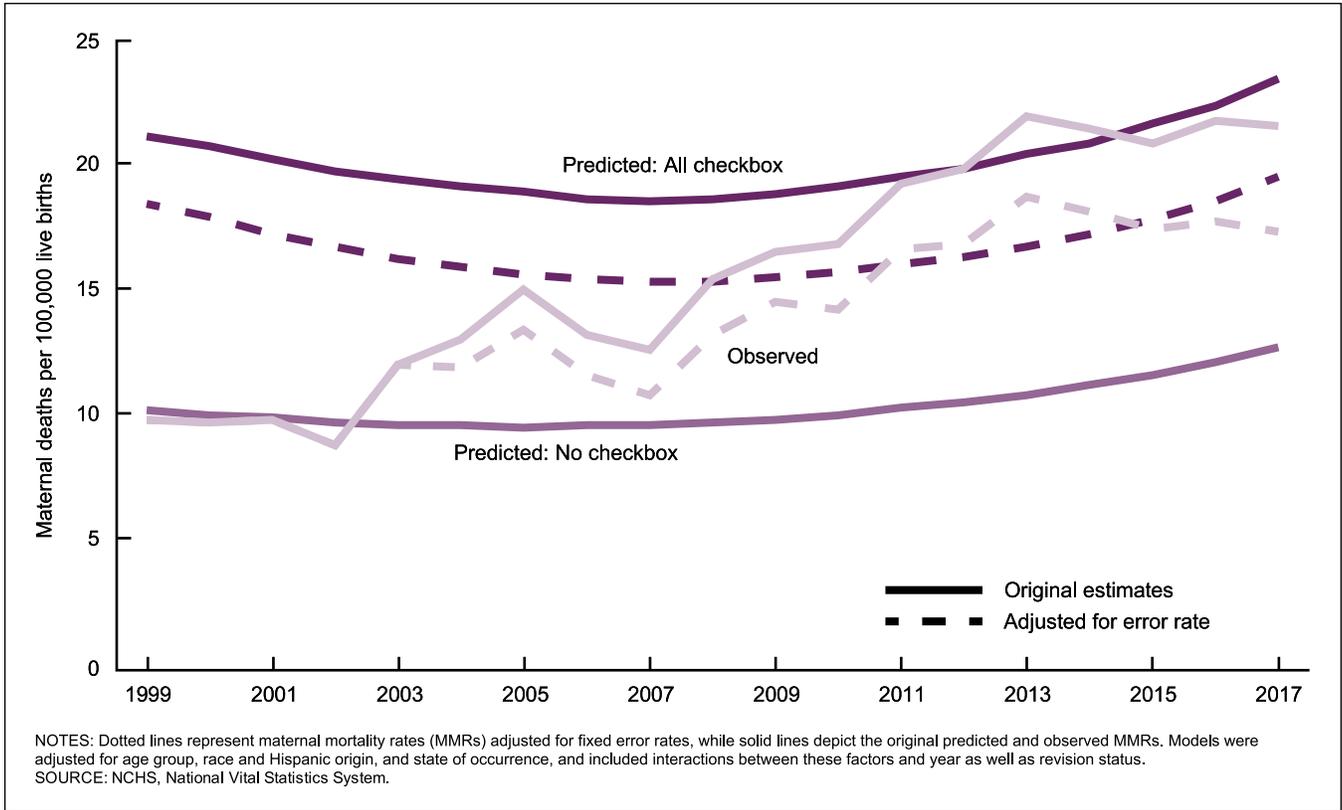
Figure 17. Observed and predicted maternal mortality rates, adjusted for an error rate of 1.00% in the pregnancy checkbox: United States, 1999–2017

NOTES: Dotted lines represent maternal mortality rates (MMRs) adjusted for fixed error rates, while solid lines depict the original predicted and observed MMRs. Models were adjusted for age group, race and Hispanic origin, and state of occurrence, and included interactions between these factors and year as well as revision status.
SOURCE: NCHS, National Vital Statistics System.
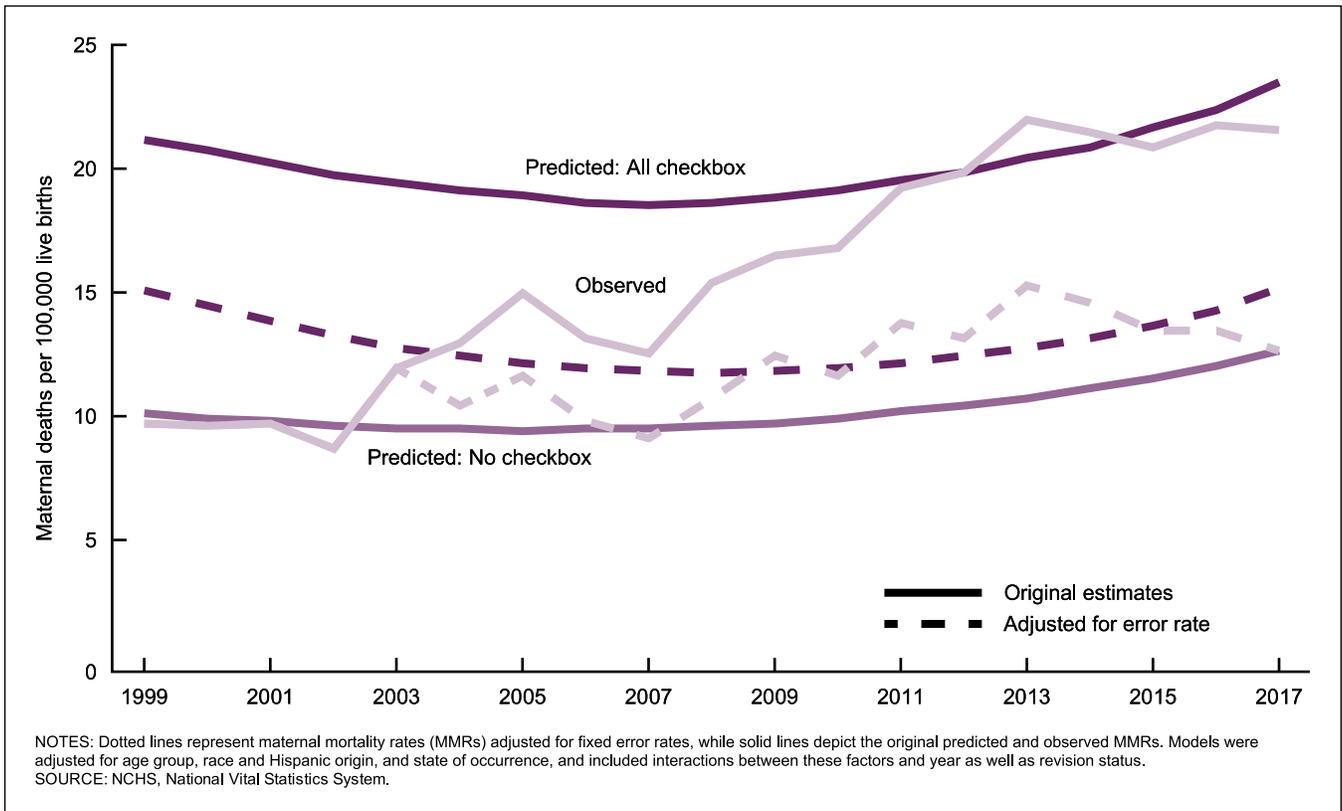
checkbox by 0.53% (95% CI: −0.85 − −0.20, *p* = 0.001) ([Table 5](#)). In contrast, there was an increase in the percentage of deaths due to these same causes among female decedents under age 10 or 55–59 (0.21, 95% CI: 0.03–0.39, *p* = 0.02). These results suggest that a small percentage of deaths due to nonmaternal causes, such as unintentional injury, may be coded as maternal deaths due to the checkbox.

Discussion

This report examined the impact of the implementation of the 2003 revision of the U.S. Standard Certificate of Death on MMRs in the United States and related trends from 1999 through 2017. Results suggest that the implementation of the revised standard certificate, which included a question to determine pregnancy status (the pregnancy checkbox), was associated with an increased identification of maternal deaths. Averaging over the period 2003–2017, the checkbox resulted in an MMR increase of 9.6 deaths per 100,000 live births (95% CI: 8.6–10.6).

Impact of the Checkbox

The impact of the checkbox on MMRs was larger among older age groups, particularly ages 40 and over. A companion report that calculated maternal mortality rates for 2015–2016 with and without considering the pregnancy checkbox also found that the impact of the checkbox was largest for older age groups. In general, the MMRs in that report that did not consider the pregnancy checkbox (based only on information in the literal text) were similar to the estimated MMRs in this report, assuming that no states had adopted the checkbox. However, the estimated MMRs assuming that no states had adopted the checkbox tended to be somewhat higher than the MMRs reported in Hoyert et al. (e.g., predicted MMRs for 2015 and 2016 were 11.7 and 12.2, respectively, compared with 8.7 in Hoyert et al. [15]), with larger discrepancies among women aged 40 and over (e.g., predicted MMRs for 2015 and 2016 were 77.5 and 82.6, respectively, compared with 30.6 and 31.1 in Hoyert et al.). These reports used different methodologies to evaluate the impact of the checkbox. One potential reason for discrepancies may be that with the addition of the checkbox, certifiers may be less likely to record pregnancy-related information in the literal text fields. Consequently, recoding death records without considering the checkbox may result in lower MMRs than would have been identified had the checkbox never been implemented.

Prior studies have suggested that the pregnancy checkbox had a larger impact on MMRs among older women, likely resulting in overestimates (17). However, other studies have suggested that the degree to which maternal deaths were undercounted prior to the implementation of the checkbox was larger for older women and teenagers. For example, a study in Maryland using data from 1993 through 2000 suggested that 58% of maternal deaths among women

aged 40 and over and 50% among women under age 20 were not reported on the death certificate, in contrast to 38% among all women (11). A study of Texas data after the implementation of the checkbox suggested that there were higher proportions of false positives and false negatives among women over 35 compared with women under 25 (24). While these estimates are based on only two states and not generalizable to the entire United States, it suggests that among the oldest and youngest age groups, maternal deaths may have been disproportionately underestimated prior to the implementation of the checkbox, which could partly explain the larger impact of the checkbox seen among these age groups in this report. Additionally, prior studies indicate that there is likely a greater percentage of false positives among older women due to the pregnancy checkbox, inflating MMRs among older ages (4,17,24,37). Thus, part of the increase seen due to the implementation of the checkbox may be related to these false positives.

Differences by race and Hispanic origin also were seen in the impact of the checkbox. The impact was smallest for Hispanic women and largest for non-Hispanic black women. It is unclear whether maternal deaths among non-Hispanic black women were disproportionately missed prior to the implementation of the checkbox, whether there is a greater number of false positives among this group after the adoption of the revised standard certificate, or both. Some evidence suggests that false positives are more likely among non-Hispanic black women compared with non-Hispanic white women (37).

Consistent with prior reports, the impact of the checkbox on MMRs was greatest for nonspecific causes of maternal death (4,13,15), including maternal deaths due to other obstetric conditions not elsewhere classified (O95–O99), and a group of nonspecific causes of maternal death (O26.8, O95, O99.8). These causes of death are more likely the ones for which the checkbox may be the only indication of a current or recent pregnancy and where errors in the pregnancy checkbox would have the greatest impact, inflating MMRs related to these causes. Consequently, errors in the application of the checkbox (indicating a current or recent pregnancy when that is not the case) may lead to deaths due to cancer or infectious disease, for example, being coded to a maternal cause of death. A companion report that examined MMRs during 2015–2016 without considering the checkbox information found that heart conditions and cancer were the causes of death most frequently identified when death certificates were re-coded without considering the pregnancy checkbox. Because these causes of death are more common with increasing age, errors in the application of the checkbox have a disproportionate impact on MMRs among older women. Additionally, deaths due to nonmaternal causes of such as unintentional injury may erroneously receive one of these nonspecific codes if the pregnancy checkbox indicates a current or recent pregnancy, depending upon what information appears in part 1 or part 2 of the death certificate (15,39,40).

Trends

Maternal mortality rates were predicted under two alternative scenarios: (1) assuming that no states adopted the checkbox and (2) assuming that all states implemented the checkbox throughout the entire period. Under both scenarios, predicted MMRs did not change significantly from 1999 through 2017 (–0.03, 95% CI: –0.09–0.03; and 0.04, 95% CI: –0.07–0.15, respectively) after adjustment for age, race and Hispanic origin, and state. In a companion report, MMRs during 2015–2016 without considering the pregnancy checkbox were similar to those for 2000–2001, suggesting that in the absence of the checkbox, MMRs would not have increased over that time period. However, results presented here suggest differences in the estimated trends by subgroup and by cause of death. Predicted MMRs declined from 1999 through 2017 for non-Hispanic black women, Hispanic women, and women aged 20–24 and 30–34. Consistent with previous studies (4), predicted MMRs increased for non-Hispanic white women and women aged 40 and over. Importantly, this analysis cannot determine what the true change was in maternal mortality over this time period, as it is unclear how much of the impact of the checkbox was due to better identification of true maternal deaths and how much was potentially due to an increase in false positives.

Consistent with prior studies (4,15,16), there were differences by cause of death in estimated trends. Predicted MMRs declined for several direct causes of maternal death, including pregnancy with abortive outcomes (O00–O07); edema, proteinuria, and hypertensive disorders in pregnancy, childbirth and the puerperium (O10–O16); complications of labor and delivery (O60–O75); and complications predominantly related to the puerperium (O85–O92). Among all direct causes, excluding the nonspecific code O26.8, predicted MMRs declined by 0.17 each year (95% CI: –0.10– –0.01) assuming no checkbox and by 0.22 (95% CI: –0.30– –0.15) assuming that all states had adopted the checkbox. Conversely, predicted MMRs increased for several indirect and nonspecific causes of maternal death, including other specified pregnancy-related conditions (O26.8); late maternal deaths (O96–O97); and the group of nonspecific causes (O26.8, O95, O99.8). It is unclear to what extent these increases may be a consequence of nonmaternal deaths (e.g., deaths due to drug overdose or unintentional injury) being assigned one of these nonspecific or indirect cause-of-death codes due to the pregnancy checkbox being selected, possibly in error. The falsification tests suggested that the percentage of all deaths among reproductive-age women due to unintentional injuries, suicide, homicide, drug overdose, or unknown or ill-defined causes declined with the implementation of the checkbox. Small increases were observed among women for whom the pregnancy checkbox does not apply (under age 10 or 55–59), largely driven by increases in drug overdose deaths. This would suggest that a small percentage of nonmaternal deaths may be misclassified as maternal among women of reproductive age.

Misclassification

Based on prior research, death certificate data may both over- and underestimate maternal or pregnancy-associated deaths. Results presented in this report describe how MMRs may vary across a range of plausible values for Se and PVP. Studies that have conducted data linkages to evaluate the validity of the death certificate data in capturing maternal or pregnancy-associated deaths before the 2003 revision have suggested that as many as 40%–70% of pregnancies among decedents were historically not captured by death certificate data (8,12,22,34,36). Similar studies conducted after the implementation of the checkbox have found that many maternal deaths have no evidence of current or recent pregnancy and that many current or recent pregnancies are not captured, with Se values (the proportion of true pregnancies among female decedents identified using death certificate data) ranging from 0.48 to 0.84 (13,17–24, 33–35), and PVP values (the proportion of maternal deaths where a current or recent pregnancy is identified) ranging from 0.32 to 1.00 (20,24,41). While national estimates of Se and PVP for identifying maternal deaths in death certificate data are not available, results from a recent study of four states suggest that Se (0.62) is slightly lower than PVP (0.68) (37). If these values are similar across the United States, then overall MMRs may be slightly underestimated, with the number of false positives smaller than the number of false negatives. One potential limitation of these types of linkage studies is the lack of information on pregnancies that have not been documented in electronic medical records, or resulted in a live birth or fetal death, which would tend to deflate PVP values.

The degree of misclassification likely varies by many factors, including age, race and Hispanic origin, state, and cause of death. Because maternal deaths are a rare event, few studies have provided estimates of Se and PVP by subgroup. A study of Texas data after the implementation of the checkbox suggested that Se and PVP values were lower for women over age 35 than for women under 25 (24). There were also differences by racial and ethnic group, with a smaller proportion of false negatives among non-Hispanic black and Hispanic women, and a higher proportion of false positives among non-Hispanic black and non-Hispanic white women (24). However, severe data quality issues in that state (23,24,42) preclude those findings from being generalized to the United States. Other studies have also suggested that false positives are more likely among older age groups compared with younger age groups and among non-Hispanic black women compared with non-Hispanic white women (37). Future studies providing more detail on Se and PVP by demographic subgroup across a wider array of states could facilitate a better understanding of the accuracy of MMRs and inform analyses adjusting for misclassification differentially by age, race and Hispanic origin, and other factors.

This analysis has several limitations. West Virginia did not adopt the revised standard certificate until mid-2017. Thus, estimates of the impact of the revision for West Virginia will be understated. California uses a question that is inconsistent with the 2003 standard certificate; it asks about pregnancy status in the past 12 months. Consequently, maternal deaths (during pregnancy or within 42 days) are likely underestimated in California, while late maternal deaths (pregnant within 43 days to 1 year) may be overstated given that checkbox-only deaths are coded to the late maternal category. Maryland, which was the only state to show a decline in MMRs with the implementation of the revised certificate, had a question prior to the revision that asked about pregnancy in the past year along with the corresponding date of delivery. It is possible that the decline in MMRs with the implementation of the revised standard certificate in Maryland is due to efforts in that state to identify maternal or pregnancy-associated deaths through data linkages and record reviews prior to implementing the revision. It is also possible that this decrease was due to chance, and no adjustments were made for multiple comparisons in this analysis. Because many states had some type of question about pregnancy status on the death certificate prior to the 2003 revision, the predicted MMRs assuming that no states had adopted the checkbox may be overestimated, as some of these states did have a pregnancy question prior to the revision.

Analyses adjusting for various error rates in the application of the checkbox on the death certificates only account for potential false positives, resulting in a likely underestimation of MMRs, as death certificate data often fail to capture many true maternal deaths. These analyses also assumed a constant error rate over time, which may not be accurate; they were based on error rates among women outside of reproductive age, which may not be comparable with the error rates among reproductive-age women. Adjustments for outcome misclassification, which account for both over- and underreporting of maternal deaths, likely provide better estimates of MMR values and trends. However, the true values for Se and PVP for the United States (and by subgroup or cause of death) are unknown, and thus these analyses are largely exploratory. It remains unknown to what extent the implementation of the pregnancy checkbox resulted in better ascertainment of maternal deaths (i.e., reductions in false negatives) and to what extent the checkbox may have increased false positives. Other data sources provide information about maternal or pregnancy-related mortality, such as the Pregnancy Mortality Surveillance System (6), data from maternal mortality review committees (20), and state-based quality-assurance projects (37). These data sources, which rely on detailed record reviews or data linkages to verify recent pregnancy status, may not be subject to the same degree of misclassification as vital records data. Finally, there may have been other factors that changed simultaneously when states revised their death certificates, confounding the estimated impact of the checkbox. Specifically, the adoption of electronic death registration systems, the implementation of various quality-assurance processes (e.g., data linkages with birth and fetal death records), and the centralization of coding cause of death at NCHS. While an indicator for when coding was completely centralized (in 2011) was included in the models, many states had already relied on NCHS to code cause-of-death information prior to 2011. Specific information regarding what years various states were responsible for cause-of-death coding prior to 2011 is not available. State-specific estimates of the impact of the checkbox may be confounded by unmeasured factors that changed at the time of the revision, such as severe influenza seasons (43), rapid increases in drug overdose mortality (44), or loss of hospital-based obstetric services (45), among other potential factors. While higher-order trends (i.e., quadratic) were not apparent at the national level, it is possible that trends in MMRs in specific states before or after the revision were nonlinear, which could have biased estimated state-level impacts of the checkbox.

