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Rural-Urban Differences in Maternal Mortality Trends in the US, 1999–2017: Accounting for the Impact of the Pregnancy Status Checkbox

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Abstract

Rural-urban differences in maternal mortality ratios (MMR) in the United States have been difficult to measure in recent years due to the incremental adoption of a pregnancy status checkbox on death certificates. Using 1999–2017 mortality and birth data, we examined the impact of the pregnancy checkbox on MMRs by rural-urban residence (large urban, medium/small urban, rural), using log-binomial regression models to predict trends as if all states had adopted the checkbox as of 1999. Implementation of the checkbox resulted in an average estimated increase of 7.5 maternal deaths per 100,000 live births (95% CI: 6.3, 8.8) in large urban areas (76% increase), 11.6 (95% CI: 9.6, 13.6) in medium/small urban areas (113% increase), and 16.6 (95% CI: 12.9, 20.3) in rural areas (107% increase), compared with MMRs prior to the checkbox. Assuming all states had the checkbox as of 1999, demographic-adjusted predicted MMRs increased in rural, declined in large urban, and did not change in medium/small urban areas. However, trends and urban-rural differences were substantially attenuated when analyses were limited to direct/specific causes of maternal death, which are likely subject to less misclassification. Accurate ascertainment

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of maternal deaths, particularly in rural areas, is important for reducing disparities in maternal mortality.

Keywords

death certificate; pregnancy; maternal death; misclassification; National Vital Statistics System; rural

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Maternal mortality is a key indicator of population health.[1, 2] Monitoring trends in maternal mortality in the US is important in order to evaluate progress in improving maternal health, make international comparisons, and track inequities by demographic subgroup.[2] Substantial disparities in maternal mortality exist by race/ethnicity and age in the US,[3, 4] and recent analyses have described rural disparities as well.[5, 6]

Maternal mortality is 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."[2] National maternal mortality ratios (MMR) for the US were not published for the data years 2004–2017 due to the staggered adoption of the 2003 revision of the US death certificate, which included a pregnancy status checkbox that was added to improve ascertainment of maternal mortality.[7]

In January 2020, MMR estimates based on the new checkbox data were published by the National Center for Health Statistics (NCHS) via the National Vital Statistics System (NVSS), the official source for US maternal mortality statistics, accompanied by evaluations of the impact of the pregnancy status checkbox.[7, 8] A report examining the impact of the checkbox during 2003–2017 found that the MMRs estimated in the years after adding the checkbox were, on average, 9.6 maternal deaths per 100,000 live births higher (MMRs increased from approximately 10 to 20 deaths per 100,000 live births) with larger increases seen for certain subgroups, such as women aged 35 and over, and non-Hispanic black women.[8] Notably, after accounting for the staggered implementation of the checkbox, and adjusting for changes in select maternal demographics over time, no significant change in the overall MMR was observed between 1999 and 2017. Therefore, the observed increases in the MMRs that had been reported for the US in the literature and popular press may have been largely artifactual, driven by increased counts of maternal deaths related to the staggered implementation of the pregnancy status checkbox by states over time. Other research has reported similar findings,[3, 9, 10] with the checkbox accounting for most, but not necessarily all the increase in MMRs. Differences across studies in the degree to which the checkbox explained increases in MMRs may be related to different time periods of analysis, methods used, and the states included, as most studies were conducted prior to all states having implemented the checkbox (in 2017).

Although women in rural areas can experience barriers to maternal care, there are few studies of rural-urban disparities in maternal deaths to date.[5, 6, 11] As of 2004, more than half of all rural US counties lacked hospital-based obstetric services, and another 9%

experienced the loss of in-county hospital-based obstetric services during 2004–2014.[12] In addition, rural pregnant women travel further to access prenatal care and to reach a hospital once labor begins compared with non-rural women.[13] Rural residents, in general, also experience higher rates of mortality,[14] including infant mortality,[15] as compared with urban residents, and this gap has been widening over time.[16] An analysis of national hospital discharge data suggested that rural areas have higher rates of maternal severe morbidity and mortality and exhibited larger increases during 2007–2015 as compared with urban areas.[5] However, that study examined a composite outcome measure that included both severe maternal morbidity and in-hospital maternal mortality, essentially reflecting rates of severe maternal morbidity, as it is 50 times more common than maternal death.[17] A recent analysis of data from the CDC Pregnancy Mortality Surveillance System found that pregnancy-related mortality ratios (pregnancy-related deaths during or within 1 year of pregnancy per 100,000 live births) from 2011–2016 were highest in the most rural areas (24.1, 95% CI: 21.4–27.1) and lowest in large metro areas (14.8, 95% CI: 14.2–15.5).[6] As neither study examined trends over time in MMRs, trends in rural-urban disparities in maternal mortality in the US remain unexamined.

The objective of our study's analysis was threefold: (1) to estimate the impact of the implementation of the pregnancy status checkbox on MMRs by rural-urban maternal residence; (2) estimate trends in MMRs from 1999 through 2017, accounting for the checkbox implementation, by rural-urban maternal residence; and (3) examine the impact of potential misclassification of pregnancy status on the death certificate on rural-urban trends in MMRs from 1999 through 2017.

Methods

This study used restricted-use all-county birth and death certificate data from the National Center for Health Statistics (NCHS), collected as part of the NVSS.

Maternal mortality ratio (MMR)

Maternal deaths and corresponding numbers of live births were aggregated by year and county from 1999 (the first year the US used the *International Classification of Disease, Tenth Revision* (ICD-10) cause of death codes) through 2017. Death data included information on the county of residence at the time of death and birth data included information on the county of maternal residence at the time of delivery.[18] MMR was calculated as maternal deaths per 100,000 live births. Absolute and relative differences in MMRs are expressed as rate differences and relative rates, respectively, for ease of interpretation.

