

Structural Factors and Racial Disparities in Severe Maternal Morbidity: An Examination of State-Level
Indicators of Structural Racism and Severe Maternal Morbidity Among Black and White Persons in the
U.S., 2009-2011

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Abstract

Structural Factors and Racial Disparities in Severe Maternal Morbidity: An Examination of State-Level Indicators of Structural Racism and Severe Maternal Morbidity Among Black and White Persons in the U.S., 2009-2011.

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Epidemiology

Background: Severe maternal morbidity (SMM) in the United States is increasing, with Black persons experiencing a disproportionate burden of SMM. Racial disparities in SMM unexplained by individual risk factors suggest that structural inequities should be explored as a potential explanation. This study aimed to examine whether exposure to higher levels of structural racism would be associated with higher risk of SMM among Black persons.

Methods: The sample comprised delivery discharge records from the Healthcare Cost and Utilization Project's (HCUP) Nationwide Inpatient Sample (NIS) during 2009-2011. The sample included n=303,943 deliveries to Black persons and n=1,007,217 deliveries to White persons from 1,087 hospitals in 30 states. The outcome was a composite measure for any SMM during delivery. State-level structural racism was measured by ratios of race-specific population prevalence of six indicators of four domains of

structural racism (criminal justice, political participation, education, and employment). Exposure categories were defined by tertiles of indicator ratios. Multilevel adjusted logistic regression models with random intercepts for hospital and state were used to calculate odds ratios (OR) and 95% confidence intervals. Separate models were created for each indicator, first using the combined sample, and then stratified by maternal race.

Results: The average maternal age for all deliveries was 27.8 years. The majority of deliveries without SMM were paid for by private insurance (55.1%) while deliveries with SMM were primarily paid for by Medicare or Medicaid (47.3%). In the combined sample, Black persons had a 1.6 times greater risk of SMM (aOR 1.57, 95% CI: 1.48,1.67) compared to White persons. Among all deliveries, those that occurred in states with the highest level of structural racism as indicated by incarceration and high school graduation rates had lower risk of SMM (aOR 0.78, 95% CI: 0.64, 0.94, and aOR 0.80, 95% CI: 0.71,0.90, respectively) compared to those in states with the lowest level of structural racism. Similar inverse associations between SMM and incarceration and high school graduation rate indicator ratios were observed among White persons (but not Black persons) in stratified models (aOR 0.78, 95% CI: 0.66,0.93 and aOR 0.79, 95% CI: 0.71,0.89 respectively). Black persons giving birth in states with the highest levels of structural racism in the employment domain had significantly lower risk of SMM compared to those with the lowest levels of structural racism (aOR 0.83, 95% CI: 0.71,0.97). Indicator ratios for voter registration, voting, and bachelor's degrees were not associated with odds of SMM among White or Black persons.

Conclusions: We found that Black persons had a higher risk of SMM during delivery than White persons. White persons had significantly lower risk of SMM in states highest in racial inequality, measured by incarceration and high school graduation rates. Black persons had significantly lower risk of SMM in states highest in racial inequality in employment, measured by managerial occupation rates. Race-specific differences in associations between criminal justice, education and employment domains of structural racism suggest areas of focus for public health policies aimed at the reduction of racial disparities in SMM. Future research should focus on refinement of measures of structural racism and develop measures which capture the ways that different domains interact to create and maintain systemic racial inequities.

Introduction

As the United States seeks to address its rising maternal mortality rate, significant attention is being paid to severe maternal morbidity (SMM). Persons who experience SMM are considered near-misses for maternal mortality. Broadly, SMM is the “Unintended outcomes of the process of labor and delivery that result in significant short-term or long-term consequences to a woman’s health.”¹ The CDC’s list of indicators for SMM includes diagnoses of myocardial infarction, renal failure, eclampsia, stroke, and embolism, as well as procedures such as blood transfusions and hysterectomy during labor and delivery.² In the US, the prevalence of SMM increased from 49.5 per 10,000 deliveries in 1993³ to 146.6 per 10,000 deliveries in 2015⁴ (the most recent national estimate available), affecting nearly 60,000 women annually. Non-Hispanic Black (hereafter referred to as Black) women in the United States are at 1.4-4.2 times higher risk of SMM than non-Hispanic Whites (hereafter referred to as White).⁵⁻⁸ Racial disparities in SMM are only partially explained by individual-level risk factors like age, socioeconomic status, comorbidities and health behaviors.^{8,9} Thus, researchers have suggested exploring system level risk factors, such as structural racism, to explain racial disparities in maternal outcomes including SMM.