Conclusions

This report examines the impact of the staggered adoption of the 2003 revision of the standard death certificate on trends in maternal mortality in the United States from 1999 through 2017. Results suggest that the observed increases in MMRs during this time period were largely due to the staggered implementation of the checkbox, which increased identification of maternal deaths. Averaging over the period 2003–2017, the checkbox resulted in an MMR increase of 9.6 deaths per 100,000 live births (95% CI: 8.6–10.6). Estimated trends accounting for the implementation of the checkbox indicated that there were no significant changes in MMRs over time, although trends varied by maternal age, race and Hispanic origin, and cause of maternal death. Additionally, the misclassification of pregnancy status on the death certificate likely contributed to increasing trends among women aged 40 and over and among nonspecific causes of maternal death.

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Table 1. Average change in maternal mortality rates associated with the pregnancy checkbox implementation, by age and race and Hispanic origin: United States, 2003–2017

Characteristic	Change in maternal mortality rate (95% CI)
Overall	9.6 (8.6 – 10.6)
Age group	
Under 15	14.5 (−10.3 – 39.3)
15–19	3.7 (1.7 – 5.7)
20–24	5.6 (4.1 – 7.1)
25–29	5.4 (3.8 – 7.1)
30–34	6.0 (3.9 – 8.0)
35–39	13.9 (9.7 – 18.0)
40 and over	145.3 (127.6 – 163.1)
Race and Hispanic origin	
Non-Hispanic white	8.6 (7.5 – 9.7)
Non-Hispanic black	19.6 (15.3 – 24.0)
Non-Hispanic other	7.1 (4.2 – 10.0)
Hispanic	6.2 (4.3 – 8.1)
Prerevision pregnancy question	
No	9.8 (8.7 – 10.9)
Yes	8.1 (6.8 – 9.4)
Centralized cause-of-death coding	
No (before 2011)	9.0 (8.0 – 10.0)
Yes (2011–2017)	10.9 (9.5 – 12.2)

NOTE: CI is confidence interval.

SOURCE: NCHS, National Vital Statistics System, 1999–2017.

Table 2. Trends in predicted maternal mortality rates, by age and race and Hispanic origin: United States, 1999–2017

	Average annual change in maternal mortality rate			
Characteristic	No checkbox (95% CI)	p	All checkbox (95% CI)	p
Overall	0.0 (−0.1 − 0.0)	0.307	0.0 (− 0.1 − 0.2)	0.459
Age group				
Under 15	0.4 (−0.8 − 1.5)	0.519	1.7 (−1.9 − 5.3)	0.359
15–19	0.0 (−0.1 − 0.1)	0.616	0.1 (−0.1 − 0.3)	0.538
20–24	− 0.1 (−0.2 − 0.0)	0.001	−0.2 (−0.4 − −0.1)	0.008
25–29	− 0.1 (− 0.2 − 0.0)	0.057	− 0.1 (−0.3 − 0.0)	0.116
30–34	− 0.2 (− 0.3 − −0.1)	0.002	− 0.3 (−0.5 − −0.1)	0.013
35–39	− 0.1 (− 0.3 − 0.1)	0.425	− 0.1 (−0.5 − 0.3)	0.552
40 and over	2.5 (1.8 − 3.3)	Less than 0.001	7.7 (6.1 − 9.4)	Less than 0.001
Race and Hispanic origin				
Non-Hispanic white	0.1 (0.1 − 0.2)	Less than 0.001	0.3 (0.2 − 0.5)	Less than 0.001
Non-Hispanic black	− 0.3 (− 0.6 − −0.1)	0.004	− 0.4 (−0.9 − 0.0)	0.072
Non-Hispanic other	− 0.1 (− 0.3 − 0.0)	0.104	− 0.2 (−0.4 − 0.1)	0.280
Hispanic	− 0.3 (− 0.3 − −0.2)	Less than 0.001	− 0.4 (−0.6 − −0.2)	Less than 0.001

NOTE: CI is confidence interval.

SOURCE: NCHS, National Vital Statistics System, 1999–2017.

Table 3. Estimated impact of the pregnancy checkbox on cause-specific maternal mortality rates: United States, 2003–2017

Cause of maternal death	Average change in maternal mortality rate (95% CI)
Direct causes	5.2 (4.4 – 6.1)
Direct causes excluding O26.8	2.0 (1.3 – 2.7)
Alternative grouping of direct causes (A34,O00–O92)	4.8 (4.0 – 5.6)
Alternative grouping of direct causes (A34,O00–O95)	5.6 (4.8 – 6.5)
O00–O07: Pregnancy with abortive outcomes	0.2 (0.0 – 0.5)
O10–O16: Edema, proteinuria and hypertensive disorders in pregnancy, childbirth and the puerperium	0.4 (0.0 – 0.7)
O20–O29: Other maternal disorders predominantly related to pregnancy	3.5 (3.1 – 4.0)
O26.6: Liver disorders in pregnancy, childbirth and the puerperium	0.5 (0.3 – 0.7)
O26.8: Other specified pregnancy-related conditions	2.6 (2.2 – 2.9)
O20–O29: Other maternal disorders predominantly related to pregnancy, excluding O26.8	1.0 (0.8 – 1.3)
O30–O48: Maternal care related to the fetus and amniotic cavity and possible delivery problems	0.3 (0.0 – 0.5)
O60–O75: Complications of labor and delivery	0.2 (– 0.1 – 0.5)
O85–O92: Complications predominantly related to the puerperium	0.4 (0.0 – 0.8)
Indirect causes	4.6 (4.1 – 5.1)
Alternative grouping of indirect causes (O98–O99)	4.2 (3.7 – 4.7)
O95–O99: Other obstetric conditions not elsewhere classified (including late maternal deaths)	8.3 (7.6 – 9.0)
O95,O98–O99: Other obstetric conditions not elsewhere classified (excluding late maternal deaths)	5.1 (4.6 – 5.6)
O99.3: Mental disorders and diseases of the nervous system complicating pregnancy, childbirth and the puerperium	0.2 (0.1 – 0.3)
O99.4: Diseases of the circulatory system complicating pregnancy, childbirth and the puerperium	1.2 (0.9 – 1.4)
O99.5: Diseases of the respiratory system complicating pregnancy, childbirth and the puerperium	0.4 (0.2 – 0.6)
O99.8: Other specified diseases and conditions complicating pregnancy, childbirth and the puerperium	2.3 (1.9 – 2.6)
O96–O97: Late maternal deaths	3.5 (3.1 – 3.9)
Nonspecific causes (O26.8,O95,O99.8)	5.6 (5.1 – 6.1)

NOTES: CI is confidence interval. Direct and indirect causes of maternal death from Say et al.; see reference 26 in this report. Alternative grouping of direct causes of maternal death (A34,O00–O92) and indirect causes (O98–O99) from MacDorman et al.; see reference 4 in this report. Alternative grouping of direct causes of maternal death (A34,O00–O95) from Hoyert et al.; see reference 15 in this report.

SOURCE: NCHS, National Vital Statistics System, 1999–2017.

Table 4. Estimated trends in predicted maternal mortality rates, by cause of death: United States, 1999–2017

Cause of maternal death	Average annual change in maternal mortality rate			
	No checkbox (95% CI)	*p*	All checkbox (95% CI)	*p*
Direct causes	− 0.05 (−0.10 – 0.01)	0.083	− 0.08 (−0.17 – 0.01)	0.099
Direct causes excluding O26.8	− 0.17 (−0.22 – −0.12)	Less than 0.001	− 0.22 (−0.30 – − 0.15)	Less than 0.001
Alternative grouping of direct causes (A34,O00−O92)	0.00 (−0.05 – 0.06)	0.950	0.00 (−0.08 – 0.09)	0.953
Alternative grouping of direct causes (A34,O00−O95)	− 0.03 (−0.09 – 0.02)	0.228	− 0.05 (−0.15 – 0.04)	0.242
O00−O07: Pregnancy with abortive outcomes	− 0.03 (−0.05 – −0.02)	Less than 0.001	− 0.05 (−0.07 – − 0.02)	0.001
O10−O16: Edema, proteinuria and hypertensive disorders in pregnancy, childbirth and the puerperium	− 0.03 (−0.05 – 0.00)	0.019	− 0.04 (−0.07 – 0.00)	0.045
O20−O29: Other maternal disorders predominantly related to pregnancy	0.09 (0.06 – 0.12)	Less than 0.001	0.26 (0.21 – 0.31)	Less than 0.001
O26.6: Liver disorders in pregnancy, childbirth and the puerperium	0.00 (0.00 – 0.01)	0.244	0.02 (−0.01 – 0.04)	0.145
O26.8: Other specified pregnancy-related conditions (pregnancy-related exhaustion and fatigue, peripheral neuritis or renal disease)	0.08 (0.05 – 0.10)	Less than 0.001	0.25 (0.21 – 0.29)	Less than 0.001
O20−O29: Other maternal disorders predominantly related to pregnancy, excluding O26.8	0.00 (−0.01 – 0.02)	0.575	0.01 (−0.02 – 0.04)	0.554
O30−O48: Maternal care related to the fetus and amniotic cavity and possible delivery problems	− 0.01 (−0.03 – 0.00)	0.039	− 0.02 (−0.05 – 0.00)	0.094
O60−O75: Complications of labor and delivery	− 0.06 (−0.08 – −0.04)	Less than 0.001	− 0.08 (−0.11 – − 0.04)	Less than 0.001
O85−O92: Complications predominantly related to the puerperium	− 0.03 (−0.06 – 0.00)	0.021	− 0.04 (−0.08 – 0.00)	0.045
Indirect causes	0.03 (0.01 – 0.05)	0.008	0.10 (0.04 – 0.16)	0.002
Alternative grouping of indirect causes (O98−O99)	0.02 (0.00 – 0.04)	0.037	0.07 (0.01 – 0.14)	0.019
O95−O99: Other obstetric conditions not elsewhere classified (including late maternal deaths)	0.13 (0.09 – 0.16)	Less than 0.001	0.39 (0.31 – 0.46)	Less than 0.001
O95,O98−O99: Other obstetric conditions not elsewhere classified (excluding late maternal deaths)	0.00 (−0.02 – 0.02)	0.895	0.00 (−0.07 – 0.08)	0.897
O99.3: Mental disorders and diseases of the nervous system complicating pregnancy, childbirth and the puerperium	0.00 (0.00 – 0.01)	0.108	0.02 (0.01 – 0.03)	0.004
O99.4: Diseases of the circulatory system complicating pregnancy, childbirth and the puerperium	0.00 (−0.01 – 0.02)	0.538	0.01 (−0.02 – 0.04)	0.514
O99.5: Diseases of the respiratory system complicating pregnancy, childbirth and the puerperium	0.00 (−0.01 – 0.00)	0.089	− 0.02 (−0.04 – 0.01)	0.225
O99.8: Other specified diseases and conditions complicating pregnancy, childbirth and the puerperium	0.01 (0.00 – 0.02)	0.141	0.04 (−0.01 – 0.08)	0.095
O96−O97: Late maternal deaths	0.12 (0.09 – 0.15)	Less than 0.001	0.34 (0.29 – 0.39)	Less than 0.001
Nonspecific causes (O26.8,O95,O99.8)	0.06 (0.04 – 0.09)	Less than 0.001	0.23 (0.17 – 0.30)	Less than 0.001

NOTES: CI is confidence interval. Models were adjusted for age group, race and Hispanic origin, and state of occurrence, and included interactions between year and age and year and race and Hispanic origin. Models for O99.3 did not include state of occurrence. Direct and indirect causes of maternal death from Say et al.; see reference 26 in this report. Alternative grouping of direct causes of maternal death (A34,O00−O92) and indirect causes (O98−O99) from MacDorman et al.; see reference 4 in this report. Alternative grouping of direct causes of maternal death (A34,O00−O95) from Hoyert et al.; see reference 15 in this report.

SOURCE: NCHS, National Vital Statistics System, 1999–2017.

Table 5. Estimated average change in the percentage of all deaths due to nonmaternal causes of death associated with the implementation of the revised standard death certificate, by age: United States, 2003–2017

| Cause of death | Change in percentage of all deaths | | | |
	15–44 years (95% CI)	p	Under 10 years or 55–59 (95% CI)	p
Unintentional injury (V01–X59,Y85–86)	−0.14 (−0.43 – 0.15)	0.344	0.15 (0.00 – 0.29)	0.047
Suicide (*U03,X60–X84,Y87.0)	−0.04 (−0.22 – 0.13)	0.635	0.04 (−0.03 – 0.10)	0.304
Drug overdose (X40–X44, X60–X64, X85, Y10–Y14)	0.86 (0.63 – 1.09)	Less than 0.001	0.37 (0.28 – 0.46)	Less than 0.001
Homicide (*U01–*U02,X85–Y09,Y87.1)	−0.10 (−0.24 – 0.04)	0.159	0.03 (−0.02 – 0.09)	0.253
Unknown (R99)	−0.40 (−0.50 – −0.31)	Less than 0.001	−0.03 (−0.10 – 0.04)	0.445
All	−0.53 (−0.85 – −0.20)	0.001	0.21 (0.03 – 0.39)	0.020

NOTES: CI is confidence interval. Models were adjusted for age group, race and Hispanic origin, and state of occurrence, and included interactions between year and age and year and race and Hispanic origin.

SOURCE: CDC/NCHS, National Vital Statistics System, 1999–2017.

Appendix I. Supplemental Tables and Details of Adjustments to Maternal Mortality Ratios for Misclassification

Table I displays the percentage of records where one of the pregnancy checkboxes was selected (either currently pregnant, pregnant within 42 days, or pregnant 43 days to 1 year) among women of ages where pregnancy would be implausible (under age 10 or 55 and over) by state of occurrence.

Table I. Percentage of deaths among female decedents under 10 years or 55 and over where one of the pregnancy checkboxes was selected, by state of occurrence: 2003–2013

State	Under 10		55 and over		Row total percent
	Percent	N	Percent	N	
Arizona	0.00	1,171	0.03	82,287	0.03
Arkansas	0.00	985	0.01	75,536	0.01
California	0.19	16,684	0.13	1,144,060	0.14
Connecticut	0.00	1,026	0.02	127,400	0.02
Delaware	0.00	383	0.01	23,875	0.01
District of Columbia	0.10	963	0.05	20,136	0.06
Florida	0.00	7,749	0.00	669,133	0.00
Georgia	0.00	3,184	0.02	186,774	0.02
Idaho	0.00	731	0.00	52,937	0.00
Illinois	0.03	3,420	0.02	274,518	0.02
Indiana	0.00	2,052	0.02	158,774	0.02
Iowa	0.00	278	0.01	40,410	0.01
Kansas	0.00	1,215	0.00	100,248	0.00
Kentucky	0.00	751	0.08	74,324	0.07
Louisiana	0.00	599	0.02	36,154	0.02
Maine	0.00	195	0.00	23,942	0.00
Michigan	0.10	4,848	0.08	393,437	0.08
Minnesota	0.00	624	0.01	56,209	0.01
Mississippi	0.00	351	0.00	25,082	0.00
Missouri	0.00	1,308	0.02	103,928	0.02
Montana	0.00	430	0.00	42,063	0.00
Nebraska	0.00	793	0.00	65,048	0.00
Nevada	0.00	668	0.04	48,836	0.04
New Hampshire	0.00	331	0.06	48,203	0.06
New Jersey	0.45	2,648	0.11	329,523	0.12
New Mexico	0.00	695	0.02	50,912	0.02
New York city	0.00	4,069	0.01	270,083	0.01
New York state	0.05	4,173	0.08	502,104	0.08
North Dakota	0.00	186	0.34	17,417	0.34
Ohio	0.00	4,275	0.02	354,857	0.02

See footnotes at end of table.

Table I. Percentage of deaths among female decedents under 10 years or 55 and over where one of the pregnancy checkboxes was selected, by state of occurrence: 2003–2013—Con.

State	Under 10		55 and over		Row total percent
	Percent	N	Percent	N	
Oklahoma	0.04	2,299	0.09	154,725	0.09
Oregon	0.00	1,205	0.01	116,620	0.01
Pennsylvania	0.00	1,125	0.00	121,313	0.00
Rhode Island	0.00	354	0.06	38,025	0.06
South Carolina	0.00	2,163	0.00	155,152	0.00
South Dakota	0.00	492	0.00	32,372	0.00
Tennessee	0.00	763	0.07	57,115	0.07
Texas	0.06	10,931	0.05	571,070	0.05
Utah	0.21	1,424	0.07	56,793	0.07
Vermont	0.00	84	0.02	14,747	0.02
Washington	0.00	2,335	0.00	215,329	0.00
Wisconsin	0.00	220	0.01	22,968	0.01
Wyoming	0.00	165	0.00	16,887	0.00

NOTES: Beginning in 2014, records indicating current or recent pregnancy among female decedents under 10 or 55 and over were recoded to "Not Applicable." States that adopted the revised standard certificate in 2014 or later are therefore not shown.

SOURCE: NCHS, National Vital Statistics System, 2003–2013.

Table II displays differences in maternal mortality rates associated with the implementation of the checkbox by state of occurrence.