Maternal deaths

Maternal deaths (deaths while pregnant or within 42 days of pregnancy) for each year were identified based on the presence of ICD-10 underlying cause of death codes A34, O00–O95, and O98–O99 on the coded death certificate, consistent with the WHO definition (Web Appendix **and** Web Table 1). This definition excludes late maternal deaths—those occurring more than 42 days, but less than 1 year, following pregnancy—which are documented on the death certificate using underlying-cause code O96--and deaths from sequelae of obstetric causes (O97) that occur a year or more after pregnancy. The WHO definition also excludes all accidental or incidental causes of death.

The addition of the pregnancy status checkbox to the 2003 revision of the standard death certificate was accompanied by changes to the methods for coding causes of death. For example, if the pregnancy checkbox indicated current or recent pregnancy (within 42 days), all contributing causes of death and the underlying cause of death were preferentially assigned to the most relevant direct or indirect obstetric cause of death code according to the open text cause of death information.[7] These rules applied to death data from 2003 through 2017 and are the basis for the data used in this analysis. Of note, with the publication of 2018 data in 2020, NCHS again revised the approach for coding maternal deaths in response to concerns about the accuracy of the pregnancy checkbox and overreporting of maternal deaths among older age groups (45+ years).[19] Historical mortality data recoded using this new approach are not yet available.

Rural-urban residence

Rurality of county of maternal residence (at the time of death and at the time of delivery) was defined for each year of data using the NCHS 6-level urban-rural classification scheme from 1990 (for years 1999–2005), 2006 (for years 2006 to 2012), and 2013 (for years 2013 to 2017). [20] Due to low annual maternal death counts among persons residing in sparsely populated rural counties, the 6-level scheme was collapsed into a 3-level measure: large urban (large central or large fringe metropolitan areas), medium/small urban (medium or small metropolitan areas), or rural (micropolitan and noncore areas).

Impact of the pregnancy checkbox

A regression-discontinuity approach was used to examine the impact of implementing the pregnancy status checkbox on MMRs by rural-urban residence. 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.[21] Assuming that observations immediately below and above the implementation of the checkbox are otherwise similar, the difference at the time of implementation corresponds to the causal effect estimate using the new pregnancy status checkbox.[21] To examine the impact of the checkbox visually, MMRs were plotted against the time since revision using fractional polynomial prediction plots, which allowed for estimation of nonlinear trends to assess potential gradual effects of checkbox implementation. Plots were limited to show trends within plus or minus 4 years of the revision year, with the discontinuity centered on the revision year.

Rural-urban trends in MMRs

We then used frequency-weighted log binomial regression models with robust standard errors to predict MMRs from 1999–2017 accounting for the checkbox, by rural-urban maternal residence. We considered two alternative scenarios: 1) assuming all states had implemented the checkbox as of 1999; and 2) assuming no states had implemented the checkbox during 1999–2017. We estimated rural-urban log-linear trends over time, adjusting for age, race/ethnicity, state of death occurrence, and all first-order interaction terms.

Average marginal effects were used to estimate the average annual change in MMRs by subgroup. We also plotted interactions by race/ethnicity and maternal age, to see if log-linear trends for rural-urban county of residence were different across these subgroups. Akaike information criterion (AIC) and Bayesian information criterion (BIC) were used to compare models with and without quadratic terms for year. As model fit was not consistently improved when quadratic terms were included, only log-linear models are presented. Plots of the standardized and deviance residuals did not show problematic patterns. As we do not have 'true' MMRs to validate the predicted MMRs (i.e., trends where no states or all states had the checkbox throughout the study period), the purpose of predicting MMRs was to account for the change in measurement over time and examine differences by rurality.

Secondary analysis

The addition of the pregnancy status checkbox could have resulted in erroneously assigning a maternal cause of death if the pregnancy checkbox was checked by mistake. Prior studies have suggested that implementing the pregnancy status checkbox may have resulted in non-maternal deaths (i.e., deaths with no corroborating evidence of pregnancy) being classified as maternal deaths, with false positive rates as high as 50%.[9, 22–27] To address this concern, we conducted a secondary analysis that examined rural-urban trends in MMRs due to specific direct obstetric causes of death only (A34, O00-O92, excluding O26.8; Web Table 1). The impact of the checkbox was not as large for this group of causes of death,[7, 8] compared with indirect or non-specific causes of maternal death, which are likely subject to a greater degree of misclassification due to checkbox errors. If the increase in rural maternal deaths was attenuated after restriction to these deaths, and the gap between rural and urban maternal deaths narrowed, this would suggest that some of the disparities we observed in the overall measure of MMR could be due to differentially coding non-maternal deaths as maternal deaths in rural areas.

All analyses were conducted using Stata 14 SE, and no adjustments were made for multiple comparisons. This study involved secondary analysis of existing data and did not involve human subjects, therefore, no Institutional Review Board approval was required. Analyses were conducted in 2020–2021.

Results

Approximately 4 million women gave birth in the US each year during 1999–2017. The total number of observed maternal deaths per year in the US was 391 in 1999 (9.9 deaths per 100,000 live births) and 832 in 2017 (21.6 deaths per 100,000 live births) (Web Table 2).

The average change in MMRs associated with the pregnancy status checkbox implementation was larger in rural areas than in urban areas. Relative to the period before the checkbox implementation, adding the checkbox resulted in an average estimated increase of 76% (RR= 1.8 [95% CI: 1.6, 1.9]; RD=7.5 deaths per 100,000 [95% CI: 6.3, 8.8], Figure 1A) in large urban areas, compared with a 113% increase (RR= 2.1 [95% CI: 1.9, 2.4]; RD=11.6 deaths per 100,000 [95% CI: 9.6, 13.6], Figure 1B) in medium/small urban areas, and an increase of 107% (relative rate [RR]= 2.1 [95% CI: 1.7, 2.4]; rate difference [RD]=16.6 deaths per 100,000 live births [95% CI: 12.9, 20.3], Figure 1C) in rural areas during 2003–2017. In 2017, rural women were estimated to have 45% to 65% higher MMR (34.4 per 100,000 live births) compared with women living in urban areas (23.7 per 100,000 live births for medium/small and 20.9 per 100,000 live births for urban areas).