Structural racism is “the macrolevel systems, social forces, institutions, ideologies, and processes that interact with one another to generate and reinforce inequities among racial and ethnic groups”¹⁰ and has been referred to as a fundamental cause of health inequities among Black Americans.¹¹⁻¹³ Despite recognition of its importance, there is little agreement about measurement of structural racism in epidemiologic research.^{14,15} The aftermath of slavery and the history of racially discriminatory real estate practices and policies against Black people in the United States resulted in racially and socioeconomically disparate neighborhoods.^{16,17} Thus, structural racism has previously been quantified using measures of racial and economic residential segregation. Recent research on structural racism has expanded measures to include domains such as criminal justice, employment, education, and political agency.¹⁸⁻²²

Structural racism, whether measured by residential segregation (both racial and economic) or by inequities in other domains, has been associated with preterm birth,^{20,23-25} infant birthweight,^{20,26} stillbirth,²⁷ and neonatal and infant mortality.²¹⁻²³ While these studies found associations of structural racism and poor birth outcomes, individual findings varied significantly depending on the measures of

structural racism utilized. Importantly, some found that associations differed by race,^{21,24,27} while others did not.^{20,26} Previous studies of structural factors associated with racial disparities in SMM have focused primarily on hospital related causes.^{5,6} However, researchers have included other contextual factors in more recent studies and found increased risk of SMM for Black and Latinx mothers in neighborhoods with high levels of poverty²⁸ and racial and economic spatial polarization.²⁹ The latter representing the only study, to our knowledge, to explicitly explore the association between structural racism and SMM.

The current study examined the association of state-level structural racism in four domains (criminal justice, political participation, education, and employment) with SMM, both overall and separately among Black and White persons in the United States. We hypothesized that exposure to higher levels of structural racism would be associated with higher risk of SMM among all participants and Black persons, but not among White persons.

Methods

Study Setting and Study Population

The study sample included delivery admissions from hospitals participating in the Healthcare Cost and Utilization Project's (HCUP) Nationwide Inpatient Sample (NIS) during 2009-2011.³⁰ Briefly, the NIS includes all-payer discharge data on hospital inpatient stays from hospitals representing a 20% sample of US hospitals within each of the following five strata: geographic region (Northeast, Midwest, West, and South); control (public, voluntary, proprietary); location (urban, rural); teaching status (teaching, non-teaching); and number of beds (small, medium, large). The NIS includes community hospitals, specialty hospitals, public hospitals, academic medical centers, and long-term acute care facilities. The NIS does not include short-term rehabilitation hospitals, psychiatric hospitals, and substance use treatment facilities. All discharges from sampled hospitals are included in the NIS. In addition to patient-level discharge data, the NIS includes information on hospital characteristics. The NIS included 1050 hospitals from 44 states in 2009, 1051 hospitals from 45 states in 2010, and 1049 hospitals from 46 states in 2011. States excluded from the current study because they did not participate in NIS

during 2009-2011 include: AL, DE, and ID. Additional states excluded from the sample because race was not reported to NIS include: MN, ND, OH, WV, WA (2010), and NC (2009).

Delivery admissions were identified by ICD-9 diagnosis codes for outcome of delivery (V27), normal delivery (650) as well as diagnosis-related group (DRG) delivery codes and delivery-related procedure codes. Deliveries with severe complications are more likely to be excluded than normal deliveries when only V27 is used to identify deliveries.³¹ Admissions for ectopic, molar pregnancies, and induced abortions were excluded. The NIS categorizes patient's race as 1) White, 2) Black, 3) Hispanic, 4) Asian/Pacific Islander, 5) Native American, or 6) Other. Races other than White and Black were excluded from the sample because our measures of structural racism were designed to only examine White-Black differences. Based on published estimates for the race-specific rates of SMM,⁴ power calculations estimated the required sample size per state to be 500 deliveries per racial group. Therefore, thirteen additional states were excluded due to less than 500 Black deliveries (AK, HI, ME, MT, NE, NH, NM, RI, SD, UT, VT, WA, WY). The final sample (n=1,311,160) included 303,943 deliveries to Black persons and 1,007,217 deliveries to White persons. Delivery discharge records came from 1,087 hospitals in 30 states. This study did not require IRB review because the UW IRB does not consider any of the data sources used to involve human subjects.