Table II. Change in maternal mortality rates associated with the pregnancy checkbox implementation, by state of occurrence

State	Change in maternal mortality rate (95% CI)
Alabama	29.0 (18.4 – 39.7)
Alaska	4.0 (–8.7 – 16.7)
Arizona	10.2 (2.2 – 18.1)
Arkansas	15.7 (1.0 – 30.4)
California	9.9 (5.2 – 14.7)
Colorado	2.0 (–4.8 – 8.8)
Connecticut	5.7 (–0.6 – 12.0)
Delaware	19.0 (–15.5 – 53.5)
District of Columbia	2.3 (–9.9 – 14.6)
Florida	9.3 (4.8 – 13.7)
Georgia	3.2 (–2.4 – 8.7)
Hawaii	–6.4 (–22.3 – 9.5)
Idaho	23.9 (4.7 – 43.2)
Illinois	17.9 (10.6 – 25.1)
Indiana	20.4 (14.3 – 26.5)
Iowa	9.5 (–1.7 – 20.7)
Kansas	14.0 (4.3 – 23.8)
Kentucky	11.6 (0.6 – 22.7)
Louisiana	38.2 (28.4 – 48.0)
Maine	6.9 (–13.5 – 27.3)
Maryland	–7.8 (–13.3 – –2.4)
Massachusetts	2.4 (–1.6 – 6.5)
Michigan	29.9 (20.4 – 39.3)
Minnesota	1.5 (–6.2 – 9.2)
Mississippi	–10.0 (–21.4 – 1.5)
Missouri	6.5 (–3.9 – 16.9)
Montana	0.4 (–24.2 – 25.0)
Nebraska	–2.6 (–16.8 – 11.7)
Nevada	–1.3 (–12.7 – 10.0)
New Hampshire	5.3 (–12.9 – 23.4)
New Jersey	16.1 (11.0 – 21.1)
New Mexico	15.7 (–5.9 – 37.2)
New York City	9.3 (2.7 – 15.9)
New York State[1]	6.6 (1.8 – 11.3)
North Carolina	9.5 (5.0 – 14.1)
North Dakota	25.3 (–14.3 – 64.9)
Ohio	19.6 (12.7 – 26.4)
Oklahoma	29.9 (16.0 – 43.8)
Oregon	5.1 (–3.7 – 13.9)
Pennsylvania	– 2.4 (–8.4 – 3.6)
Rhode Island	–0.8 (–13.5 – 11.8)
South Carolina	18.3 (9.8 – 26.7)
South Dakota	14.8 (–7.1 – 36.7)
Tennessee	18.8 (11.2 – 26.3)
Texas	12.5 (8.8 – 16.1)
Utah	10.9 (0.1 – 21.6)
Vermont	4.4 (–16.6 – 25.4)
Virginia	7.4 (2.5 – 12.3)
Washington	3.7 (–2.3 – 9.6)
West Virginia	4.6 (–17.4 – 26.6)
Wisconsin	–4.8 (–12.9 – 3.2)
Wyoming	84.4 (–22.5 – 191.3)

[1]Excludes New York City.

NOTE: CI is confidence interval.

SOURCE: NCHS, National Vital Statistics System, 1999–2017.

Table III displays the observed maternal mortality rates (MMRs), predicted MMRs assuming that no states had adopted the checkbox during this time period, and predicted MMRs assuming that all states had adopted the checkbox during the entire time period.

Table III. Observed and predicted maternal mortality rates: United States, 1999–2017

Year	Maternal mortality rate	Predicted maternal mortality rate, no checkbox	Predicted maternal mortality rate, all checkbox
1999	9.9 (8.9 – 10.9)	10.3 (7.4 – 13.2)	21.2 (11.2 – 31.2)
2000	9.8 (8.8 – 10.8)	10.1 (7.2 – 13.0)	20.8 (11.6 – 30.0)
2001	9.9 (8.9 – 10.9)	10.0 (7.3 – 12.7)	20.3 (11.5 – 29.1)
2002	8.9 (8.0 – 9.8)	9.8 (7.3 – 12.3)	19.8 (12.0 – 27.6)
2003	12.1 (11.0 – 13.2)	9.7 (7.2 – 12.2)	19.5 (12.4 – 26.6)
2004	13.1 (12.0 – 14.2)	9.7 (7.2 – 12.2)	19.2 (12.7 – 25.7)
2005	15.1 (13.9 – 16.3)	9.6 (7.1 – 12.1)	19.0 (12.5 – 25.5)
2006	13.3 (12.2 – 14.4)	9.7 (7.0 – 12.4)	18.7 (12.8 – 24.6)
2007	12.7 (11.6 – 13.8)	9.7 (6.8 – 12.6)	18.6 (13.1 – 24.1)
2008	15.5 (14.3 – 16.7)	9.8 (6.7 – 12.9)	18.7 (13.4 – 24.0)
2009	16.6 (15.4 – 17.8)	9.9 (6.6 – 13.2)	18.9 (14.2 – 23.6)
2010	16.9 (15.6 – 18.2)	10.1 (6.2 – 14.0)	19.2 (14.9 – 23.5)
2011	19.3 (17.9 – 20.7)	10.4 (6.1 – 14.7)	19.6 (14.9 – 24.3)
2012	19.9 (18.5 – 21.3)	10.6 (5.9 – 15.3)	19.9 (15.2 – 24.6)
2013	22.0 (20.5 – 23.5)	10.9 (5.6 – 16.2)	20.5 (16.2 – 24.8)
2014	21.5 (20.1 – 22.9)	11.3 (5.8 – 16.8)	20.9 (16.2 – 25.6)
2015	20.9 (19.5 – 22.3)	11.7 (6.2 – 17.2)	21.7 (16.6 – 26.8)
2016	21.8 (20.3 – 23.3)	12.2 (6.5 – 17.9)	22.4 (16.9 – 27.9)
2017	21.6 (20.1 – 23.1)	12.8 (6.5 – 19.1)	23.5 (17.4 – 29.6)

NOTE: Models were adjusted for age group, race and Hispanic origin, and state of occurrence, and included interactions between these factors and year as well as revision status.

SOURCE: NCHS, National Vital Statistics System, 1999–2017.

Table IV displays the predicted MMRs assuming that no states had adopted the checkbox during this time period, and predicted MMRs assuming that all states had adopted the checkbox during the entire time period by varying degrees of outcome misclassification.

Table IV. Predicted maternal mortality rates, adjusted for outcome misclassification: United States, 1999 and 2017

Levels of outcome misclassification, by sensitivity and predictive value positive		Predicted maternal mortality rate assuming no states had adopted the checkbox		Predicted maternal mortality rate assuming all states had adopted the checkbox	
Sensitivity	Predictive value positive	1999	2017	1999	2017
0.3	0.5	17.1	21.4	35.3	39.2
0.3	0.6	20.5	25.6	42.4	47.1
0.3	0.7	24.0	29.9	49.5	54.9
0.3	0.8	27.4	34.2	56.6	62.8
0.3	0.9	30.8	38.5	63.6	70.6
0.4	0.5	12.8	16.0	26.5	29.4
0.4	0.6	15.4	19.2	31.8	35.3
0.4	0.7	18.0	22.4	37.1	41.2
0.4	0.8	20.5	25.6	42.4	47.1
0.4	0.9	23.1	28.8	47.7	52.9
0.5	0.5	10.3	12.8	21.2	23.5
0.5	0.6	12.3	15.4	25.4	28.2
0.5	0.7	14.4	17.9	29.7	32.9
0.5	0.8	16.4	20.5	33.9	37.7
0.5	0.9	18.5	23.1	38.2	42.4
0.6	0.5	8.6	10.7	17.7	19.6
0.6	0.6	10.3	12.8	21.2	23.5
0.6	0.7	12.0	15.0	24.7	27.5
0.6	0.8	13.7	17.1	28.3	31.4
0.6	0.9	15.4	19.2	31.8	35.3
0.7	0.5	7.3	9.2	15.1	16.8
0.7	0.6	8.8	11.0	18.2	20.2
0.7	0.7	10.3	12.8	21.2	23.5
0.7	0.8	11.7	14.7	24.2	26.9
0.7	0.9	13.2	16.5	27.3	30.3
0.8	0.5	6.4	8.0	13.3	14.7
0.8	0.6	7.7	9.6	15.9	17.6
0.8	0.7	9.0	11.2	18.6	20.6
0.8	0.8	10.3	12.8	21.2	23.5
0.8	0.9	11.6	14.4	23.9	26.5
0.9	0.5	5.7	7.1	11.8	13.1
0.9	0.6	6.8	8.5	14.1	15.7
0.9	0.7	8.0	10.0	16.5	18.3
0.9	0.8	9.1	11.4	18.9	20.9
0.9	0.9	10.3	12.8	21.2	23.5

NOTE: Sensitivity refers to the proportion of true maternal deaths captured by death certificate data. Predictive value positive refers to the proportion of maternal deaths identified in death certificate data that are true maternal deaths.

SOURCE: NCHS, National Vital Statistics System, 1999–2017.

Table V displays how death certificate data compare with gold standard data, where T_y is the true number of maternal deaths, and T_n is the number of nonmaternal deaths, while D_y is the number of maternal deaths as indicated by death certificate data, and D_n is the number of nonmaternal deaths.

Table V. Comparison of pregnancy status on death certificates with pregnancy status assessed by a gold standard measure

| Gold standard | Death certificate | | Total |
	Yes	No	
Yes	a	b	T_y
No	c	d	T_n
Total	D_y	D_n	Total number

NOTE: The gold standard is based on prior analyses of the validity of death certificate data in ascertaining maternal deaths, which rely on linkages of death certificates with birth certificate, fetal death certificate, and electronic medical record data to determine whether a female decedent was currently or recently pregnant.

Sensitivity (Se) is the proportion of true maternal deaths classified as maternal deaths on the death certificate. Predictive value positive (PVP) is the proportion of maternal deaths in mortality data that are truly maternal deaths. The proportion of maternal deaths from death certificate data that are false positives (FP) is $1 - PVP$, corresponding to the proportion of maternal deaths with no evidence of current or recent pregnancy. Using these values, the true number of maternal deaths corrected for misclassification, T_y, can be calculated as follows:

$$Se = \frac{a}{T_y} \tag{1}$$

Therefore,

$$a = Se \bullet T_y \tag{2}$$

Additionally,

$$PVP = \frac{a}{D_y} \tag{3}$$

$$FP = (1 - PVP) = \frac{c}{D_y} \tag{4}$$

Therefore,

$$c = (1 - PVP) \bullet D_y \tag{5}$$

T_y is unknown, while D_y is observed, and values for Se and PVP are estimated from prior studies.

$$D_y = a + c = Se \bullet T_y + (1 - PVP) \bullet D_y \tag{6}$$

The following formula can then be used to calculate T_y from Se, PVP, and D_y:

$$T_y = \frac{D_y - (1 - PVP) \bullet D_y}{Se} = \frac{D_y \bullet PVP}{Se} \tag{7}$$

Technical Notes

Cause-of-death classification

Mortality statistics are compiled in accordance with World Health Organization (WHO) regulations specifying that WHO member nations classify and code causes of death in accordance with the current revision of the *International Statistical Classification of Diseases and Related Health Problems* (ICD). ICD provides the basic guidance used in virtually all countries to code and classify causes of death. It provides not only disease, injury, and poisoning categories, but also the rules used to select the single underlying cause of death for tabulation from the conditions reported on the death certificate, as well as definitions, tabulation lists, the format of the death certificate, and regulations on use of the classification. Causes of death for data presented in this report were coded according to ICD guidelines described in annual issues of the National Center for Health Statistics instruction manuals (39).

Appendix II. Supplemental Figures

Figure I. Observed and predicted maternal mortality rates for direct causes of maternal death: United States, 1999–2017

NOTES: Models were adjusted for age group, race and Hispanic origin, and state of occurrence, and included interactions between year and age, and year and race and Hispanic origin. Direct causes of maternal death from Say et al.; see reference 26 in this report.
SOURCE: NCHS, National Vital Statistics System.
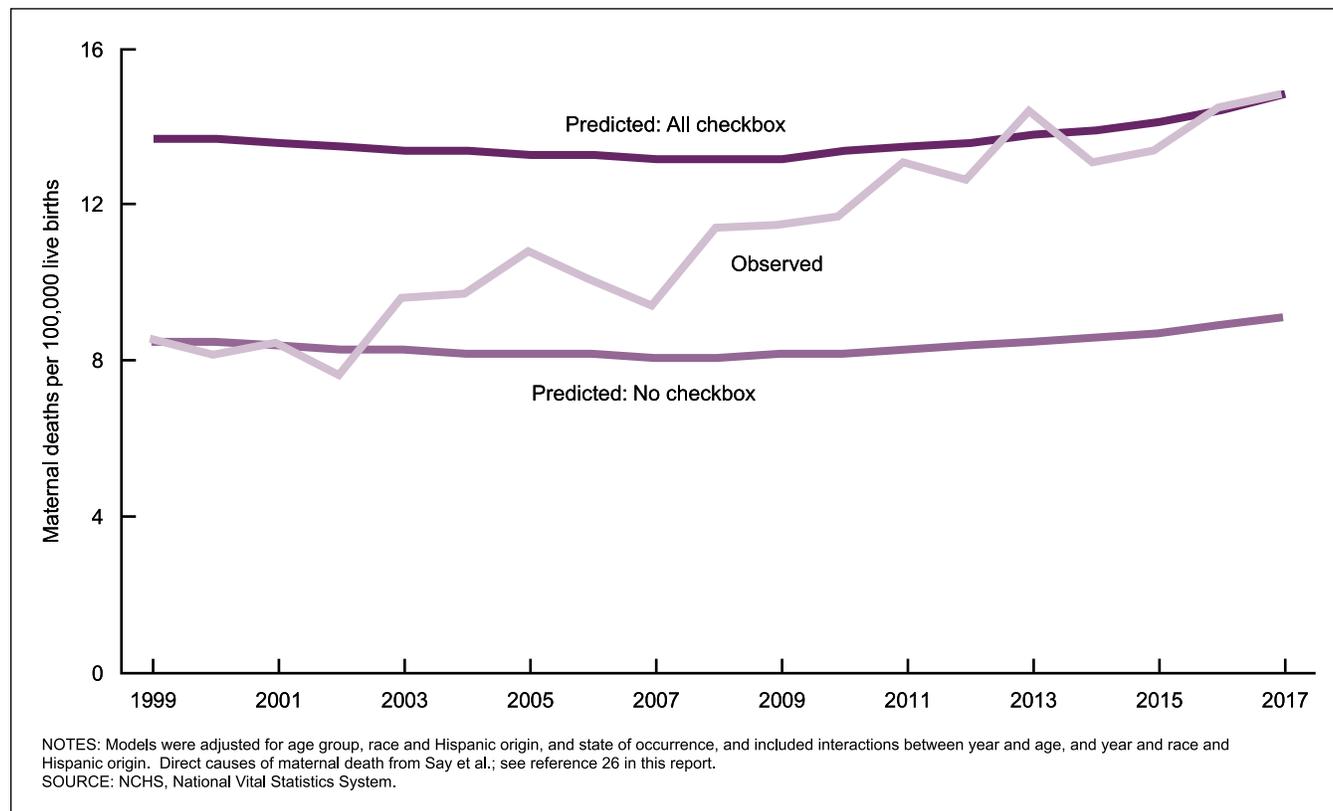
Figure II. Observed and predicted maternal mortality rates for direct causes of maternal death, excluding O26.8: United States, 1999–2017

NOTES: Models were adjusted for age group, race and Hispanic origin, and state of occurrence, and included interactions between year and age, and year and race and Hispanic origin. Direct causes of maternal death from Say et al.; see reference 26 in this report.
SOURCE: NCHS, National Vital Statistics System.

Figure III. Observed and predicted maternal mortality rates for direct causes of maternal death (A34, O00–O92): United States, 1999–2017

NOTES: Models were adjusted for age group, race and Hispanic origin, and state of occurrence, and included interactions between year and age, and year and race and Hispanic origin. Alternative grouping of direct causes of maternal death (A34,O00–O92) from MacDorman et al.; see reference 4 in this report.
SOURCE: NCHS, National Vital Statistics System.

Figure IV. Observed and predicted maternal mortality rates for direct causes of maternal death (A34, O00–O95): United States, 1999–2017

NOTES: Models were adjusted for age group, race and Hispanic origin, and state of occurrence, and included interactions between year and age, and year and race and Hispanic origin. Alternative grouping of direct causes of maternal death (A34,O00–O95) from Hoyert et al.; see reference 15 in this report.
SOURCE: NCHS, National Vital Statistics System.
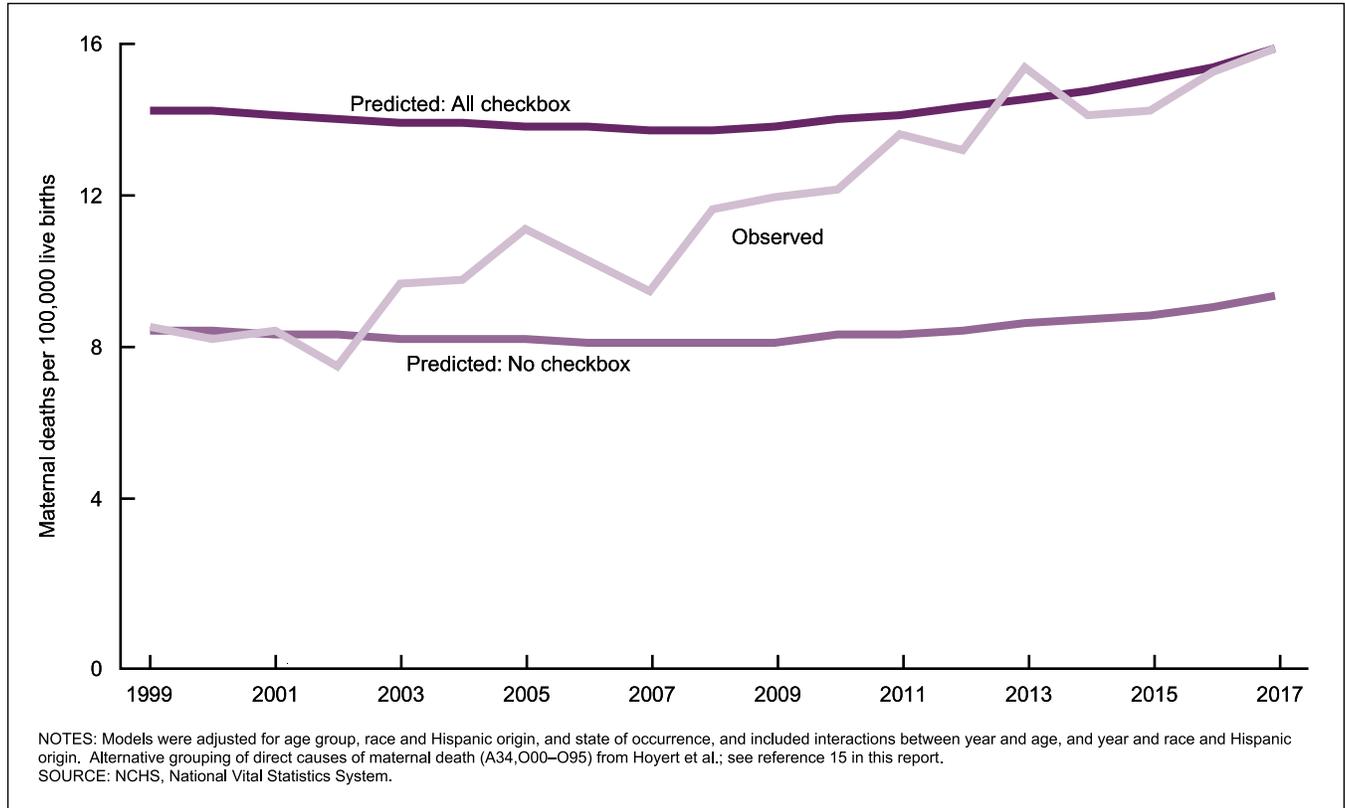
Figure V. Observed and predicted maternal mortality rates for pregnancy with abortive outcomes (O00–O07): United States, 1999–2017