Under the scenario that all states had implemented the pregnancy status checkbox over the entire period, predicted log-linear trends suggested that MMRs declined in large urban areas from 1999–2017 (average annual change = −0.2 [95% CI: −0.4, −0.1] $p<0.01$) from 22.5 in 1999 to 20.9 in 2017 (Figure 2A; Web Table 2). In contrast, predicted MMRs increased in rural areas (0.6 [95% CI: 0.2, 1.0] $p<0.01$) from 20.9 in 1999 to 34.4 in 2017, while no significant change was seen in medium/small urban areas (Figure 2A; Web Table 2). Interactions by race/ethnicity showed there were differences in trends by race/ethnicity across residence areas, with increasing predicted MMRs over time for non-Hispanic White women in medium/small urban and rural areas, and decreasing predicted MMRs for non-Hispanic Black and Hispanic women from large urban areas (Figure 3A). Interactions by age showed there were decreasing predicted MMRs across most age groups for women in large urban areas, except for women aged 40 and over, where substantial increases were observed in all three rural-urban residence areas (Figure 4A; Web Figure 1). Predicted MMRs assuming all states had not implemented the pregnancy status checkbox are included in Web Table 2.

In our secondary analysis, which was restricted to maternal deaths due to direct and specific obstetric causes, findings were generally attenuated. The overall change in MMRs due to the implementation of the pregnancy status checkbox was greater in rural areas (RD = 3.6 deaths per 100,000 live births) than in large urban areas (RD= 2.1 deaths per 100,000 births) and in medium/small urban areas (RD = 2.4 deaths per 100,000 live births), but the overall effect of the checkbox implementation was attenuated. Assuming that all states had adopted the checkbox, the predicted MMRs due to direct and specific causes decreased during 1999–2017 in large urban areas (average annual change =−0.3 deaths per 100,000 live births [95% CI: −0.4, −0.2) per year $p<0.001$] from 11.4 in 1999 to 7.5 in 2017, decreased in medium/small urban areas (−0.1 [95% CI: −0.2, −0.03] $p<0.02$) from 8.9 in 1999 to 7.9 in 2017, and no statistically significant change was found for rural areas (−0.03 [95% CI: −0.2, 0.2) $p=0.75$) from 10.4 in 1999 to 10.3 in 2017 (Figure 2B). In large urban areas, MMRs for direct and specific causes declined for all racial/ethnic groups and for all age groups <40 years (Figures 3B and 4B; Web Figure 1). Declines were seen for medium/small urban areas among Hispanic women and those 20–24 and 30–34 years. In rural areas, MMRs for direct and specific causes declined among Hispanic women and those 20–24 years, but increased among women 40 and older.

Discussion

High level summary

The impact of the pregnancy status checkbox on MMRs was larger for rural areas than urban areas in the US. Assuming all states had adopted the checkbox from 1999–2017, predicted MMRs increased in rural areas while declining in large urban areas; however, this increase was attenuated after restricting the analysis to direct and specific causes of maternal death, which are less prone to pregnancy checkbox errors, indicating that some of the increase may be due to differential misclassification of maternal deaths. Taken together with previous evaluations of the impact of the pregnancy status checkbox,[8] older women (35 and older) and rural women, particularly non-Hispanic white women, are among the only subgroups with increases in predicted MMRs during 1999–2017; urban non-Hispanic Black and Hispanic women experienced decreases in predicted MMRs during this time period. Overall, rural women were estimated to have around 45% and 65% higher predicted MMRs as compared with women living in medium/small urban areas and large urban areas, respectively, in 2017. Our findings add to what is already documented on the substantially higher MMRs among older women and non-Hispanic Black women in the US.[3, 4, 28]

Consistency with prior literature

These study findings are generally consistent with the two contemporary studies of rural-urban difference in maternal mortality in the US. Using national hospital discharge data, Kozhimannil et al. found severe maternal morbidity and in-hospital maternal mortality in 2007–2015 were 9% higher in rural residents as compared with urban residents,[5] and Merkt et al. found pregnancy-related deaths in 2011–2016 were 63% higher in the most rural areas (rural noncore areas) as compared to large metro areas.[6] However, despite the consistent direction of the present study findings, our study is the first to specifically examine rural-urban trends in MMRs over time using national data, accounting for the staggered adoption of the pregnancy checkbox across states over time. Our study's rural-urban RR, RD, or average annual change estimates could still be upwardly biased due to differential misclassification of pregnancy status on the death certificate; when restricted to only direct causes of maternal death, which are less likely to be misclassified, we no longer found increases in MMRs in rural areas over time. Nevertheless, the rural-urban gradient persisted, with large urban areas exhibiting significant decreases over time in MMRs, and rural areas showing no significant change. In sum, existing evidence suggests that MMRs are higher in rural areas and are not showing the same patterns of improvements as in urban areas over the past nearly two decades. Notably, trends among non-Hispanic Black and Hispanic women in urban areas have improved over time, while trends among non-Hispanic white women living in medium/small urban and rural areas have declined; though MMRs remain higher among Black women.[29]

What our study findings imply

Our study findings suggest that there is room for improvement of measurement and surveillance of maternal mortality in the US, particularly for rural areas. Currently, we are unable to determine how much of the increase in rural MMRs during 1999–2017 was due to true increases in maternal mortality, increased identification of maternal deaths (i.e., under-ascertainment before the checkbox), or false positive maternal deaths (i.e., over-ascertainment after the checkbox). True increases in maternal mortality in rural areas are plausible given recent trends in rural mortality overall,[16] and documented barriers to maternal and obstetric care in rural areas, [12] which could contribute to inadequate obstetric care for rural women. Increased identification of rural maternal deaths is also plausible, as there could have been a greater degree of under-ascertainment of maternal deaths in rural areas prior to the checkbox implementation, though there is little research on this.[30] The impact of the checkbox on MMRs due to direct and specific causes of maternal death was larger in rural vs. urban areas, providing some support for the this explanation. Rural maternal deaths might also be more likely to include false positive maternal deaths as compared with urban areas, particularly from deaths due to unintentional injuries, such a drug overdoses, which are higher among rural women.[3132] These deaths could be erroneously coded as maternal deaths in rural areas to a greater extent than in urban areas. Limited evidence from a few states suggests that the accuracy of the pregnancy checkbox may vary based on whether the certifier is a medical examiner, coroner, or physician.[33] It remains unclear how accuracy might differ by rural-urban residence.