Severe Maternal Morbidity

The outcome of interest was the occurrence of any SMM during a delivery hospitalization, excluding antepartum and postpartum admissions. A composite measure of SMM was constructed using the CDC's index² of indicators and corresponding ICD-9 diagnosis and procedure codes (See Appendix A). The indicators include diagnoses such as acute myocardial infarction, acute renal failure, amniotic fluid embolism, eclampsia, severe anesthesia complications, shock, and procedures such as blood transfusions and hysterectomy during delivery hospitalization. A binary indicator for any SMM during delivery was used as the outcome variable.

Measures of Structural Racism

Data to characterize structural racism came from several publicly available sources. State population estimates, employment, education, and voting data came from the U.S. Census Bureau.³² State high school graduation rates were available from the U.S. Department of Education.³³ Data for incarceration were available from the U.S. Bureau of Justice Statistics, National Prisoner Statistics (NPS).³⁴

The primary exposure of interest was state-level structural racism measured across four domains- criminal justice, political participation, education, and employment (Table 1). Following methods in previously published studies,^{18,21} each domain was measured using one or two state-level indicators. Given the exploratory nature of the study, and the lack of agreement in the literature as to the best measures of each domain, political participation and education were measured using two indicators. The indicator for criminal justice was the incarcerated proportion of the state's adult population. The political participation domain was measured by two indicators: the proportion of the state's citizen population registered to vote, and the proportion of the state's citizen population who voted. Education indicators included the proportion of the state's population aged 25 years and older with a bachelor's degree or higher, and the state's 4-year adjusted cohort high school graduation rate. Adjusted high school graduation rates are calculated using the number of entering 9th grade students and the number of graduating 12th grade students four years later, adjusting for the number of students who exit or enter the district during that period. The employment indicator was the proportion of state's employed population aged 16 years and older in a managerial occupation. Percentage of the population that was registered to vote or voted was not available if the race-specific populations were less than 75,000, therefore political participation indicator ratios could not be constructed for IA or OR. Data for the high school graduation rate indicator was not available for KY or OK. Structural racism indicator data from years as close to the study period (2009-2011) as possible were used. Details of indicator calculations, data sources, and years are shown in Table 1.

Each indicator was constructed separately for the state's Black and White populations. Ratios of race-specific indicators were then calculated for each state. Political participation, education, and employment ratios were calculated as the proportion of the White population to the proportion of the Black

population. For incarceration, the ratio of the incarcerated proportion of the Black population to the incarcerated proportion of the White population was used so that all indicator ratios could be interpreted in the same way- values greater than one signified structural racism. States were then categorized into low, moderate, or high levels of structural racism using indicator-specific tertiles of ratios as cut points. States in the highest tertile of an indicator represent the states with the greatest structural racism for each indicator. (Figure 1).

Covariates

Individual covariates included maternal age (continuous) and primary expected payment source (Medicare or Medicaid, private insurance, self-pay, or other). At the hospital level, only teaching status (teaching or non-teaching) was used as an adjustment variable. State-level covariates included the percent of the state's population identifying as Black (2010 Decennial Census) and the percent of the state's population below the federal poverty line (2006-2010 American Community Survey 5-year estimates) using categories of 1) < 12.5%, 2) 12.5% - <15%, 3) 15% - < 17.5%, 4) \geq 17.5%.