[1] Observed rates suppressed when the number of deaths is fewer than 20 (2002, 2015, 2017).
NOTE: Models were adjusted for age group, race and Hispanic origin, and state of occurrence, and included interactions between year and age, and year and race and Hispanic origin.
SOURCE: NCHS, National Vital Statistics System.
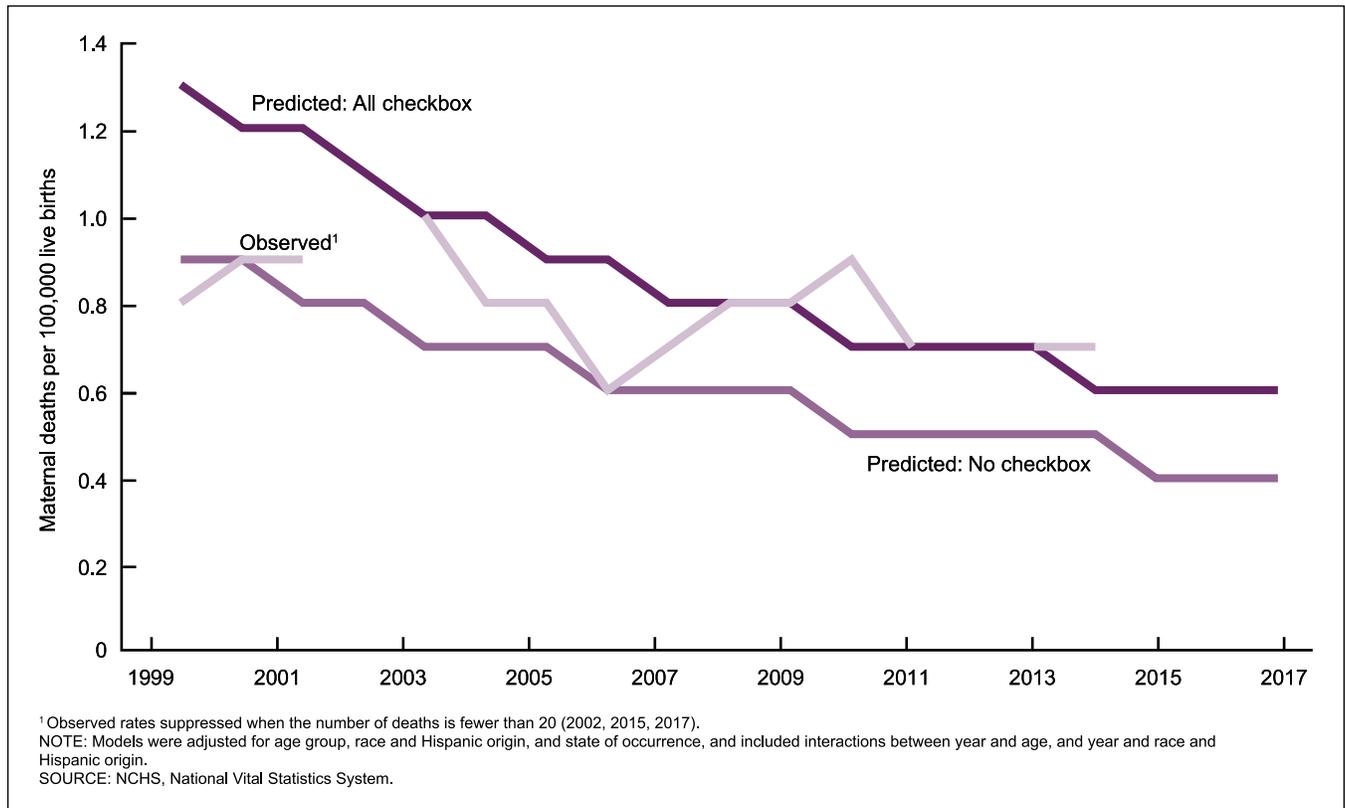
Figure VI. Observed and predicted maternal mortality rates for edema, proteinuria, and hypertensive disorders in pregnancy, childbirth, and the puerperium (O10–O16): United States, 1999–2017

NOTE: Models were adjusted for age group, race and Hispanic origin, and state of occurrence, and included interactions between year and age, and year and race and Hispanic origin.
SOURCE: NCHS, National Vital Statistics System.
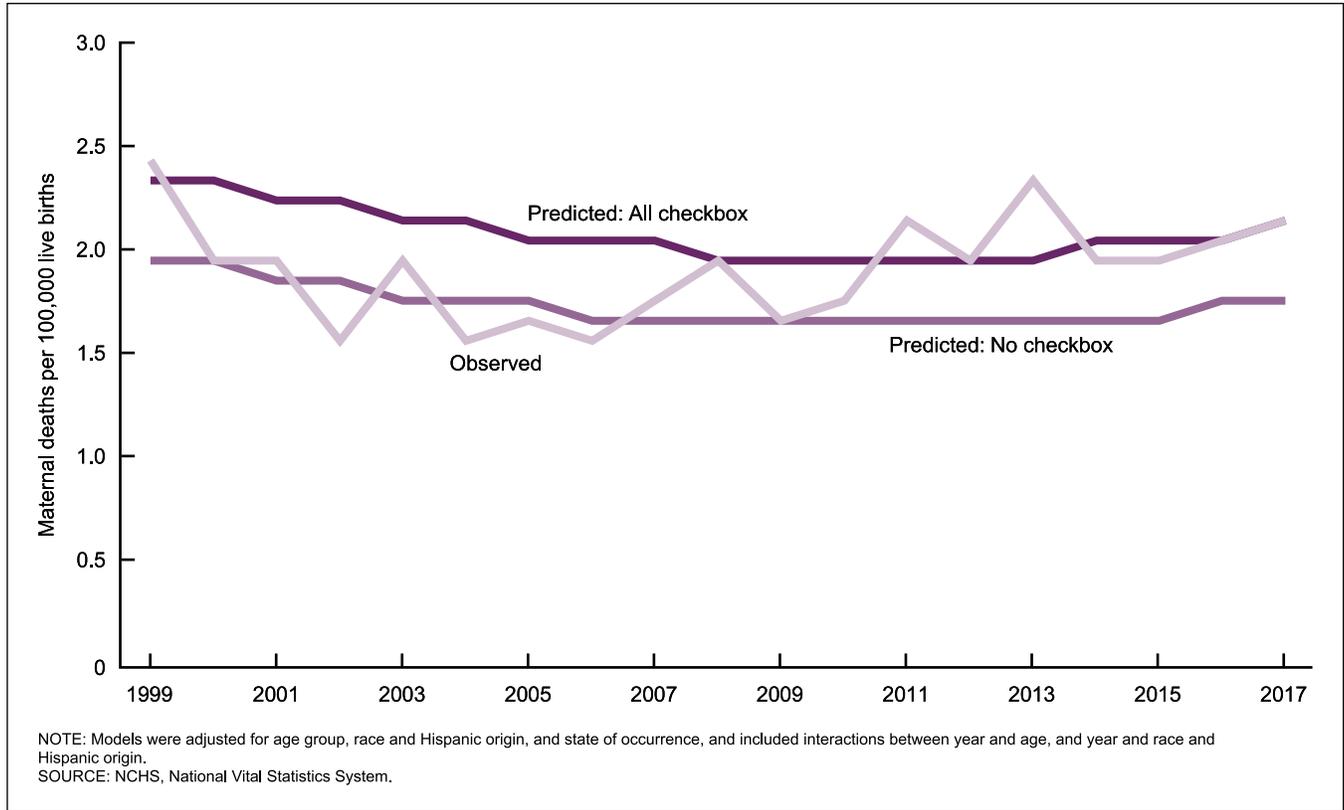
Figure VII. Observed and predicted maternal mortality rates for other maternal disorders predominantly related to pregnancy (O20–O29): United States, 1999–2017

NOTE: Models were adjusted for age group, race and Hispanic origin, and state of occurrence, and included interactions between year and age, and year and race and Hispanic origin.
SOURCE: NCHS, National Vital Statistics System.
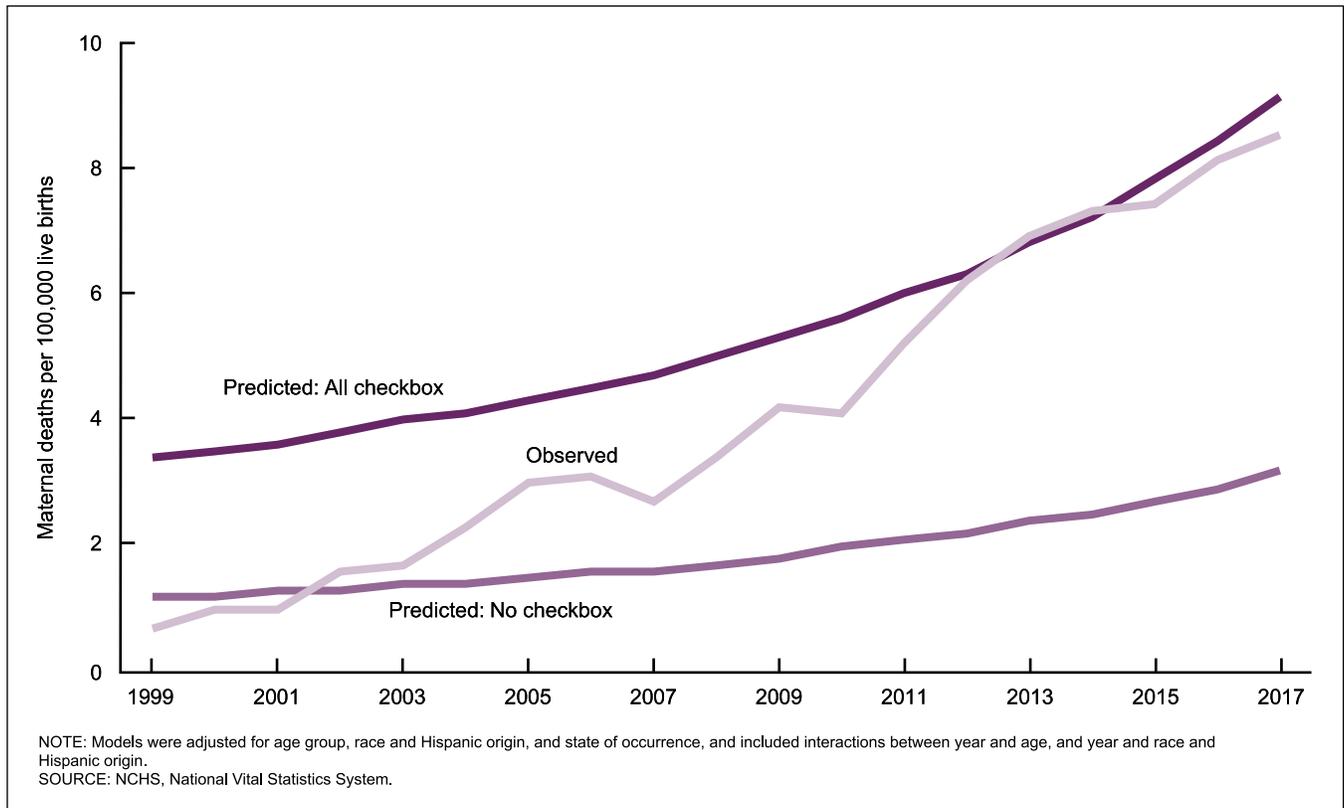
Figure VIII. Observed and predicted maternal mortality rates for liver disorders in pregnancy, childbirth, and the puerperium (O26.6): United States, 1999–2017
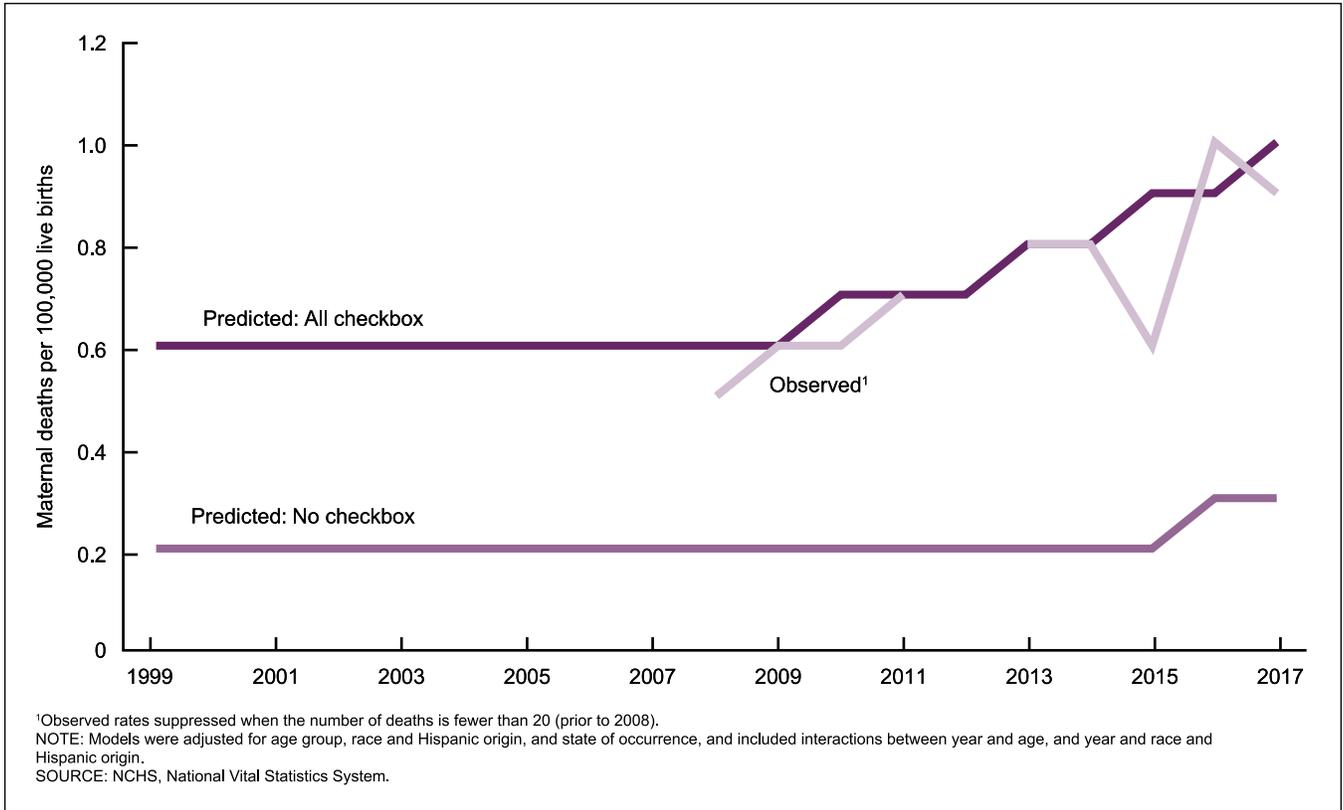
Figure IX. Observed and predicted maternal mortality rates for other specified pregnancy-related conditions (O26.8): United States, 1999–2017
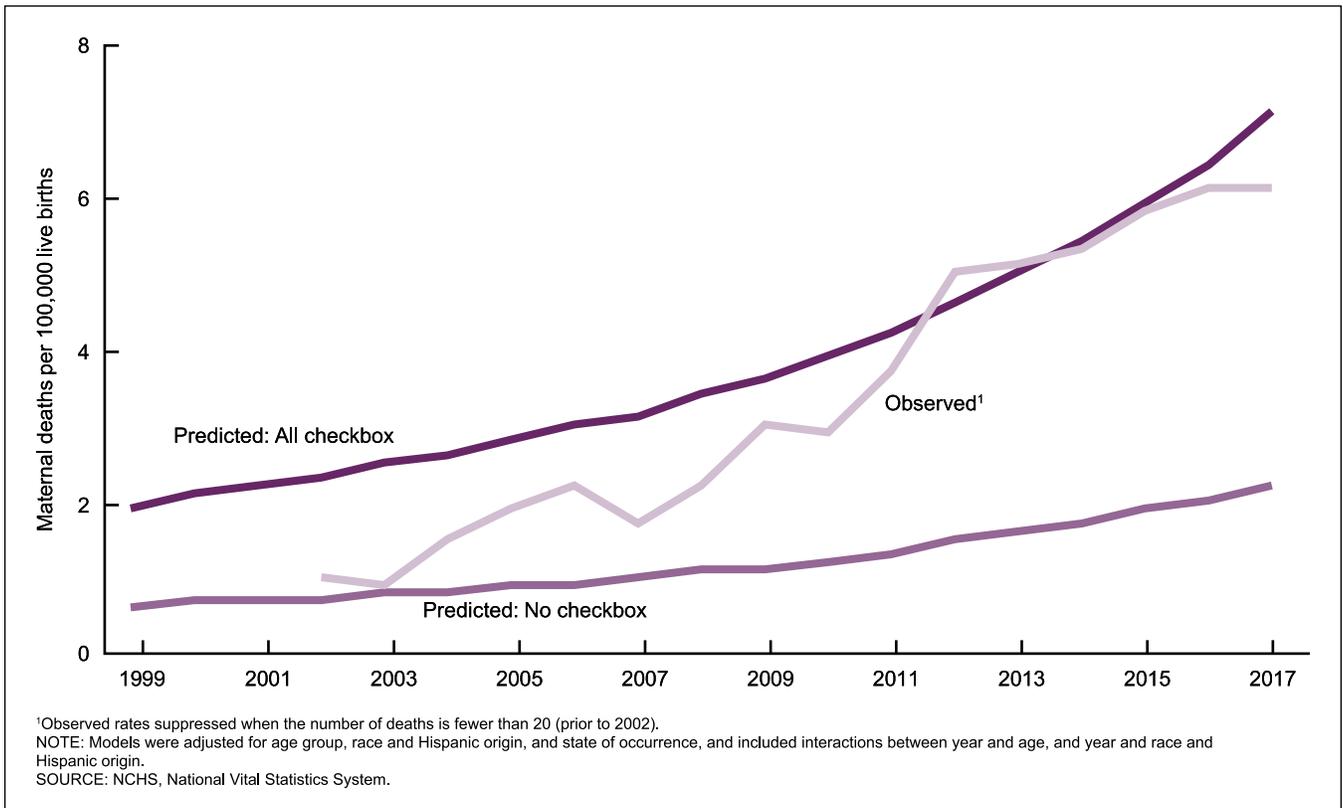
Figure X. Observed and predicted maternal mortality rates for other maternal disorders predominantly related to pregnancy (O20–O29), excluding nonspecific O26.8: United States, 1999–2017