Higher death rates generally among reproductive-aged women in rural areas could result in substantially inflated MMRs with even a small number of false positive maternal deaths. Additional research on mortality reporting may help in understanding potential differences in ascertainment and data quality by rural-urban residence. Data linkages, routine follow-up of possible maternal death records, and other data quality improvement efforts could help reduce false positive maternal deaths, and may be especially needed in rural areas. Other efforts to collect data on maternal and pregnancy related deaths, including the CDC’s Pregnancy Mortality Surveillance System and state-based Maternal Mortality Review Committees (not currently active in all states), use methods that provide more detail about pregnancy-related deaths, which may reduce false positives and improve data quality for those systems. However, the information used for these initiatives is not currently incorporated into the National Vital Statistics System.[34, 35]

We explored two alternative scenarios (i.e., one where no states had adopted the checkbox, and one where all states had adopted the checkbox) in order to account for the change in measurement that occurred across different jurisdictions over time. It is worth noting that both of these scenarios have limitations with respect to accurately capturing maternal deaths. Concerns about under-ascertainment led to the pregnancy checkbox being added to the US standard certificate of death in 2003, but evaluations in select states after the checkbox was implemented have suggested that over-ascertainment may inflate MMRs, particularly for some demographic groups (i.e., older women).[3, 33] Thus, the ‘true’ MMRs likely fall somewhere between these two scenarios, and additional research may offer insight about the degree of misclassification overall and potential differences across subgroups.

Our study findings also imply that rural areas have not experienced the same level of improvement in MMRs due to direct and specific causes of maternal death compared with more urban areas, suggesting that factors such as adequate obstetric and maternal care, perinatal regionalization, and transportation in rural areas may be lacking.[36, 37] The American College of Obstetrics and Gynecologists recommends several approaches to improve the health of rural women, including continued monitoring of service availability, political advocacy for rural healthcare providers, improved consultation and training opportunities, and more research on the root causes of rural disparities in women’s health.[38]

Limitations

Our study has several limitations. First, the impact of misclassification of maternal deaths may be greater in rural areas, because a small number of false positives is more influential than for large urban areas, which have larger numbers of deaths. Second, NCHS recently transitioned to an updated coding approach for maternal deaths, which no longer assigns maternal causes of death based on the pregnancy checkbox alone for women 45 years and over to reduce false positives.[19] This may render our analysis less relevant to future analysis of rural-urban disparities and trends in MMRs. Once the recoded pregnancy checkbox historical data (2003–2017) become available, further evaluations of MMRs and related trends can be done based on the new approach for coding maternal deaths. Additionally, some states, notably California, use a non-standard pregnancy checkbox[7]; these states were treated as checkbox implementers, but the impact of the checkbox may differ in those states. Despite using national data, counts for some racial/ethnic groups were too small to estimate reliable trends by urban/rural residence. Finally, the predicted trends and differences were estimated from models accounting for the staggered implementation of the pregnancy checkbox across jurisdictions but are subject to the limitations of modeling (e.g., assumptions, measurement error, model misspecification). Other factors that were not included in the models may be important for explaining trends and/or measurement error, including variables like type of certifier (medical examiner, coroner, physician), along with socioeconomic factors or maternal characteristics. In addition, while we present log-linear time trends in MMR from 1999 to 2017, there may be non-linear trends within this time period and through more recent years that can be further explored in future research.

Strengths

Study strengths include the use of national data and a methodological approach that allows for a more valid assessment of trends over time, accounting for the staggered implementation of the checkbox. Finally, as maternal deaths are rare events with typically very small counts in rural areas each year, NVSS is the only source of data large enough to estimate rural MMRs and related trends and disparities.

In conclusion, the impact of the pregnancy status checkbox on MMR estimates was larger in rural than in urban areas in the US. Predicted trends accounting for the staggered checkbox implementation demonstrated that MMRs increased in rural areas, while no increases were found in more urban areas. Some of the increase in MMRs in rural areas could have been due to errors in the pregnancy checkbox; this explanation is supported by our attenuated findings for direct and specific maternal causes of death. More work is needed to better understand the potential impact of pregnancy misclassification on MMR estimates to improve the monitoring of maternal deaths, particularly in rural areas.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Data Availability Statement:

Procedures to request access to the restricted-use vital statistics data used in this study can be found here: https://www.cdc.gov/nchs/nvss/nvss-restricted-data.htm.