Statistical Analysis

Descriptive statistics were calculated for sample and hospital characteristics overall and by presence or absence of SMM, as well as tertiles of structural racism indicator ratios. A binary indicator of any SMM during delivery was used to model the outcome. Exposure to structural racism was modeled by assigning states to categories of low, moderate, or high structural racism using tertiles of indicator ratios, where the highest tertiles of all indicators correspond to the highest levels of structural racism. Odds ratios and 95% confidence intervals were calculated using multilevel logistic regression with random intercepts for state and hospital to account for the nested structure of the data and resulting non-independence of observations. Deliveries were nested in hospitals (level 2) which were nested in states (level 3). Previous literature has documented significant differences in maternal morbidity and mortality outcomes by hospital, after adjusting for patient risk factors and demographics.^{6,29} All models used robust standard errors clustered at the state level.

First, to examine the effect of race on SMM in the study sample, a model was constructed using maternal race as the exposure and SMM as the outcome before adding structural racism indicators. Next, to examine the association of structural racism and SMM among all deliveries, separate models were constructed for each of the six indicators for the four domains of structural racism, with maternal race as a covariate. To test the hypothesis that associations between exposure to higher levels of structural racism and odds of SMM differ among Black and White persons, we used two approaches. First, interaction terms for maternal race and structural racism indicators were added to each model that included all deliveries. Second, all structural racism indicator and SMM models were stratified by maternal race. In all models with structural racism indicators, linear trend tests were performed to test the hypothesis that higher levels of structural racism indicators were associated with higher risk of SMM.

All sets of models described above were adjusted following the same pattern. Model A included only maternal age. Model B included maternal age plus expected payment source and hospital teaching status. Model C included all model B covariates plus percent of the state's population identifying as Black and percent of state population below poverty.

Significance level was set at $\alpha = 0.05$. All analyses were completed in Stata IC version 16.1. (StataCorp. 2019. Stata Statistical Software: Release 16. College Station, TX: StataCorp LLC.)

Results

As shown in Table 2, overall, 23.2% of deliveries in the sample were to Black persons. However, 36.2% of deliveries with SMM were among Black persons. A larger proportion of deliveries with SMM had Medicare or Medicaid as the primary expected payor (47.3%) compared to deliveries without SMM (39.6%). The majority (45.4%) of all deliveries occurred in Southern states. Deliveries with SMM also occurred more often in the South (50.2%). The average maternal age among deliveries with SMM, 28.1 years, was slightly older than among deliveries without SMM, 27.8 years.

Means of all ratios were greater than one (Table 3), showing that for states in the sample, on average, a greater proportion of Whites had the positive indicator (e.g. had a bachelor's degree, were registered to vote, or held a managerial occupation) compared with the proportion of Blacks. For

example, on average, the proportion of Whites with a bachelor's degree was 75% higher than the proportion of Blacks. All other indicator ratios can be interpreted similarly, except incarceration. The mean of the incarceration indicator ratios was 7.39, revealing that on average the proportion of incarcerated Blacks is nearly seven and a half times greater than the proportion of Whites. The incarceration indicator ratios also had the widest range (3.64 to 15.26). The ranges for bachelor's degree, high school graduation rate and managerial occupation ratios all fell between one and three. Only ranges for voter registration and voting ratios included values less than one (0.88 to 1.59 and 0.89 to 1.53, respectively). In the few states with ratios less than one, a higher proportion of Blacks were registered to vote or voted compared to Whites. Means and ranges of indicator ratios were very similar for states included in our analyses as compared with ratios for all available states (Table 3).

See Table 4 for presence of SMM during deliveries by tertile of structural racism indicator ratios. The distribution of deliveries across tertiles varied by indicator. For all indicators, except high school graduation rate and incarceration (among deliveries with SMM), the largest proportion of all deliveries occurred in the middle tertile. A majority (of all deliveries, deliveries with SMM, and deliveries without SMM) occurred in the highest tertile of high school graduation rate ratios (41.7%, 38.3%, and 41.7%, respectively). The majority of deliveries with SMM were in the lowest tertile of the incarceration indicator (35.9%).