[1]Observed rates suppressed when the number of deaths is fewer than 20 (1999).
NOTE: Models were adjusted for age group, race and Hispanic origin, and state of occurrence, and included interactions between year and age, and year and race and Hispanic origin.
SOURCE: NCHS, National Vital Statistics System.
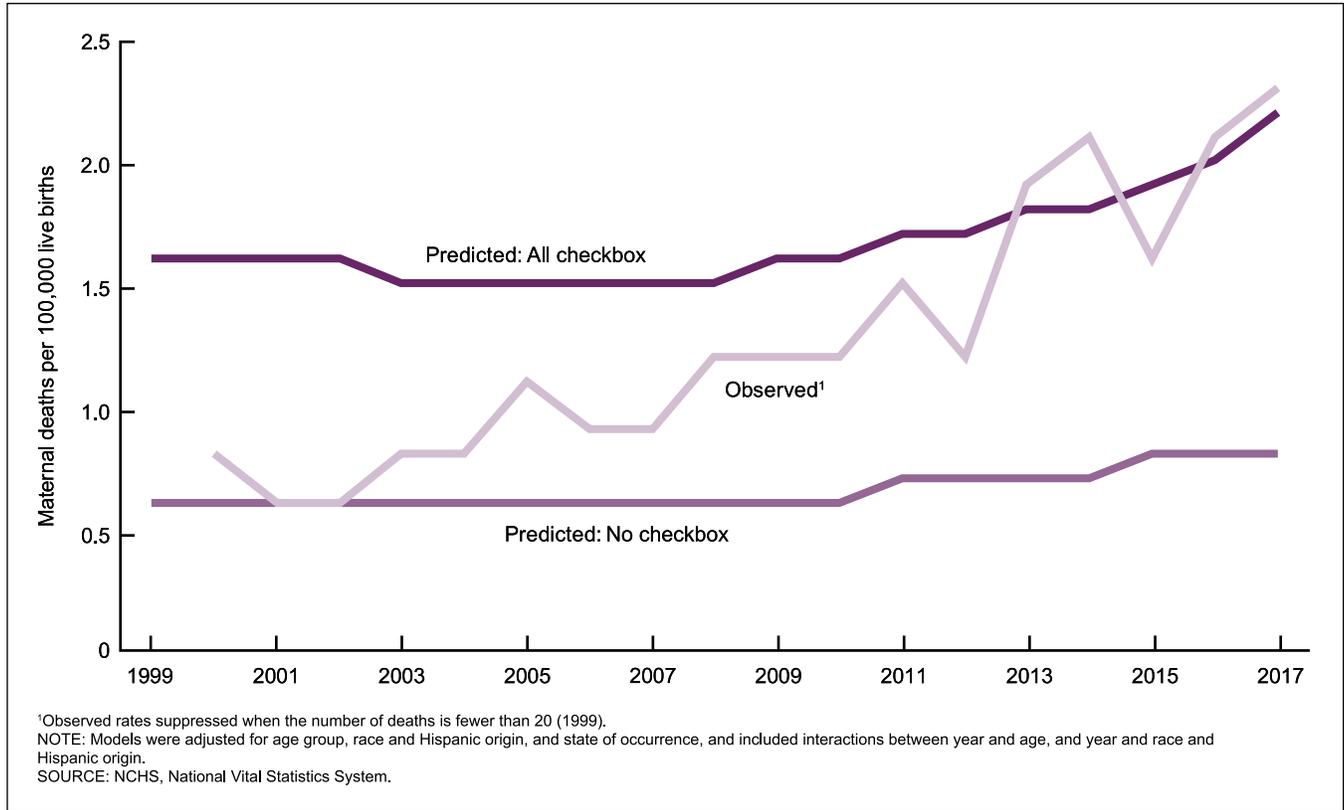
Figure XI. Observed and predicted maternal mortality rates for maternal care related to the fetus and amniotic cavity and possible delivery problems (O30–O48): United States, 1999–2017

[1]Observed rates suppressed when the number of deaths is fewer than 20 (2002).
NOTE: Models were adjusted for age group, race and Hispanic origin, and state of occurrence, and included interactions between year and age, and year and race and Hispanic origin.
SOURCE: NCHS, National Vital Statistics System.
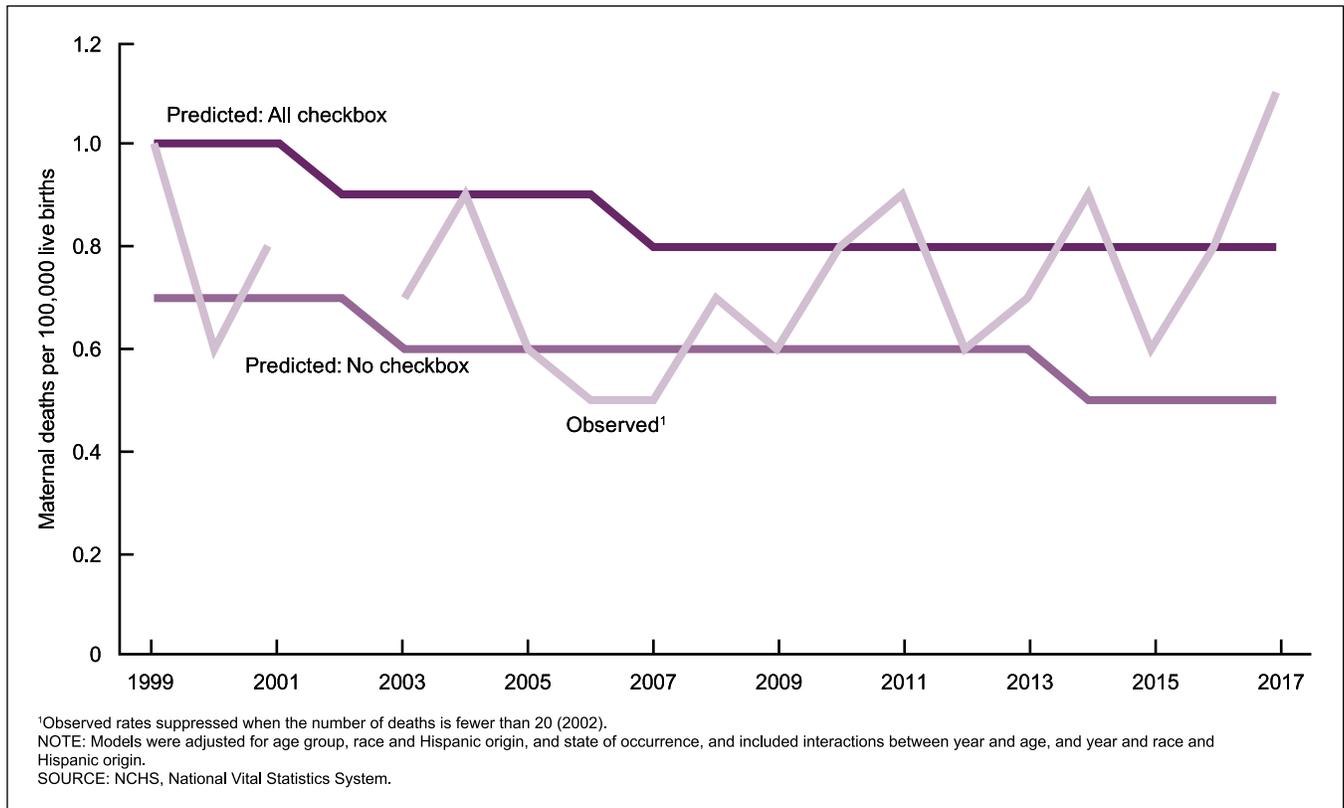
Figure XII. Observed and predicted maternal mortality rates for complications of labor and delivery (O60–O75): United States, 1999–2017

NOTE: Models were adjusted for age group, race and Hispanic origin, and state of occurrence, and included interactions between year and age, and year and race and Hispanic origin.
SOURCE: NCHS, National Vital Statistics System
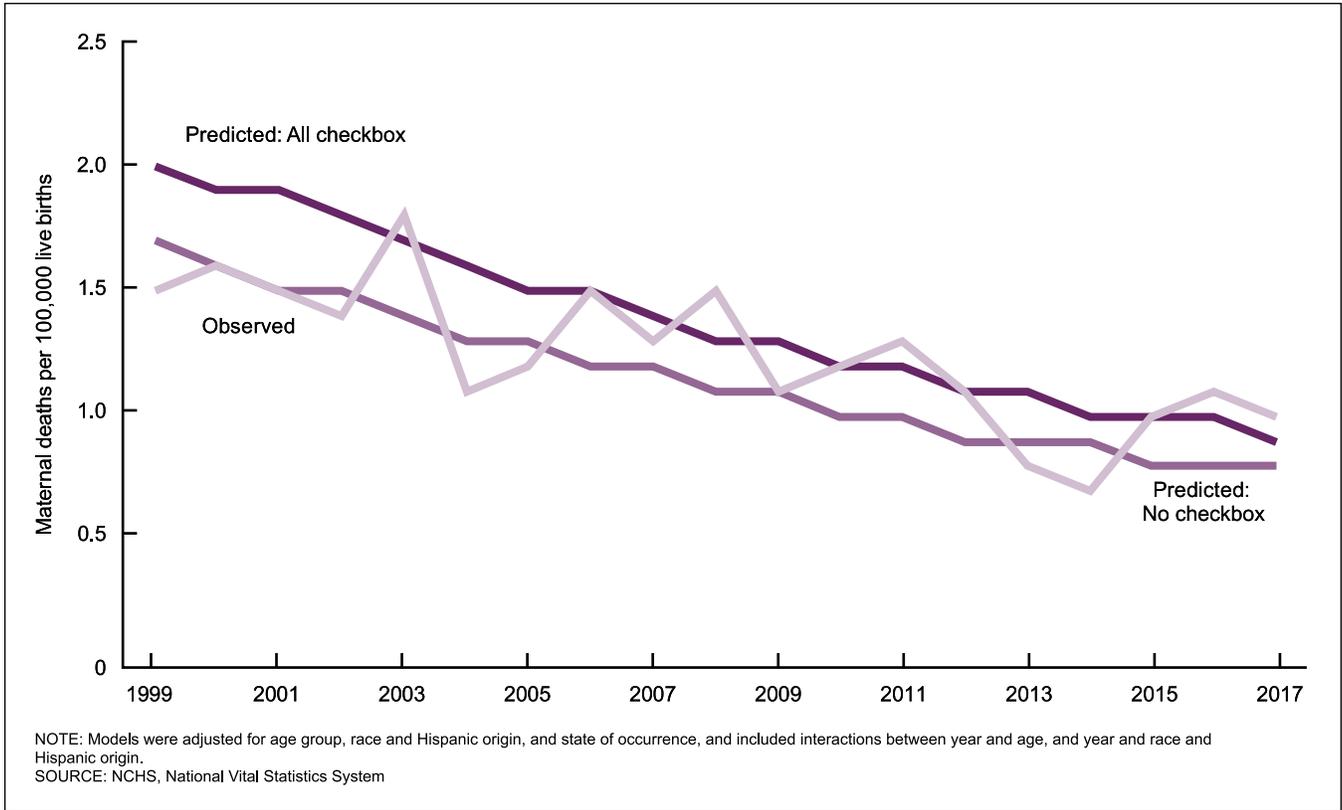
Figure XIII. Observed and predicted maternal mortality rates for complications predominantly related to the puerperium (O85–O92): United States, 1999–2017

NOTE: Models were adjusted for age group, race and Hispanic origin, and state of occurrence, and included interactions between year and age, and year and race and Hispanic origin.
SOURCE: NCHS, National Vital Statistics System.
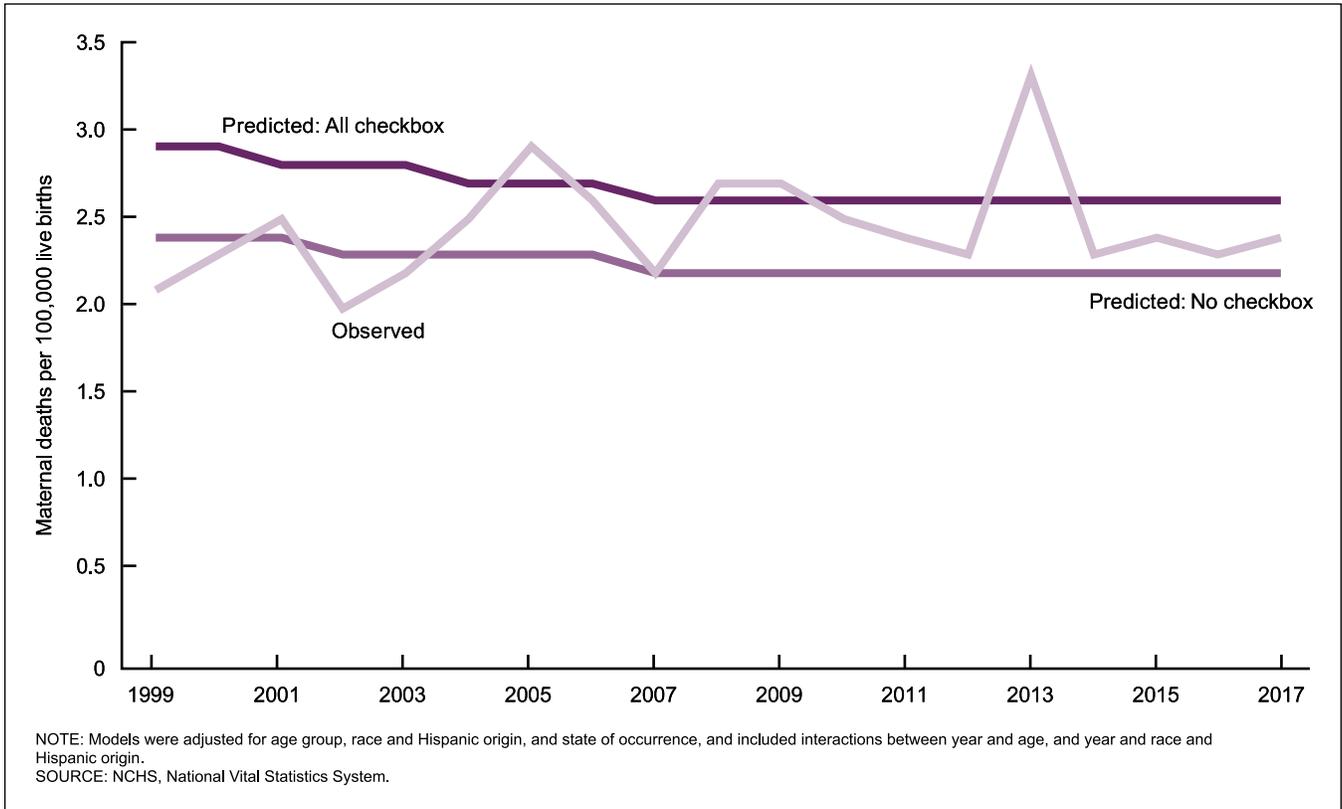
Figure XIV. Observed and predicted maternal mortality rates for indirect causes of maternal death: United States, 1999–2017

NOTES: Models were adjusted for age group, race and Hispanic origin, and state of occurrence, and included interactions between year and age, and year and race and Hispanic origin. Indirect causes of maternal death from Say et al.; see reference 26 in this report.
SOURCE: NCHS, National Vital Statistics System.
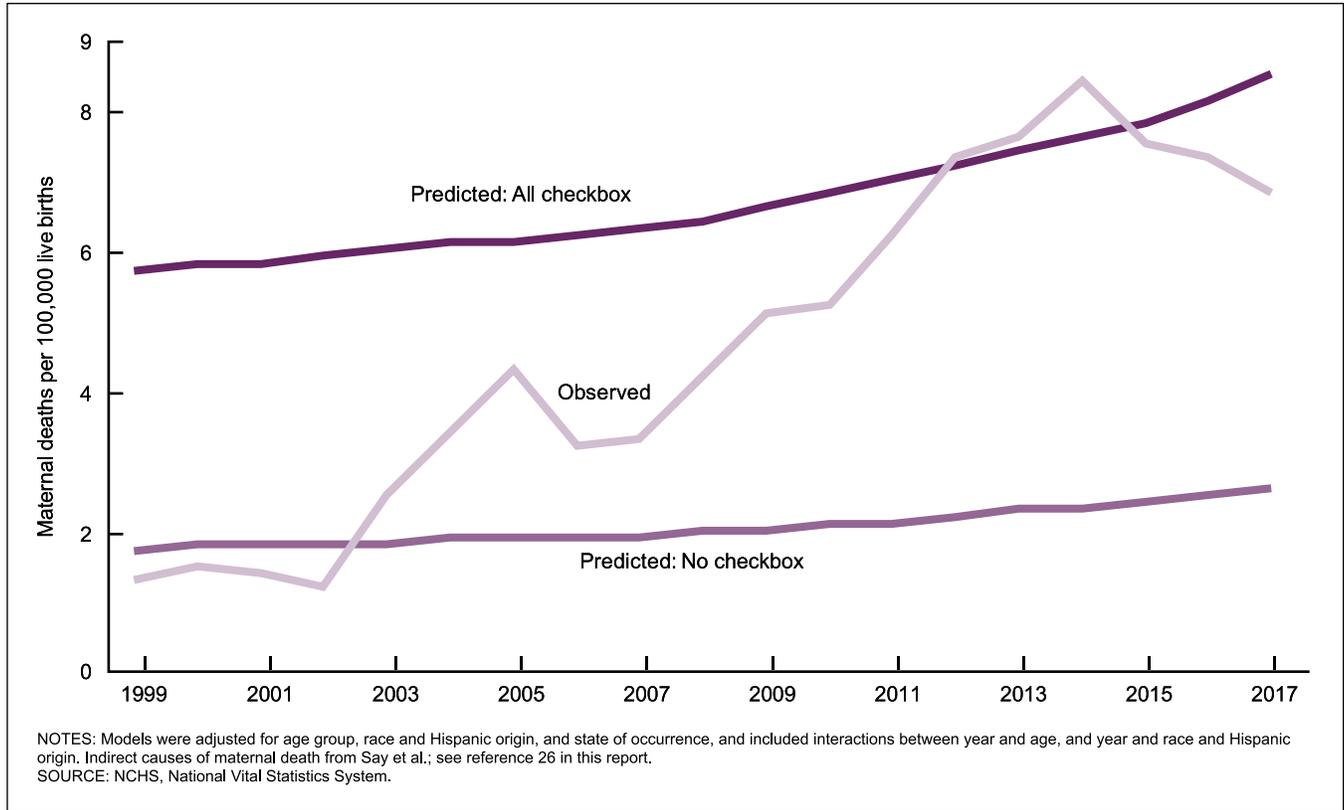
Figure XV. Observed and predicted maternal mortality rates for alternative grouping of indirect causes of maternal death (O98–O99): United States, 1999–2017