References

1. Hunt P, Bueno de Mesquita J. Reducing maternal mortality: the contribution of the right to the highest attainable standard of health. Essex, UK: University of Essex Human Rights Centre, 2010. https://www.unfpa.org/publications/reducing-maternal-mortality. Accessed December 17, 2021.
2. World Health Organization. Trends in maternal mortality: 1990 to 2015: estimates by WHO, UNICEF, UNFPA, World Bank Group and the United Nations Population Division. Geneva, Switzerland: World Health Organization, 2015. https://www.who.int/reproductivehealth/publications/monitoring/maternal-mortality-2015/en/. Accessed December 17, 2021.
3. MacDorman MF, Declercq E, Thoma ME. Trends in Maternal Mortality by Sociodemographic Characteristics and Cause of Death in 27 States and the District of Columbia. Obstet Gynecol. May 2017;129(5):811–818. [PubMed: 28383383]
4. Petersen EE, Davis NL, Goodman D, et al. Vital Signs: Pregnancy-Related Deaths, United States, 2011–2015, and Strategies for Prevention, 13 States, 2013–2017. MMWR Morb Mortal Wkly Rep. May 10 2019;68(18):423–429. [PubMed: 31071074]
5. Kozhimannil KB, Interrante JD, Henning-Smith C, Admon LK. Rural-Urban Differences In Severe Maternal Morbidity And Mortality In The US, 2007–15. Health Aff (Millwood). Dec 2019;38(12):2077–2085. [PubMed: 31794322]
6. Merkt PT, Kramer MR, Goodman DA, et al. Urban-rural differences in pregnancy-related deaths, United States, 2011–2016. Am J Obstet Gynecol. 2021;225(2):183.e1–183.e16. [PubMed: 33640361]
7. Hoyert DL, Uddin SFG, Minino AM. Evaluation of the Pregnancy Status Checkbox on the Identification of Maternal Deaths. Natl Vital Stat Rep. 2020 Jan;69(1):1–25.
8. Rossen LM, Womack LS, Hoyert DL, Anderson RN, Uddin SFG. The Impact of the Pregnancy Checkbox and Misclassification on Maternal Mortality Trends in the United States, 1999–2017. Vital Health Stat 3. Jan 2020;(44):1–61.
9. Davis NL, Hoyert DL, Goodman DA, Hirai AH, Callaghan WM. Contribution of maternal age and pregnancy checkbox on maternal mortality ratios in the United States, 1978–2012. Am J Obstet Gynecol. Sep 2017;217(3):352 e1–352 e7. [PubMed: 28483570]
10. Joseph KS, Lisonkova S, Muraca GM, et al. Factors Underlying the Temporal Increase in Maternal Mortality in the United States. Obstet Gynecol. Jan 2017;129(1):91–100. [PubMed: 27926651]
11. Dorn HF. Maternal Mortality in Rural and Urban Areas. Public Health Reports (1896–1970). 1939;54(17):684–690.
12. Hung P, Henning-Smith CE, Casey MM, Kozhimannil KB. Access to obstetric services in rural counties still declining, with 9 percent losing services, 2004–14. Health Aff (Millwood). 2017 2017;36(9):1663–1671. [PubMed: 28874496]
13. Rayburn WF, Richards ME, Elwell EC. Drive times to hospitals with perinatal care in the United States. Obstet Gynecol. 2012 2012;119(3):611–616. [PubMed: 22353960]
14. Garcia MC, Rossen LM, Bastian B, et al. Potentially Excess Deaths from the Five Leading Causes of Death in Metropolitan and Nonmetropolitan Counties - United States, 2010–2017. MMWR Surveill Summ. Nov 8 2019;68(10):1–11.
15. Womack LS, Rossen LM, Hirai AH. Urban-Rural Infant Mortality Disparities by Race and Ethnicity and Cause of Death. Am J Prev Med. Feb 2020;58(2):254–260. [PubMed: 31735480]
16. Yaemsiri S, Alfier JM, Moy E, et al. Healthy People 2020: Rural Areas Lag In Achieving Targets For Major Causes Of Death. Health Aff (Millwood). Dec 2019;38(12):2027–2031. [PubMed: 31794308]

17. Callaghan WM, Mackay AP, Berg CJ. Identification of severe maternal morbidity during delivery hospitalizations, United States, 1991–2003. Am J Obstet Gynecol. Aug 2008;199(2):133.e1–8. [PubMed: 18279820]
18. National Center for Health Statistics, Centers for Disease Control and Prevention. National Vital Statistics System: Birth Data. https://www.cdc.gov/nchs/nvss/births.htm. Updated December 9, 2021. Accessed December 17, 2021.
19. Hoyert DL, Miniño AM. Maternal Mortality in the United States: Changes in Coding, Publication, and Data Release, 2018. Natl Vital Stat Rep. Jan 2020;69(2):1–18.
20. Ingram DD, Franco SJ. 2013 NCHS Urban-Rural Classification Scheme for Counties. Vital Health Stat 2. 2014 Apr;(166):1–73.
21. Oldenburg CE, Moscoe E, Barnighausen T. Regression Discontinuity for Causal Effect Estimation in Epidemiology. Curr Epidemiol Rep. 2016;3:233–241 [PubMed: 27547695]
22. Baeva S, Saxton DL, Ruggiero K, et al. Identifying Maternal Deaths in Texas Using an Enhanced Method, 2012. Obstet Gynecol. May 2018;131(5):762–769. [PubMed: 29630012]
23. Saucedo M, Bouvier-Colle MH, Chantry AA, Lamarche-Vadel A, Rey G, Deneux-Tharaux C. Pitfalls of national routine death statistics for maternal mortality study. Paediatr Perinat Epidemiol. Nov 2014;28(6):479–88. [PubMed: 25356902]
24. Tran T, Roberson E, Borstell J, Hoyert DL. Evaluation of pregnancy mortality in Louisiana using enhanced linkage and different indicators defined by WHO and CDC/ACOG: challenging and practical issues. Matern Child Health J. Oct 2011;15(7):955–63. [PubMed: 20091108]
25. Tennessee Department of Health. Tennessee Maternal Mortality: Review of 2017 Maternal Deaths. Nashville, Tennessee: Tennessee Department of Health, 2017. https://www.tn.gov/content/dam/tn/health/documents/mch/MMR_Annual_Report_2017.pdf. Accessed December 17, 2021.
26. Daymude AEC, Catalano A, Goodman D. Checking the pregnancy checkbox: Evaluation of a four-state quality assurance pilot. Birth. 2019;46(4):648–655. [PubMed: 30873658]
27. Mitchell C, Lawton E, Morton C, McCain C, Holtby S, Main E. California Pregnancy-Associated Mortality Review: mixed methods approach for improved case identification, cause of death analyses and translation of findings. Matern Child Health J 2014;18(3):518–26. [PubMed: 23584929]
28. Neggers YH. Trends in maternal mortality in the United States. Reprod Toxicol. Sep 2016;64:72–6. [PubMed: 27063184]
29. Petersen EE, Davis NL, Goodman D, et al. Racial/Ethnic Disparities in Pregnancy-Related Deaths — United States, 2007–2016. Morbidity and Mortality Weekly Report (MMWR). 2019;68(35):762–765. [PubMed: 31487273]
30. Miller Temple K The Death Certificate: A Document to be Honored and Accurate. The Rural Monitor. Rural Health Information Hub. https://www.ruralhealthinfo.org/rural-monitor/death-certificates/. Published August 8, 2018. Accessed December 17, 2021.
31. Hedegaard H, Miniño AM, Warner M. Urban-rural Differences in Drug Overdose Death Rates, by Sex, Age, and Type of Drugs Involved, 2017. NCHS Data Brief. Aug 2019;(345):1–8.
32. Hirai AH, Ko JY, Owens PL, Stocks C, Patrick SW. Neonatal Abstinence Syndrome and Maternal Opioid-Related Diagnoses in the US, 2010–2017. JAMA. 2021;325(2):146–155. [PubMed: 33433576]
33. Catalano A, Davis NL, Petersen EE, et al. Pregnant? Validity of the pregnancy checkbox on death certificates in four states, and characteristics associated with pregnancy checkbox errors. Am J Obstet Gynecol. 2020;222(3):269 e1–269 e8. [PubMed: 31639369]
34. St Pierre A, Zaharatos J, Goodman D, Callaghan WM. Challenges and Opportunities in Identifying, Reviewing, and Preventing Maternal Deaths. Obstet Gynecol. 2018;131(1):138–142. [PubMed: 29215526]
35. Zaharatos J, St Pierre A, Cornell A, Pasalic E, Goodman D. Building U.S. Capacity to Review and Prevent Maternal Deaths. J Womens Health (Larchmt). 2018;27(1):1–5.
36. DeSisto CL, Oza-Frank R, Goodman D, Conrey E, Shellhaas C. Maternal transport: an opportunity to improve the system of risk-appropriate care. J Perinatol. 2021;41(9):2141–2146. [PubMed: 33547406]