In a model with only the binary SMM outcome variable and no predictors, the intraclass correlation (ICC) for state was 0.012 (95% CI: 0.006,0.0245) while the ICC for hospital was 0.107 (95% CI: 0.089,0.128). As seen on Table 5, in non-stratified models, Black persons had 1.7 times higher odds for SMM in model A (aOR 1.66, 95% CI: 1.56,1.77). The increased odds for Black persons remained after adjustments in model B and C (aOR 1.57, 95% CI: 1.48,1.67, for both models). In model A for the incarceration indicator, overall deliveries in states with high levels of structural racism had 0.79 times lower odds (95% CI: 0.64,0.96) compared to deliveries in states in the lowest category. The association remained significant in model B and linear trend tests were significant for both models ($p=0.019$ and $p=0.011$, respectively). However, the association was no longer significant after further adjustment in model C. Deliveries in states with the highest levels of structural racism in education as measured by the

high school graduation rate indicator had significantly lower odds of SMM compared to those in the lowest category in model A, (aOR 0.82, 95% CI: 0.72,0.95), model B (aOR 0.80, 95% CI: 0.71,0.90) and model C (aOR 0.86, 95% CI: 0.76,0.97). Linear trends were significant for all high school graduation rate models ($p < 0.01$ for all). Associations between managerial occupation, voter registration, voting, or bachelor's degree indicator ratios and SMM were non-significant in all models.

In models stratified by maternal race odds of SMM among White persons were significantly associated with the incarceration and high school graduation indicator ratios (Table 6). In adjusted model A, White persons who gave birth in states with the highest level of structural racism in criminal justice were less likely to experience SMM during delivery than those who gave birth in states with the lowest level (aOR 0.79, 95% CI: 0.66,0.94). The association remained essentially unchanged in model B. However, after adjusting for state-level covariates in model C, the association was attenuated and became no longer significant (aOR 0.89, 95% CI: 0.70,1.12). Tertiles of incarceration indicator ratios showed a significant linear trend among White persons in models A and B ($p < 0.01$ for both), but not model C. White persons who gave birth in states in the highest level of structural racism measured by the high school graduation indicator were less likely to experience SMM during delivery compared to those who gave birth in states in the lowest level (aOR 0.81, 95% CI: 0.72,0.97). The association remained significant in adjusted models B and C. Among White persons there was a significant linear trend for tertiles of the high school graduation indicator ratios in all models ($p < 0.01$ for all). These associations of structural racism measured by both incarceration and high school graduation with SMM were not observed among Black persons. We observed statistically significant multiplicative interactions between race and level of structural racism based on high school graduation rate ($p < 0.01$) but not incarceration.

Black persons in states in the middle tertile for the managerial occupation indicator ratios had lower odds of SMM compared to Black persons in states in the lowest tertile in model A (aOR 0.82, 95% CI: 0.70,0.98). The odds remained significantly lower after adjustments in model B and C. In model C, Black persons in states in the highest tertile of managerial occupation indicator ratios had lower odds of SMM compared to those in the lowest tertile (aOR 0.83, 95% CI: 0.71,0.97). The linear trend was only significant in the fully adjusted model C ($p = 0.04$). Similar associations were not observed among White

persons. There was a significant multiplicative statistical interaction between race and structural racism measured by the managerial occupation indicator ($p < 0.01$). Indicator ratios for voter registration, voting, and bachelor's degrees were not associated with odds of SMM for White or Black persons.

Discussion

The current study, to our knowledge, is the first to explore how state-level structural factors which result in racial inequities in the domains of criminal justice, political participation, education, and employment, may explain racial disparities in SMM in the U.S. For all states in the sample, on average, a greater proportion of Whites had a positive indicator of domains of structural racism compared with the proportion of Blacks. The distributions of indicator ratios demonstrate the pervasive nature of racial inequities across all domains of structural racism. We found that risk of SMM during delivery among Black persons was 1.6 times greater than among White persons. Overall, we found that deliveries in states with the highest levels of structural racism in education (using high school graduation rates) and criminal justice domains (using incarceration) had 0.8 times lower risk of SMM compared to deliveries in states with the lowest levels. These associations were in general attenuated after adjustment for percent of the state's population identifying as Black and percent of state population below poverty. Structural racism as measured by incarceration and high school graduation ratios was inversely related to SMM among White persons, but not Black persons. On the other hand, managerial occupation ratios were inversely associated with SMM for Black persons, but not White persons. Interestingly, the associations observed among White persons were attenuated after adjustment for percent of the state's population identifying as Black and percent of state population below poverty while the associations among Black persons were strengthened after adjusting for the same. In comparison to low levels, moderate or high levels of structural racism in any domain were not associated with higher odds of SMM among White or Black persons.