NOTES: Models were adjusted for age group, race and Hispanic origin, and state of occurrence, and included interactions between year and age, and year and race and Hispanic origin. Alternative grouping of indirect causes of maternal death (O98–O99) from MacDorman et al.; see reference 4 in this report.
SOURCE: NCHS, National Vital Statistics System.
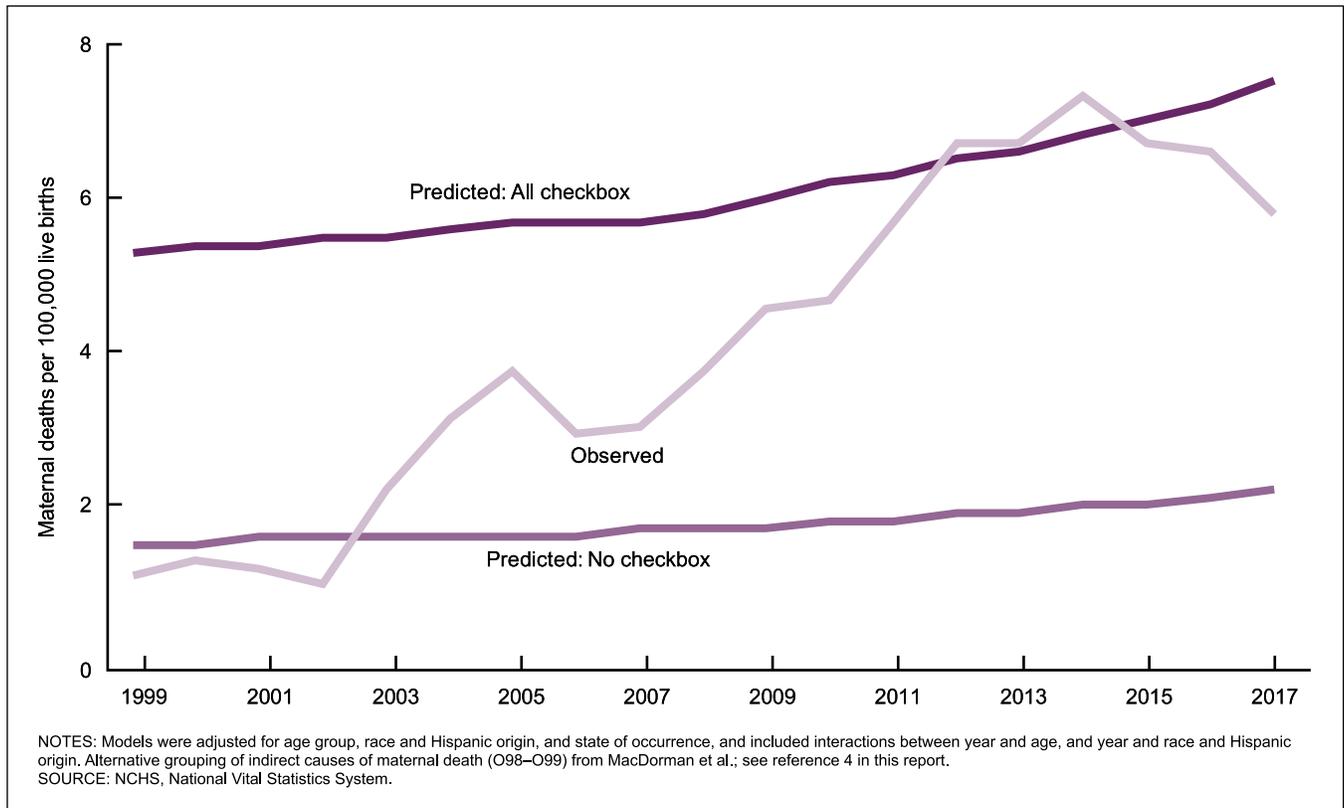
Figure XVI. Observed and predicted maternal mortality rates for other obstetric conditions not elsewhere classified, including late maternal deaths (O95–O99): United States, 1999–2017

NOTE: Models were adjusted for age group, race and Hispanic origin, and state of occurrence, and included interactions between year and age, and year and race and Hispanic origin.
SOURCE: NCHS, National Vital Statistics System.
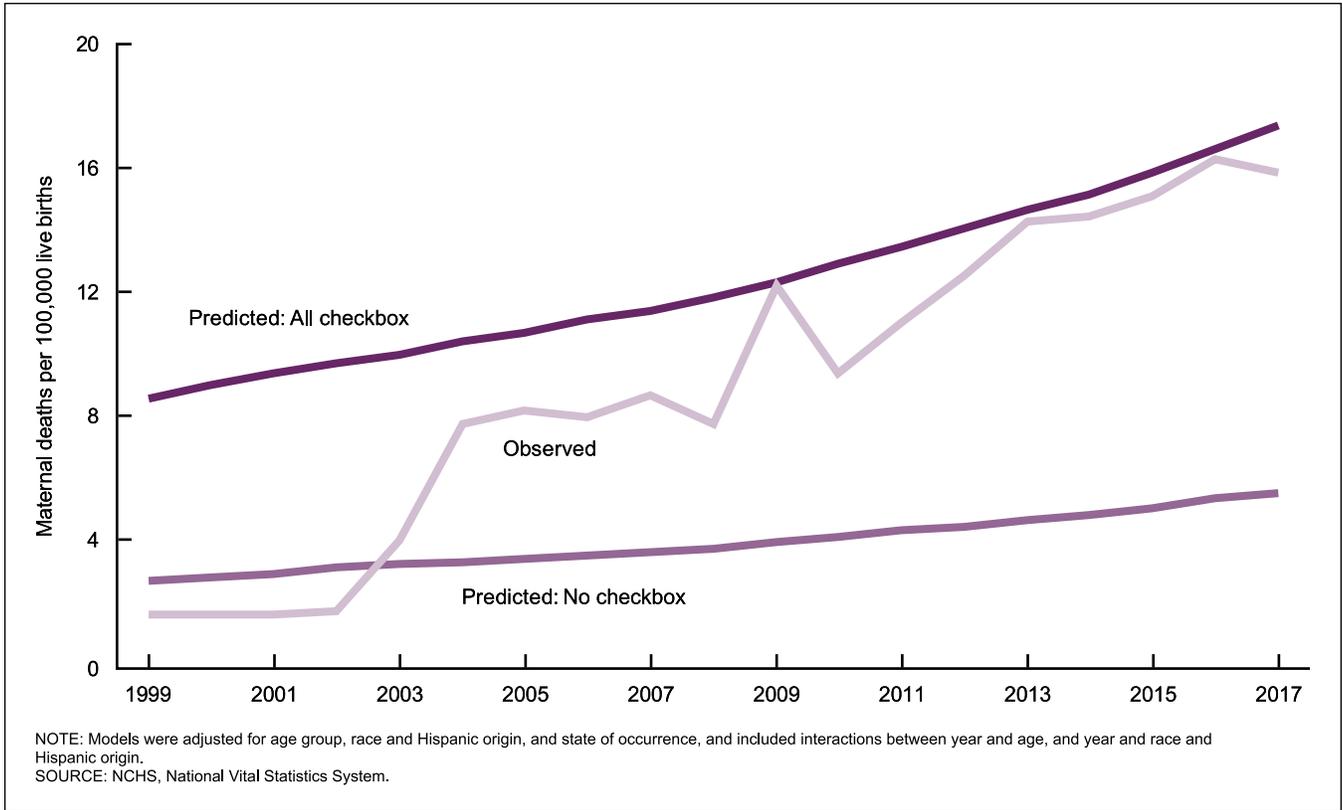
**Figure XVII. Observed and predicted maternal mortality rates for other obstetric conditions not elsewhere classified, excluding late maternal deaths (O95, O98–O99): United States, 1999–2017**


NOTE: Models were adjusted for age group, race and Hispanic origin, and state of occurrence, and included interactions between year and age, and year and race and Hispanic origin.
SOURCE: NCHS, National Vital Statistics System.
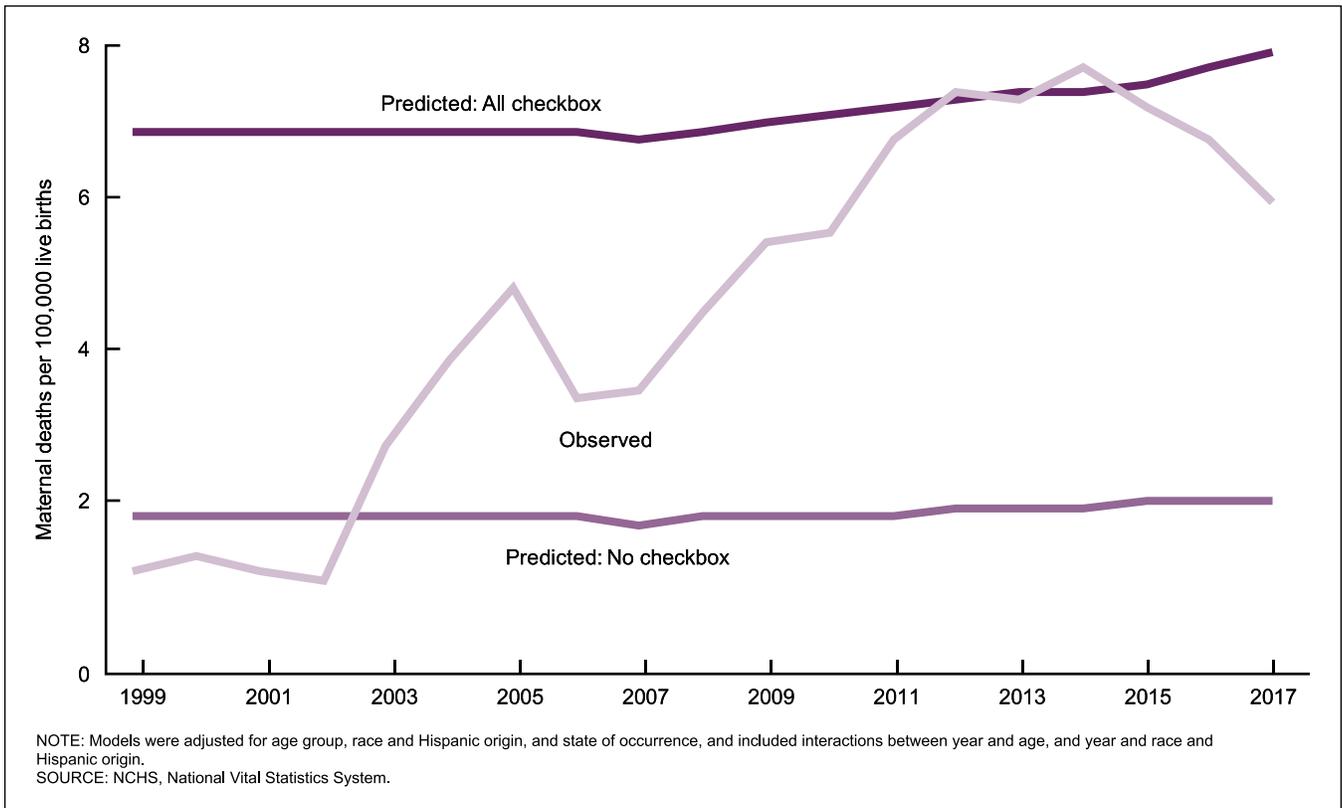
Figure XVIII. Observed and predicted maternal mortality rates for mental disorders and diseases of the nervous system complicating pregnancy, childbirth, and the puerperium (O99.3): United States, 1999–2017


[1]Observed rates suppressed when the number of deaths is fewer than 20 (all years except 2009 and 2016).
NOTE: Models were adjusted for age group and race and Hispanic origin, and the interactions between year and these factors.
SOURCE: NCHS, National Vital Statistics System.
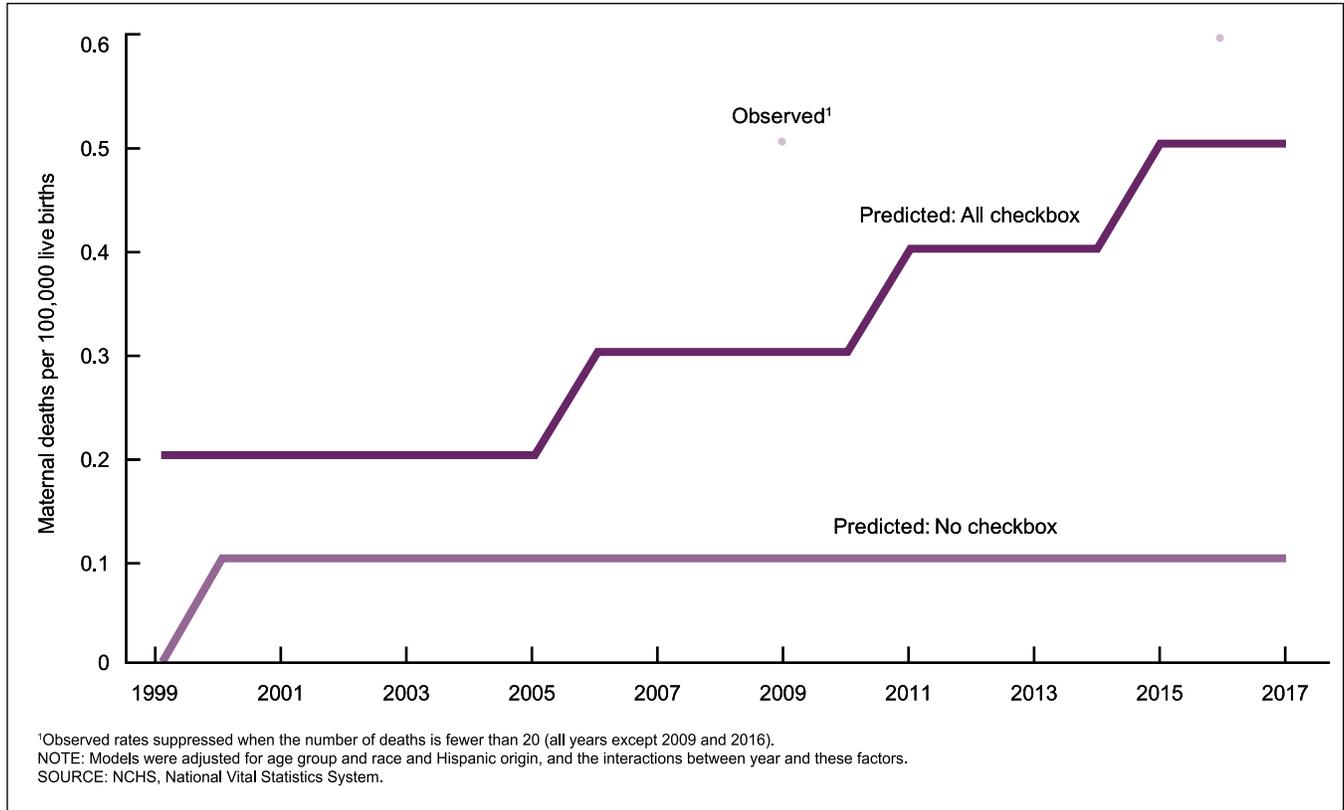
Figure XIX. Observed and predicted maternal mortality rates for diseases of the circulatory system complicating pregnancy, childbirth, and the puerperium (O99.4): United States, 1999–2017

[1]Observed rates suppressed when the number of deaths is fewer than 20 (prior to 2001).
NOTE: Models were adjusted for age group, race and Hispanic origin, and state of occurrence, and included interactions between year and age, and year and race and Hispanic origin.
SOURCE: NCHS, National Vital Statistics System.
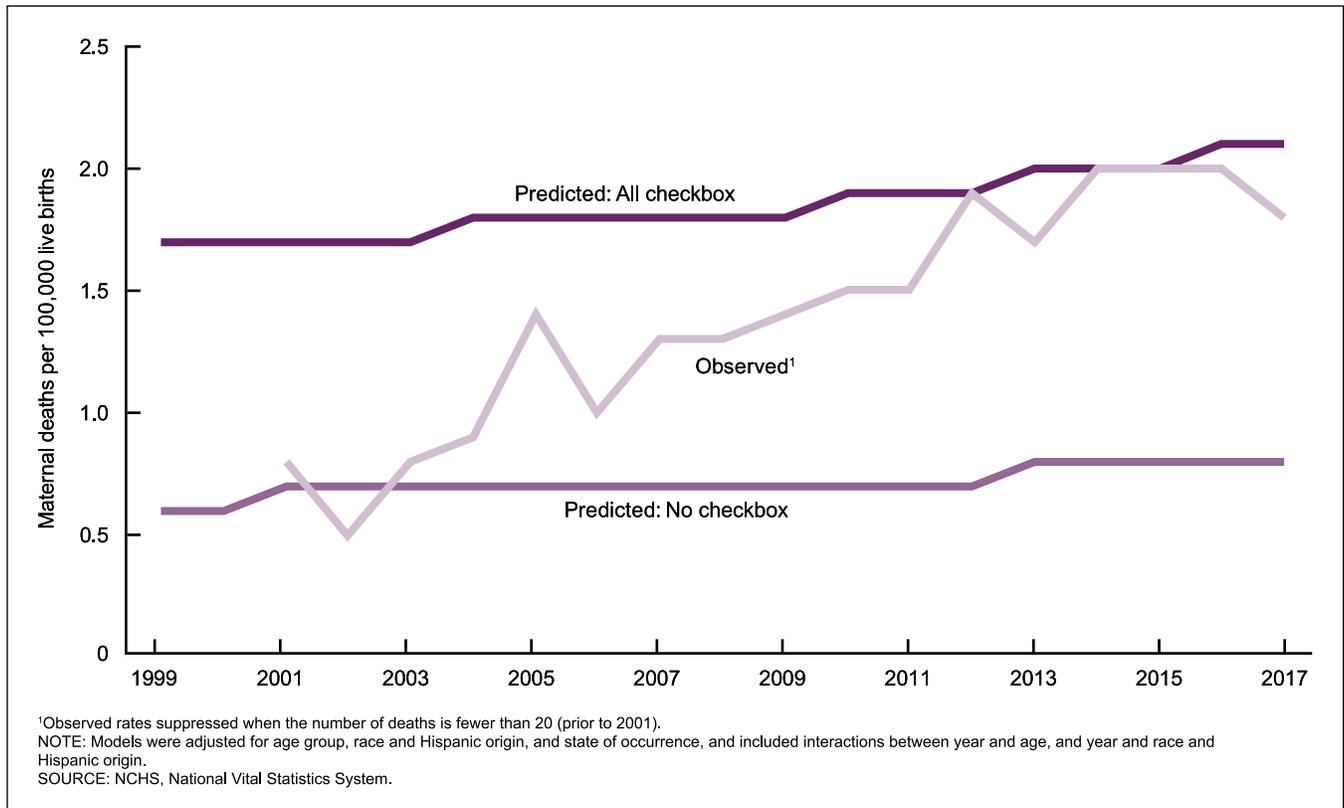
Figure XX. Observed and predicted maternal mortality rates for diseases of the respiratory system complicating pregnancy, childbirth, and the puerperium (O99.5): United States, 1999–2017