37. Kozhimannil KB, Hung P, Henning-Smith C, Casey MM, Prasad S. Association Between Loss of Hospital-Based Obstetric Services and Birth Outcomes in Rural Counties in the United States. JAMA. 2018;319(12):1239–1247. [PubMed: 29522161]

38. ACOG Committee Opinion No. 586: Health disparities in rural women. Obstet Gynecol. Feb 2014;123(2 Pt 1):384–388. [PubMed: 24451676]

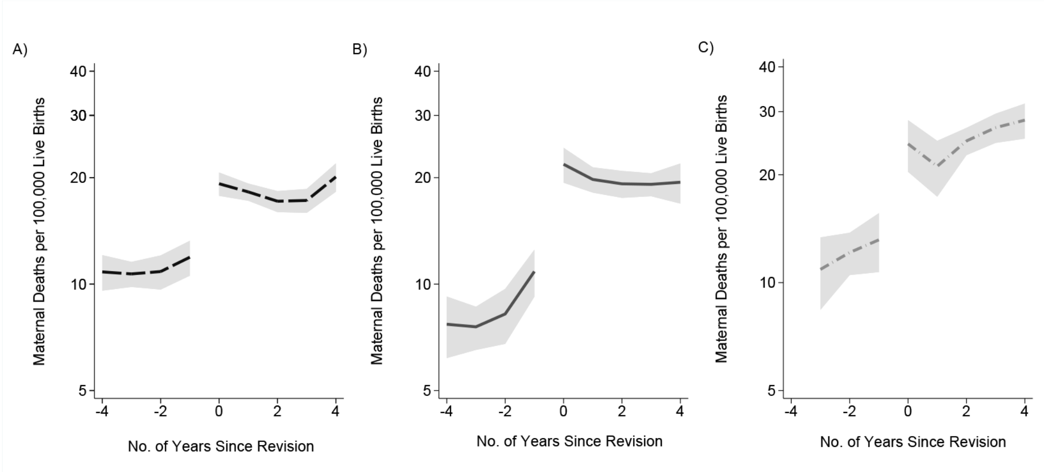

Figure 1:

Impact of the pregnancy status checkbox on maternal mortality rates in the US by rural-urban maternal residence (A) Large urban, B) Medium/small urban, C) Rural) and years since checkbox revision, 1999–2017

Note: Trend plots show modeled estimates generated using fractional polynomial prediction plots in Stata 14 SE, with shaded areas representing 95% confidence intervals.