To our knowledge, no other study has used ratios of race-specific indicators to examine the impact of structural racism on SMM, therefore our results are not directly comparable to previous literature. We can compare our results to studies of other health outcomes that used similar measures to quantify structural racism, or to studies of other structural factors and racial disparities in SMM. The

increased risk of SMM among Black persons is consistent with previous literature^{4,5,8} though estimates on the magnitude of the increased risk vary, potentially due to regional differences in rates of SMM,^{4,35} variation in rates of SMM between hospitals^{6,36} and differences in how SMM is defined.⁷

In interpretation of our results, it is important to keep in mind that though some states may be relatively “low” on our measures of structural racism, there are arguably no states without any structural racism. There are no Black persons in our sample who are unexposed to structural racism. Ranges of ratios for states in the lowest category were still greater than one (signifying structural racism) for incarceration, high school graduation and managerial occupation. The two political participation indicators have ranges close to one for the lowest category: 0.88-1.03, and 0.89-1.04. In these states (n=9), the proportion of Blacks is greater than, or very close to, the proportion of Whites who are registered to vote or who voted.

Our findings of lower risk of SMM for deliveries in states with the highest level of racial inequity in incarceration and high school graduation are in contrast with our hypothesized results. After stratifying analyses by maternal race, we find that the lower risk is experienced by White persons but not Black persons. In contrast to our findings, other studies of maternal and child health outcomes using similar ratio measures have not observed this inverse association with high structural racism in education and incarceration and White health outcomes.^{20–22,26} Studies of other health outcomes however, have reported inverse associations similar to our findings. Lukachko et al. found lower risk of myocardial infarction among Whites in states with the highest ratios of incarcerated Blacks to incarcerated Whites (OR 0.84, 95% CI: 0.74,0.96).¹⁸ Dougherty et al. constructed a multi-indicator scale for multiple domains of structural racism at the county level, and found that a 1 unit increase on this scale was associated with a 0.065 (95% CI: -0.125, -0.005 kg/m²) lower body mass index (BMI) among Whites and a 0.188 (95% CI: 0.101, 0.275 kg/m²) higher BMI among Blacks.¹⁹ These findings suggest that practices and policies in areas with higher levels of structural racism which systematically disadvantage Black persons and advantage White persons may confer a positive impact on White health. In states where rates of high school graduation are significantly higher for Whites than Blacks, it may be that Whites benefit from increased opportunities for economic advancement from a young age, improving their access to better

health care and health promoting resources. This could be compounded in states where Whites are both more likely to graduate high school and less likely to be incarcerated. In those instances, Whites could benefit from higher education and less competition for available opportunities.

Results regarding the relationship between managerial occupation ratios and Black health outcomes have been mixed. Wallace et al. found no association between managerial occupation ratios and Black or White infant mortality.²¹ Similarly Pabayo et al. found no association between professional occupation ratios and infant or neonatal mortality among Black or White persons.²² However, they did observe an inverse association between managerial occupation ratios when comparing states in the middle tertile to those in the lowest tertile for Black infant mortality (aOR 0.90, 95% CI: 0.81, 0.98) and neonatal mortality (aOR 0.85, 95% CI: 0.73, 0.97).²² The association was not observed comparing the highest tertile to the lowest. Lukachko et al. dichotomized occupation indicator ratios using the median and found that Black persons in states above the median for managerial positions and professional specialty had 0.76 (95% CI: 0.65,0.89) and 0.55 (95% CI: 0.46,0.65) times lower risk of myocardial infarction than those in states below the median.¹⁸ They suggested the inverse relationship could be due to higher levels of interpersonal racism reported by Blacks in prestigious occupations leading to increased stress and therefore a higher risk of myocardial infarction. As it relates to SMM, psychosocial stress has been associated with increased risk of pregnancy hypertension and preeclampsia,³⁷ both comorbidities which increase the risk of SMM. The hypothesis proposed by Lukachko could thus be applicable to SMM, where Black persons in states with less inequality in employment (and thus more Blacks in managerial occupations) are in fact exposed to a higher level of interpersonal racism leading to increased stress and poor health outcomes. This suggests that the inverse association between Black-White occupational ratios and Black health outcomes observed in our and other studies may be affected by unmeasured cross-level confounding due to experiences of interpersonal racism.