¹Observed rates suppressed when the number of deaths is fewer than 20 (all years).
NOTE: Models were adjusted for age group, race and Hispanic origin, and state of occurrence, and included interactions between year and age, and year and race and Hispanic origin.
SOURCE: NCHS, National Vital Statistics System.
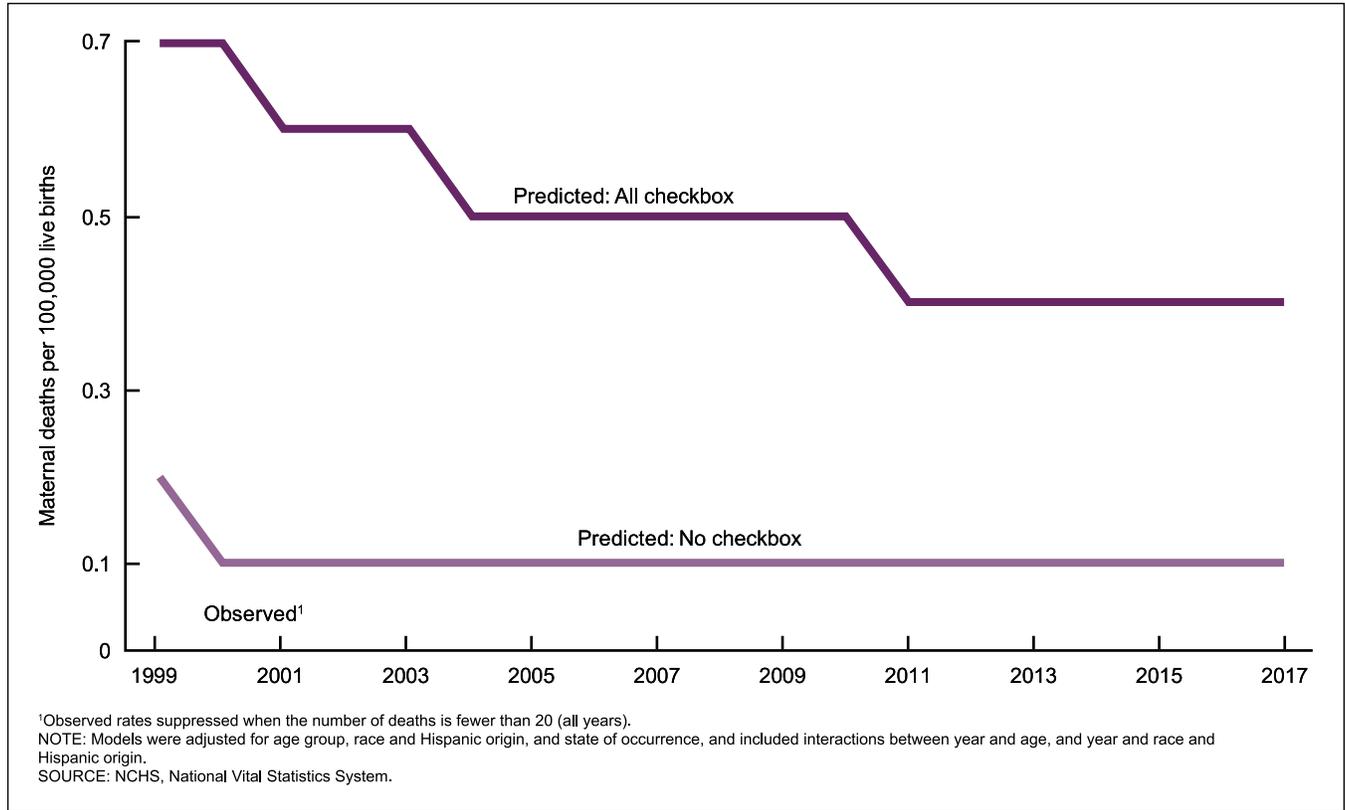
Figure XXI. Observed and predicted maternal mortality rates for other specified diseases and conditions complicating pregnancy, childbirth, and the puerperium (O99.8): United States, 1999–2017

¹Observed rates suppressed when the number of deaths is fewer than 20 (2001–2002).
NOTE: Models were adjusted for age group, race and Hispanic origin, and state of occurrence, and included interactions between year and age, and year and race and Hispanic origin.
SOURCE: NCHS, National Vital Statistics System.
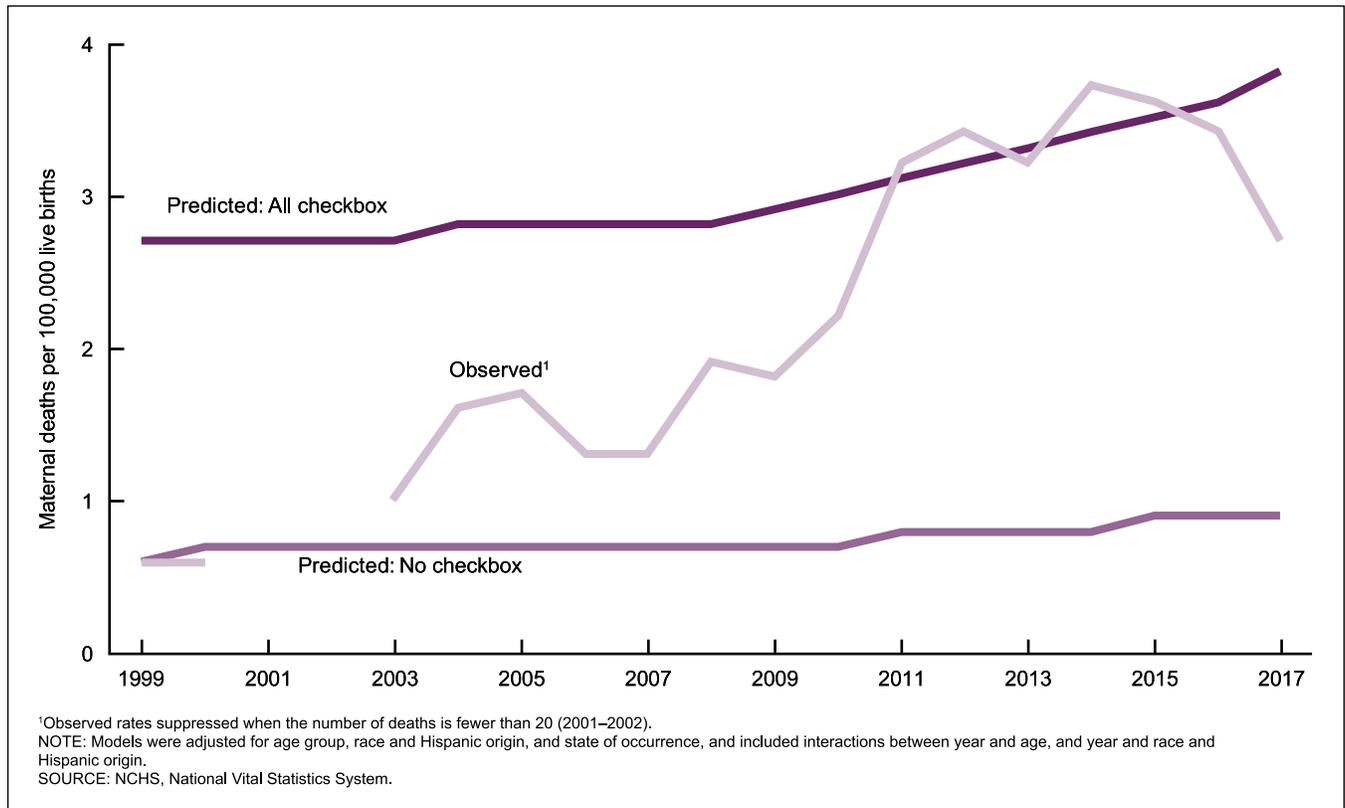
Figure XXII. Observed and predicted maternal mortality rates for late maternal deaths (O96–O97): United States, 1999–2017

[1]Observed rates suppressed when the number of deaths is fewer than 20 (prior to 2002).
NOTE: Models were adjusted for age group, race and Hispanic origin, and state of occurrence, and included interactions between year and age, and year and race and Hispanic origin.
SOURCE: NCHS, National Vital Statistics System.
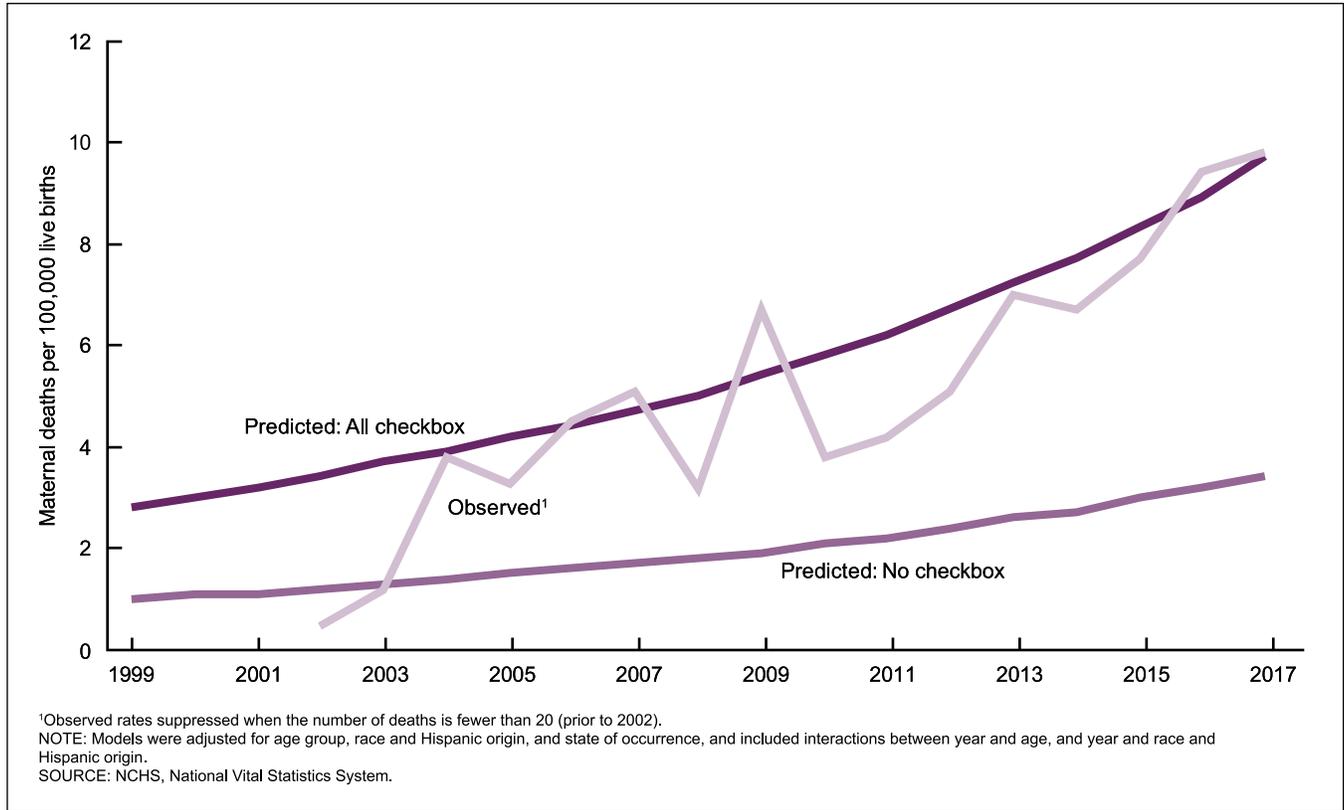
Figure XXIII. Observed and predicted maternal mortality rates for nonspecific causes of maternal death (O26.8, O95, O99.8): United States, 1999–2017

NOTE: Models were adjusted for age group, race and Hispanic origin, and state of occurrence, and included interactions between year and age, and year and race and Hispanic origin.
SOURCE: NCHS, National Vital Statistics System.
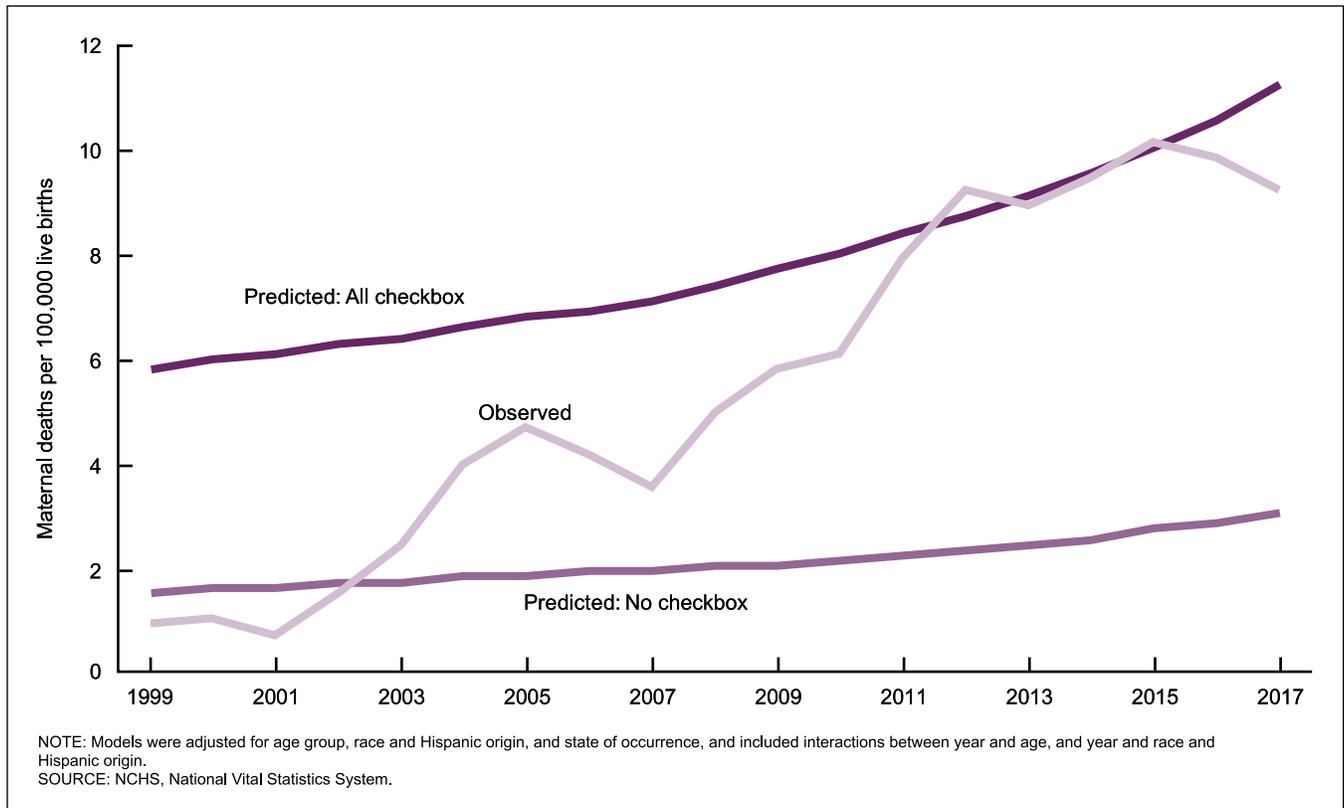
Figure XXIV. Observed and predicted maternal mortality rates among females aged 15–19, adjusted for an error rate of 0.50% in the pregnancy checkbox: United States, 1999–2017

¹Observed rates suppressed when the number of deaths is fewer than 20 (2000).
NOTES: Dotted lines represent maternal mortality rates (MMRs) adjusted for fixed error rates, while solid lines depict the original predicted and observed MMRs. Models were adjusted for age group, race and Hispanic origin, and state of occurrence, and included interactions between these factors and year as well as revision status.
SOURCE: NCHS, National Vital Statistics System.

Figure XXV. Observed and predicted maternal mortality rates among women aged 20–24, adjusted for an error rate of 0.50% in the pregnancy checkbox: United States, 1999–2017


NOTES: Dotted lines represent maternal mortality rates (MMRs) adjusted for fixed error rates, while solid lines depict the original predicted and observed MMRs. Models were adjusted for age group, race and Hispanic origin, and state of occurrence, and included interactions between these factors and year as well as revision status.
SOURCE: NCHS, National Vital Statistics System.
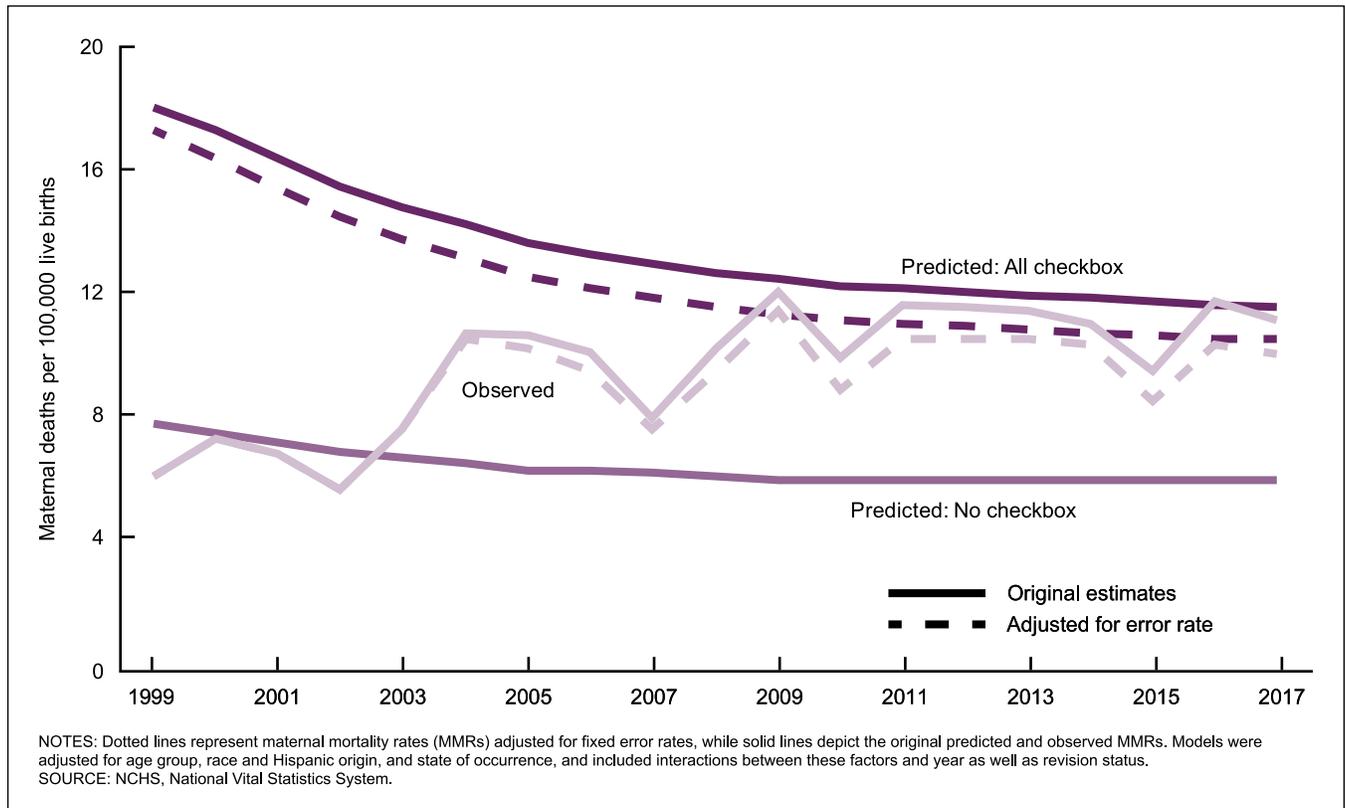
Figure XXVI. Observed and predicted maternal mortality rates among women aged 25–29, adjusted for an error rate of 0.50% in the pregnancy checkbox: United States, 1999–2017