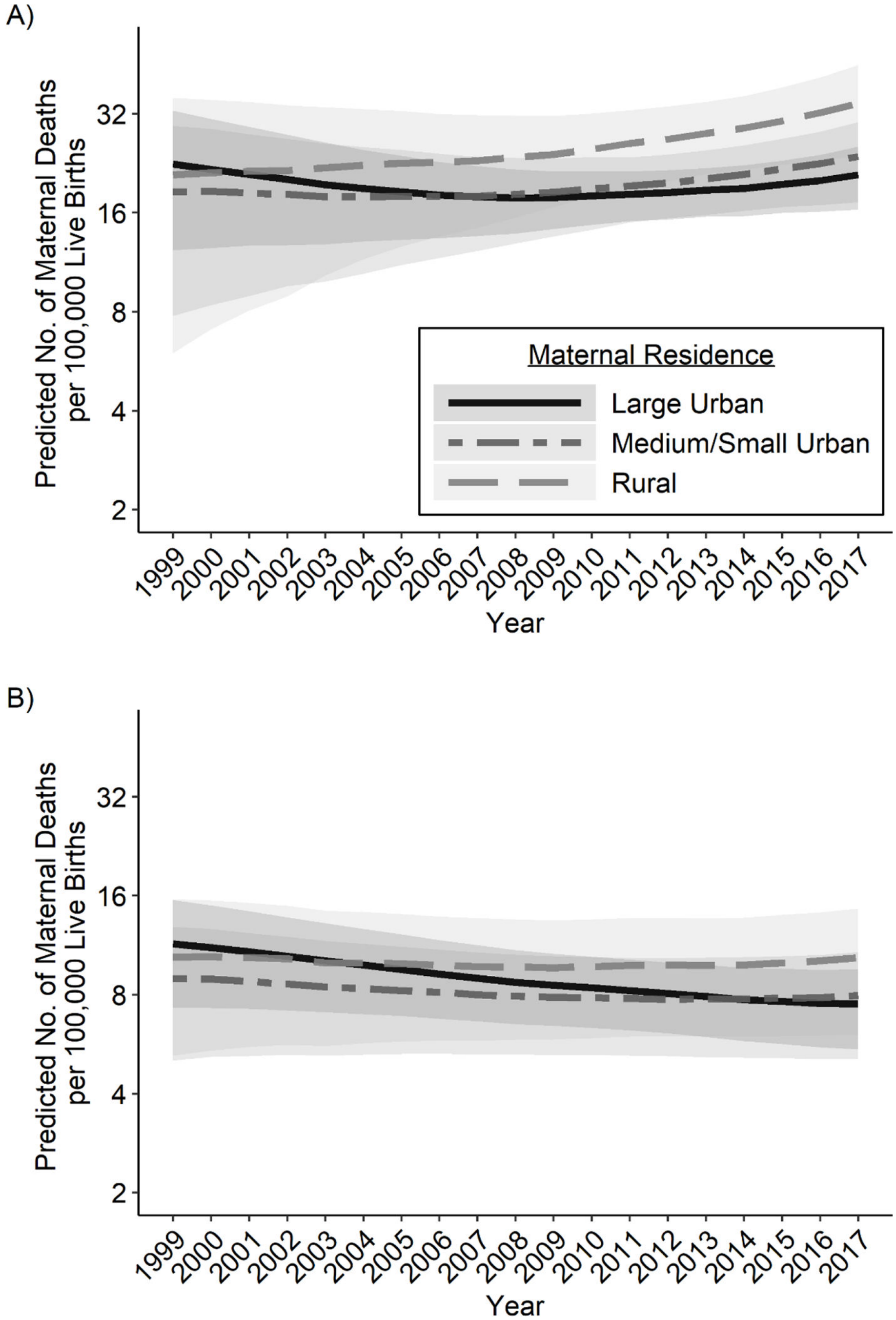

Figure 2.

Predicted maternal mortality ratios in the US overall (A) and from direct/specific causes (B) assuming all states adopted the pregnancy status checkbox by rural-urban maternal residence, 1999–2017

Note: Demographic-adjusted predicted maternal mortality rates per year are displayed. After demographic adjustment, average annual change for overall MMRs in large urban areas was −0.2 per 100,000 live births (95% CI: −0.4, −0.1; $p<0.01$), medium/small urban areas was 0.2 per 100,000 live births (95% CI: −0.04, 0.4; $p=0.11$), and rural areas was 0.6 per 100,000 live births (95% CI: 0.2, 1.0; *p*<0.01). For MMRs due to direct and specific causes, average annual change for large urban areas was −0.3 per 100,000 live births (95% CI: −0.4, −0.2; p<0.001), medium/small urban areas was −0.1 per 100,000 live births (95% CI: −0.2, −0.03; p<0.02), and rural areas was −0.03 per 100,000 live births (95% CI: −0.2, 0.2; p=0.75). Shaded areas represent 95% CIs.