While our results did not show increased risk of SMM among Black persons delivering in states with higher levels of structural racism, studies of other health outcomes using similar measures have found such increased risk. Wallace et al. found higher risk of Black infant mortality (RR 1.05, 95% CI: 1.01, 1.10) in states with high racial inequity in unemployment and lower risk of Black infant mortality (RR

0.92, 95% CI: 0.85, 0.99) in states with lower racial inequity in educational attainment (Bachelor's degree).²¹ They found no associations of either of these measures of structural racism with White infant mortality. Importantly, the study by Wallace et al. was ecological, and thus is susceptible to potential ecologic bias where associations may be different at the individual level. Differences in our studies' findings may also be related to differences in measures (we did not use unemployment as an indicator) or samples, since their study included all 50 states compared to the 30 states in our sample. However, we found that descriptive statistics for the indicator ratios in sample states in our study and all available states were quite similar. Therefore, it is unlikely that exclusion of 20 states resulted in selection bias in our study.

Pabayo et al.²² conducted a study of infant and neonatal mortality using a similar methodology and indicators (incarceration, bachelor's degree, managerial occupation, voter registration, voting), to ours: multilevel logistic regression stratified by race (Black or White) using tertiles of structural racism indicator ratios. Similar to our findings, the majority of structural racism indicators were not associated with the considered outcomes. They found an increased risk of Black infant mortality (aOR 1.25, 95% CI: 1.03, 1.51) and neonatal mortality (aOR 1.35, 95% CI: 1.03, 1.76) for states in the highest tertile of bachelor's degree ratios, contrasting our null findings.²² Similar to our study, they found no association between incarceration and Black health outcomes but did find increased risk of Black infant mortality (aOR 1.15, 95% CI: 1.01, 1.31) and neonatal mortality (aOR 1.17, 95% CI: 1.06, 1.30) associated with high structural racism in capital punishment.²²

We are not aware of any studies of SMM that have used similar ratio measures to quantify structural racism, however, studies of SMM in New York City have sought to identify neighborhood-level factors associated with racial disparities. Howland et al. found that Black persons had 1.8 times higher risk of SMM compared to non-Latinx White persons which increased to 2.4 times higher risk for Black persons who lived in high poverty neighborhoods.²⁸ Janevic et al. found that Black and Latinx persons in zip codes with the highest concentration of low-income, Blacks or low-income Blacks had the greatest risk of SMM.²⁹ They were also more likely to deliver in hospitals in these neighborhoods. Janevic et al. hypothesized that White persons in these neighborhoods had access to additional resources enabling

them to deliver in better hospitals outside of their neighborhoods. Similarly, Howell et al. found that Black persons were more likely to deliver in NYC hospitals with higher risk-standardized SMM rates than White persons.⁶

Taken together, these results provide evidence that mechanisms of structural racism that result in such racially and economically segregated neighborhoods result in increased racial disparities in health outcomes, consistent with racism as a fundamental cause of racial health inequities.¹¹ This suggests that one explanation for our many null results is that the mechanisms of structural racism which lead to increased rates of SMM among Black persons operate on a smaller geographic scale than states. That is, policies that maintain and perpetuate structural inequity are being made by local and municipal governments. For example, in many states county governments are responsible for improving the infrastructure for civic engagement and school districts (often at the sub-county level) provide resources for improving high school graduation rates. As the studies of SMM in NYC show, there is significant variation in SMM between neighborhoods in a single city. Further, hospital and provider factors such as those targeted by quality improvement programs^{38,39} may be most relevant to preventing SMM. Thus, measures of structural racism which capture differential access to high quality obstetric care may be needed for studies of racial disparities in SMM.