NOTES: Dotted lines represent maternal mortality rates (MMRs) adjusted for fixed error rates, while solid lines depict the original predicted and observed MMRs. Models were adjusted for age group, race and Hispanic origin, and state of occurrence, and included interactions between these factors and year as well as revision status.
SOURCE: NCHS, National Vital Statistics System.
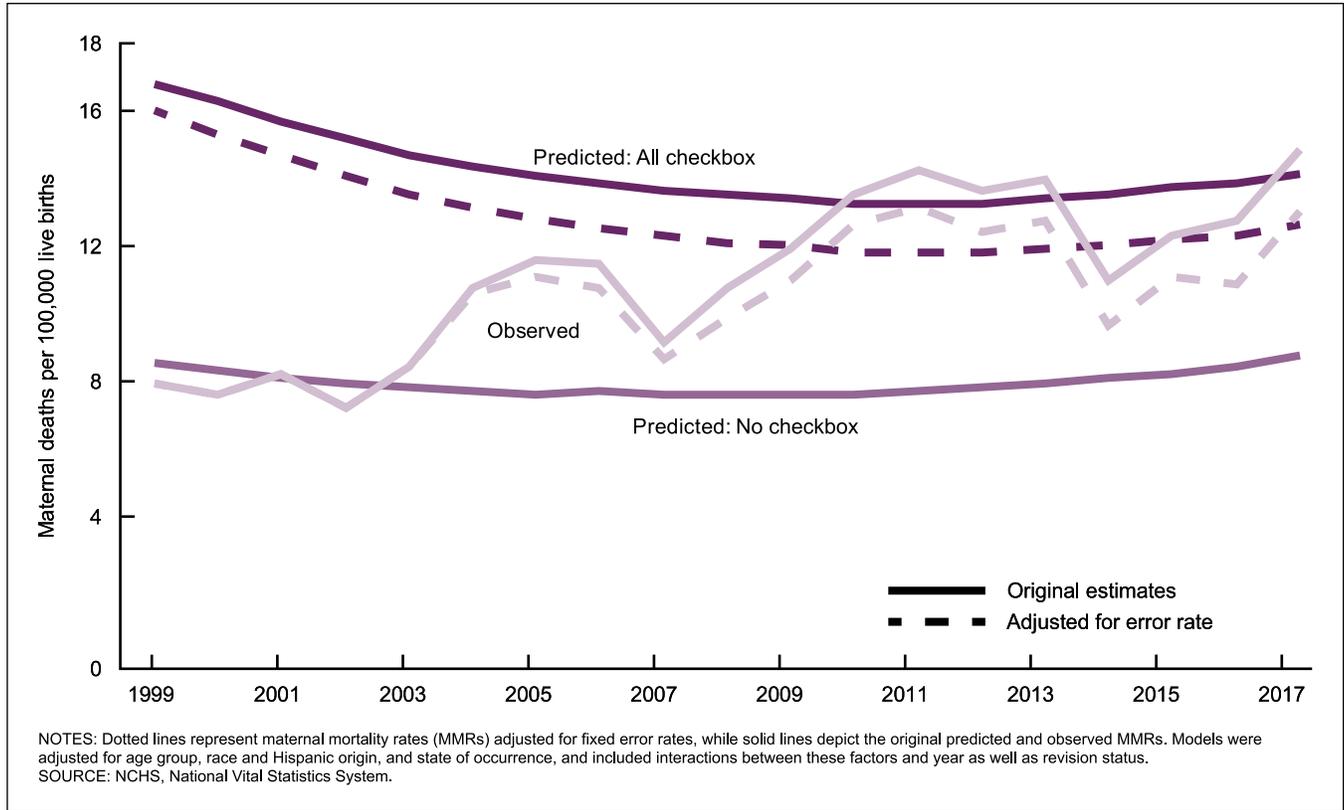
Figure XXVII. Observed and predicted maternal mortality rates among women aged 30–34, adjusted for an error rate of 0.50% in the pregnancy checkbox: United States, 1999–2017


NOTES: Dotted lines represent maternal mortality rates (MMRs) adjusted for fixed error rates, while solid lines depict the original predicted and observed MMRs. Models were adjusted for age group, race and Hispanic origin, and state of occurrence, and included interactions between these factors and year as well as revision status.
SOURCE: NCHS, National Vital Statistics System.
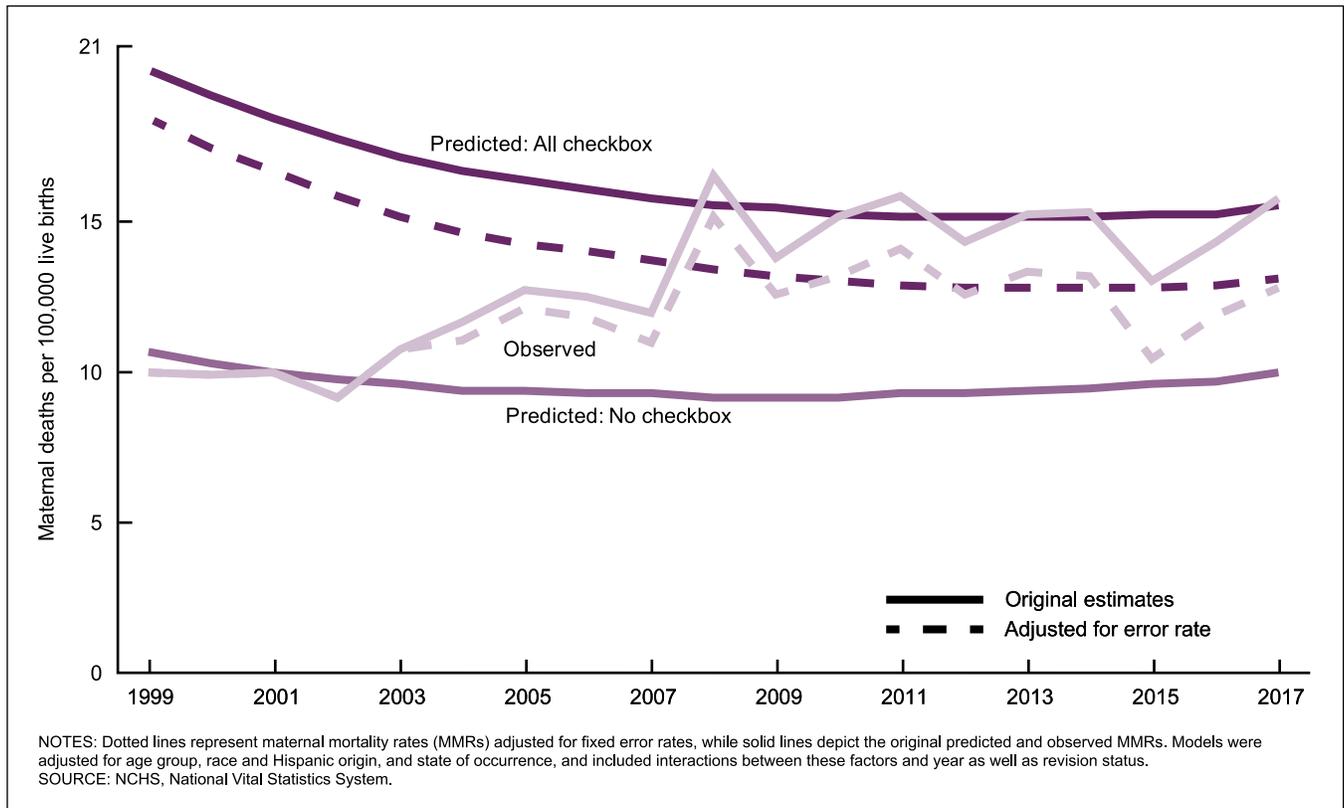
Figure XXVIII. Observed and predicted maternal mortality rates among women aged 35–39, adjusted for an error rate of 0.50% in the pregnancy checkbox: United States, 1999–2017

NOTES: Dotted lines represent maternal mortality rates (MMRs) adjusted for fixed error rates, while solid lines depict the original predicted and observed MMRs. Models were adjusted for age group, race and Hispanic origin, and state of occurrence, and included interactions between these factors and year as well as revision status.
SOURCE: NCHS, National Vital Statistics System.
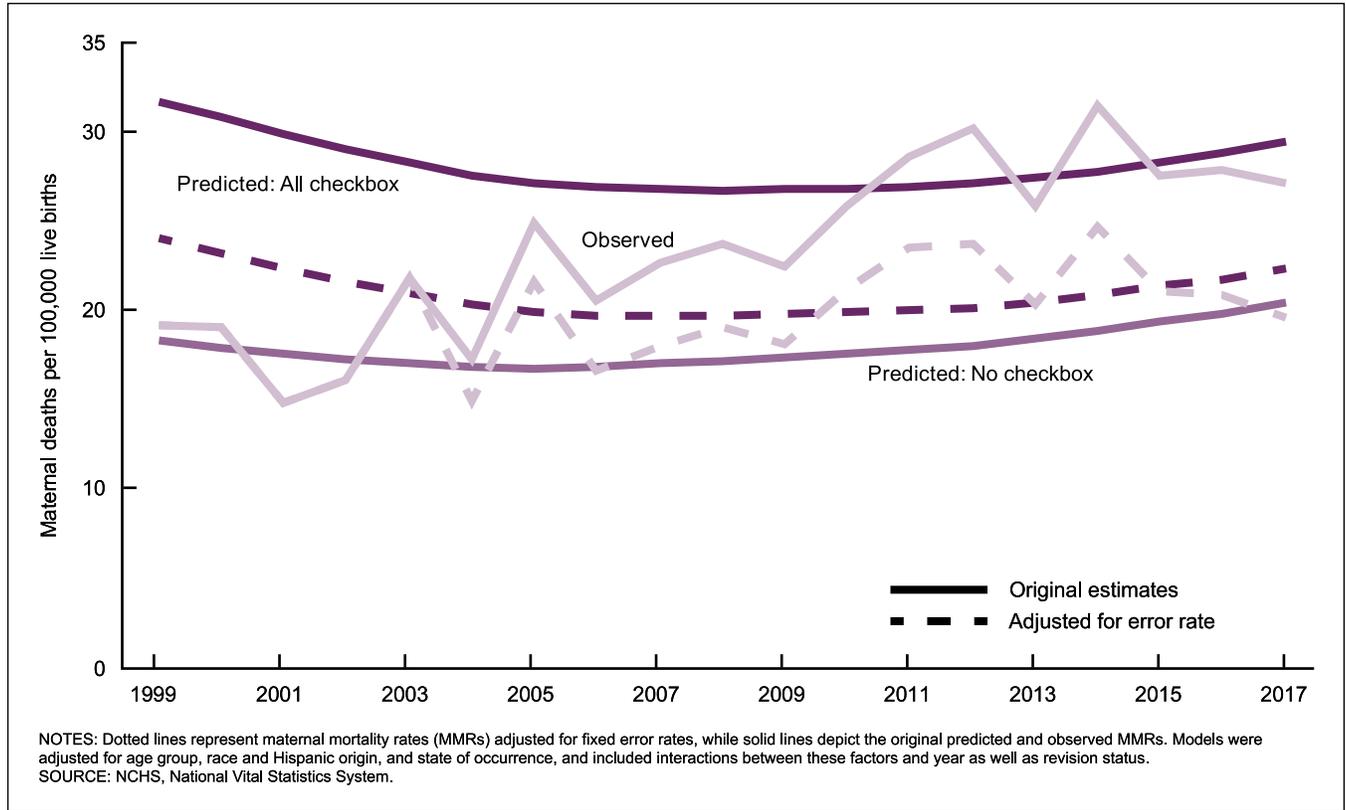
Figure XXIX. Observed and predicted maternal mortality rates among women aged 40 and over, adjusted for an error rate of 0.50% in the pregnancy checkbox: United States, 1999–2017

NOTES: Dotted lines represent maternal mortality rates (MMRs) adjusted for fixed error rates, while solid lines depict the original predicted and observed MMRs. Models were adjusted for age group, race and Hispanic origin, and state of occurrence, and included interactions between these factors and year as well as revision status.
SOURCE: NCHS, National Vital Statistics System.
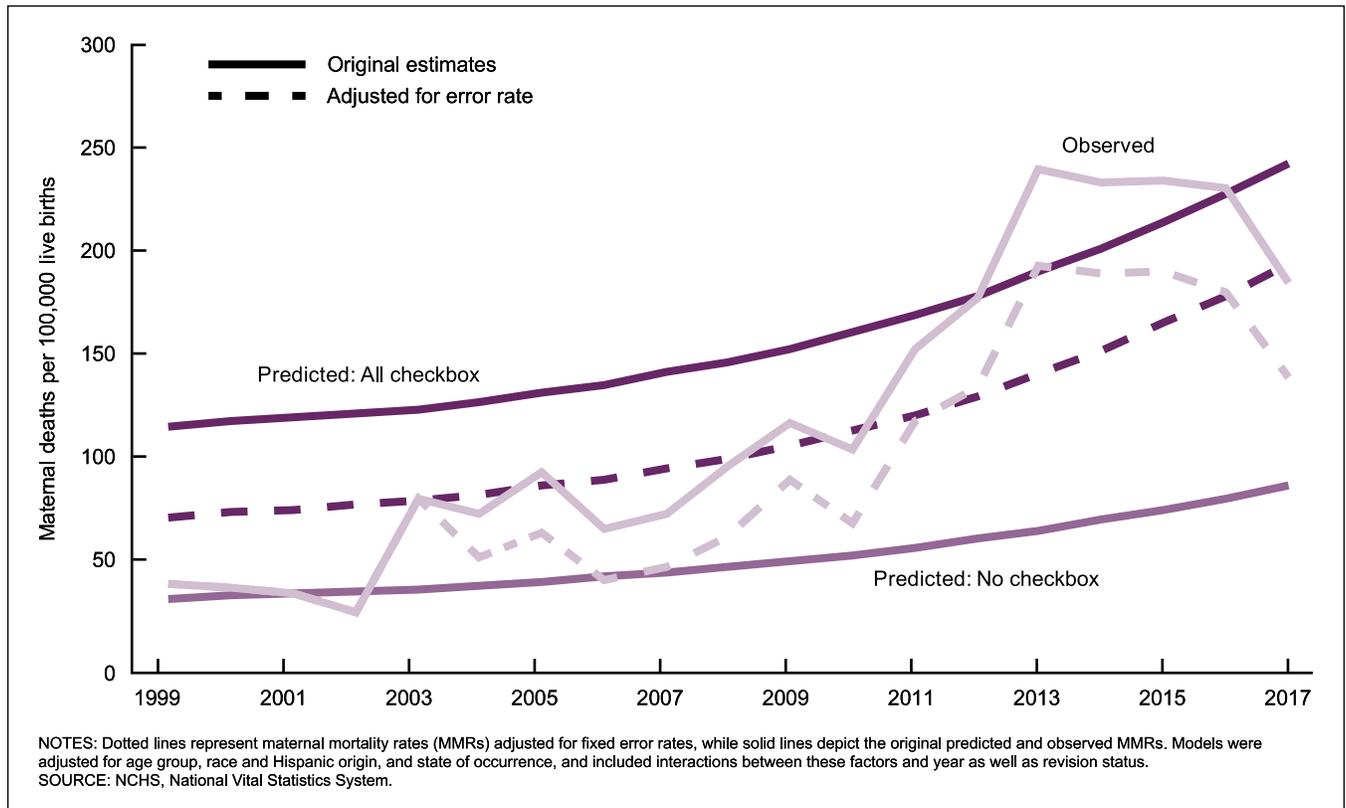
Figure XXX. Observed and predicted maternal mortality rates, by race and Hispanic origin, adjusted for an error rate of 0.50% in the pregnancy checkbox: United States, 1999–2017
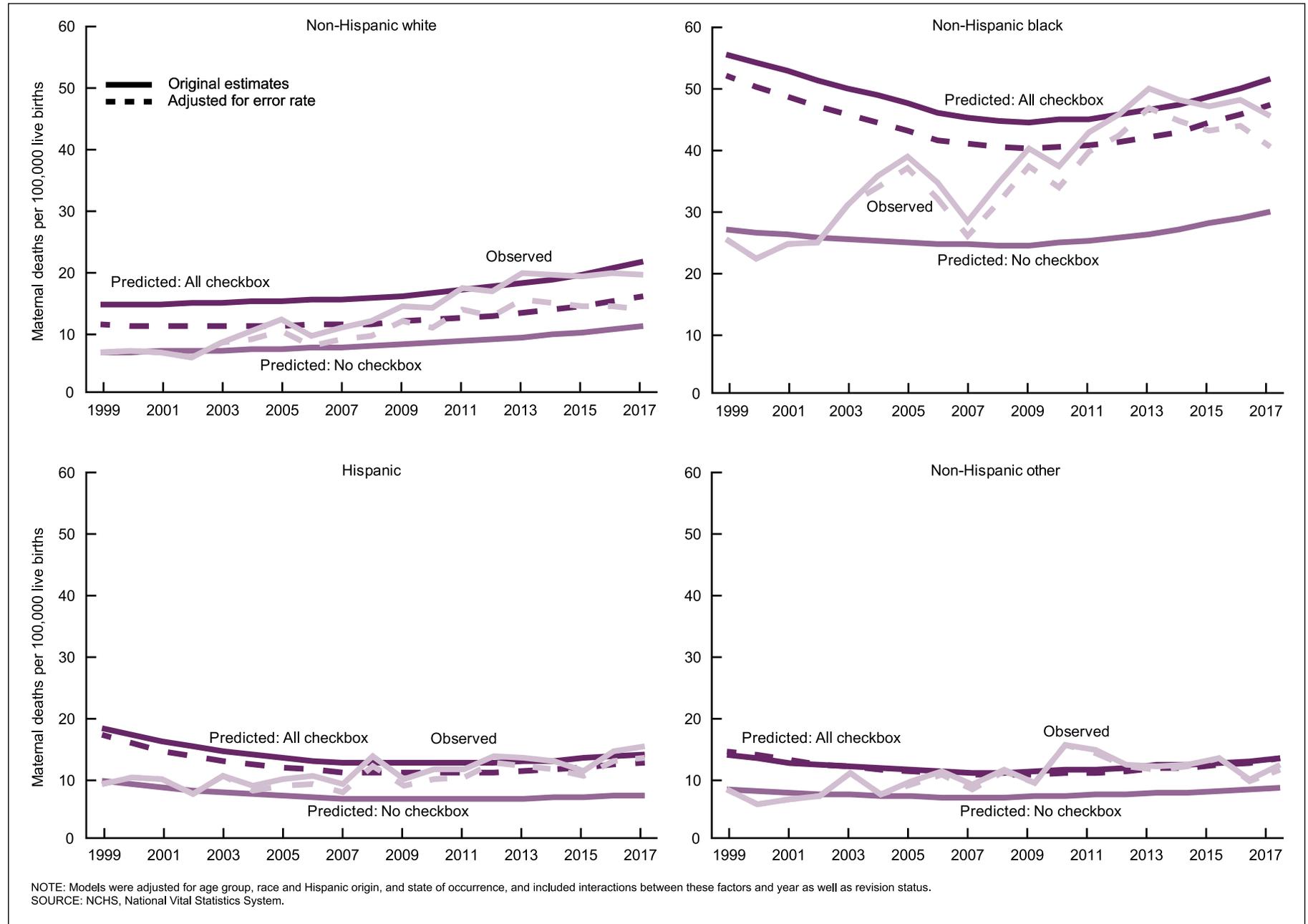
NOTE: Models were adjusted for age group, race and Hispanic origin, and state of occurrence, and included interactions between these factors and year as well as revision status.
SOURCE: NCHS, National Vital Statistics System.

Maternal Mortality
Statistics

NEW

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