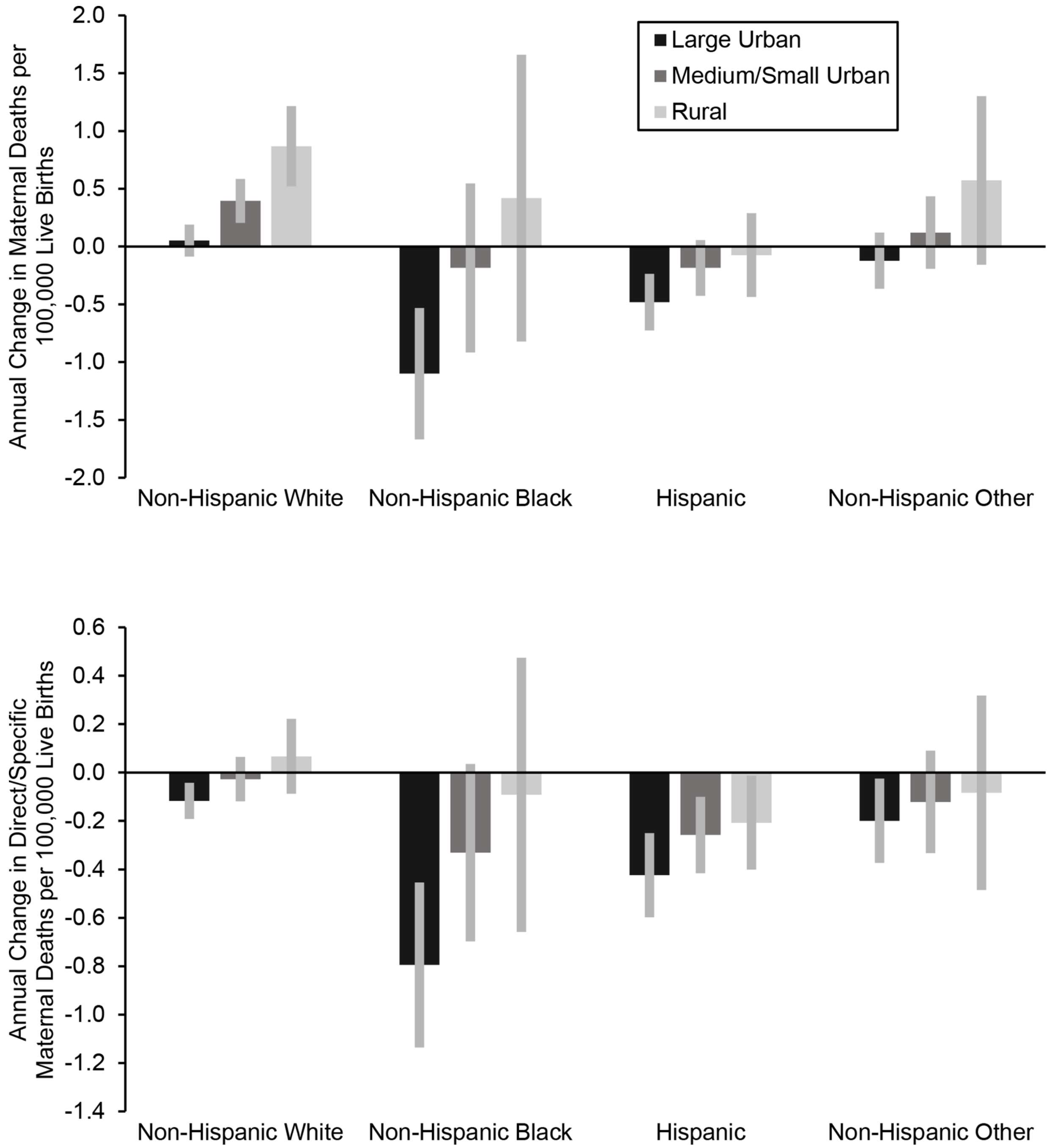

Figure 3.

Trends in maternal mortality ratios in the US overall (A) and from direct/specific causes (B) assuming all states adopted the pregnancy status checkbox by rural-urban maternal residence, 1999–2017, and by race/ethnicity

Note: Average marginal effects from the regression models including interactions between urban/rural residence and demographic variables were used to estimate the average annual change in MMRs by group. Error bars depict 95% CIs.

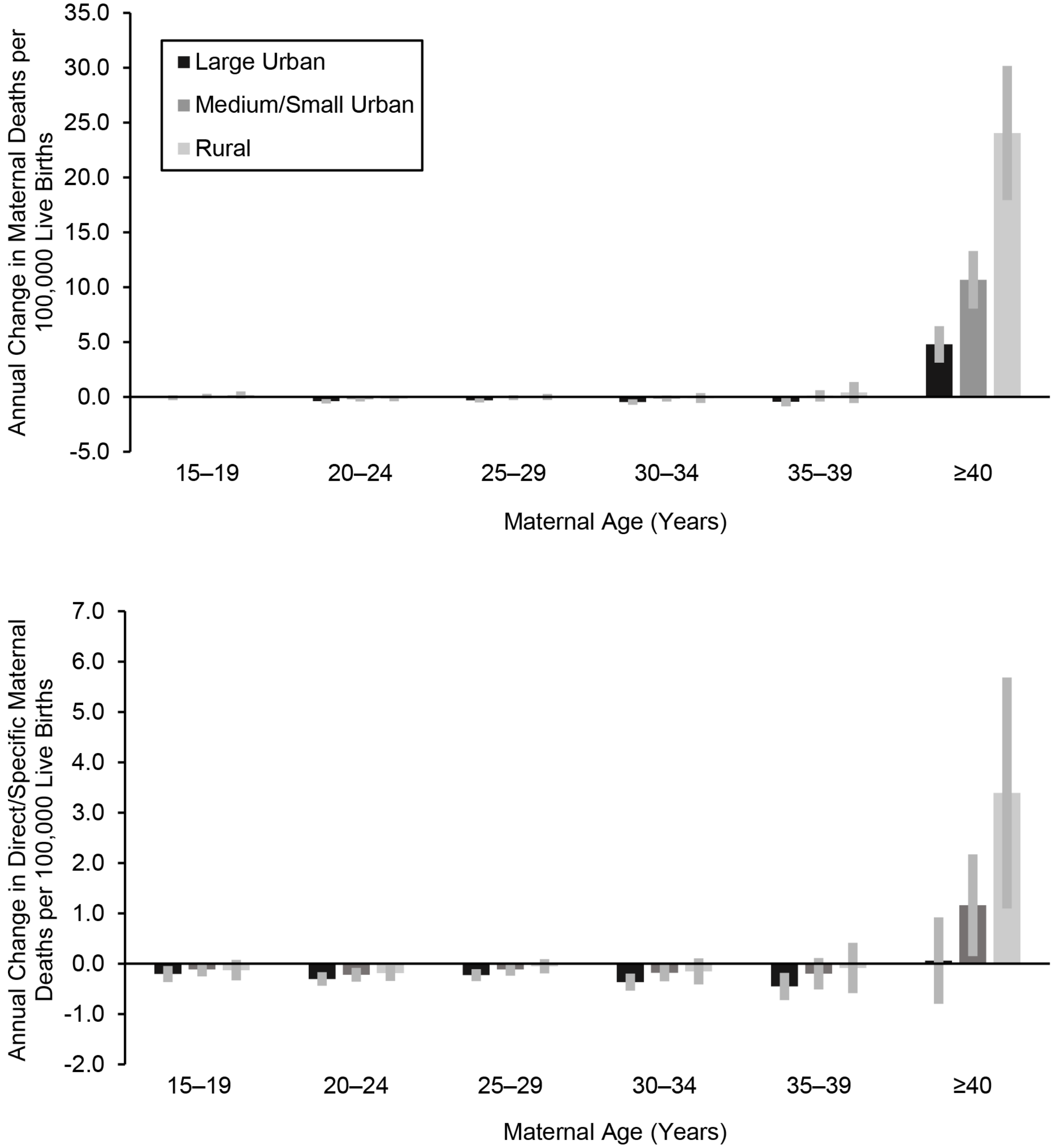

Figure 4.

Trends in maternal mortality ratios in the US overall (A) and from direct/specific causes (B) assuming all states adopted the pregnancy status checkbox by rural-urban maternal residence, 1999–2017, and by maternal age (years) at death

Note: Average marginal effects from the regression models including interactions between urban/rural residence and demographic variables were used to estimate the average annual change in MMRs by group. Error bars depict 95% CIs.