Racist systems and institutions have been clearly shown to have negative health impacts for Black Americans.^{11-13,40} There are various potential mechanisms by which these structural inequities could result in higher risk of SMM among Black persons. There are two primary points where consequences of these mechanisms may manifest disparities in SMM. The first is the poorer health status and resulting comorbidities which are known to occur more frequently in Black pregnancies than in White pregnancies⁴¹ and which are associated with higher risk of SMM.⁵ Structural factors which result in differential access to health promoting resources¹¹ prior to pregnancy could lead to these disparities in maternal pre-conception health. Pathways proposed for other health outcomes such as the embodiment of racial discrimination⁴² and weathering⁴³ and allostatic load⁴⁴ may operate similarly in SMM. The second is in access to high-quality obstetric care during pregnancy and delivery. As the studies in New York City demonstrate, quality of care may vary dramatically by hospital and Black persons disproportionately give

birth in worse hospitals. Given that more than a third of SMM cases are estimated to be preventable,⁴⁵ systemic barriers to care are likely an important factor. Even when care is accessed, Black persons may receive poorer quality care than White persons due to institutional and provider bias.⁴⁰

Ratio measures such as the ones used in this study have been proposed as a way to quantify the effects of racist policies and practices which underlie all of these domains,¹⁸ arguing that continuing to use only measures of racial and economic residential segregation does not capture the full spectrum of racist systems which negatively impact people of color in the U.S. The results of this and other studies utilizing ratio measures to quantify structural racism suggest that further refinement of such measures is necessary. Measures of structural racism should effectively capture the ways in which minority racial groups are systematically harmed relative to the dominant (White) racial group. Studies utilizing similar ratio measures of structural racism which found associations of increased individual risk of poor birth outcomes such as small-for-gestational-age (SGA)²⁶ or low birth weight²⁰ with structural racism but did not find evidence of effect modification by race may not be specifically identifying structural racism, merely structural inequities that harm everyone's health. Unfortunately, such results do not provide evidence for specific domains of structural racism that could be directly applicable to the reduction of racial health disparities.

As seen in our data, high structural racism in one domain does not necessarily imply the same for other domains. No state in our sample was in the same tertile for all indicators. Given that the different domains of structural racism are connected by mutually reinforcing, dynamic relationships, perhaps a single measure which combines indicators from multiple domains such as the one used by Dougherty et al.¹⁹ would be a better measure for structural racism. While combined measures can make identification of specific policy actions difficult, they have the potential benefit of more closely representing the totality of exposure to racist systems experienced by minorities. However, admittedly, coming up with a unifying measure of structural racism is challenging. Alternatively, researchers could examine three-way interactions between race and multiple domains of structural racism. While beyond the scope of the current study, the inverse associations between White SMM and incarceration and high school graduation ratios suggests one such analysis.

Limitations and Strengths

Our study's findings should be considered in context of its limitations. First, the NIS is a nationally representative sample of hospitals, so there is the potential for a non-representative sample at the state level. Hospitals were sampled from multiple strata, and the relative over- or under-representation of hospitals (and thus deliveries) from each stratum in each state is not known. Second, the cross-sectional nature of the study does not allow us to quantify exposure to structural racism over the life course or even the entire pregnancy. The relative level of structural racism a person is exposed to in the state where they give birth is unlikely to represent a single, constant, level of exposure throughout their life, given that even in the same state, such exposure would vary over time as policies change. This cross-sectional snapshot thus may not correspond to the etiologic period for an exposure like structural racism which may require lag time between exposure and observable differences in outcomes. Third, the administrative source of data for the study sample has the potential for misclassification of SMM. However, the CDC's index of ICD-9 codes has been validated for use in studies of SMM using administrative data.⁴⁶ Another limitation of administrative data is its lack of individual covariates, particularly education and occupation, which could result in unmeasured cross-level confounding. Without individual education, we cannot separate the effect of individual education from state-level education. This is particularly true for our findings of lower risk of SMM for White persons in states in the highest tertile of high school graduation ratios. Those states have very high proportions of the White population graduating high school, and it could be that it is the individual's educational attainment that is primarily responsible for the beneficial association. Similarly, our findings of an inverse association between managerial occupation and Black SMM may be subject to cross-level confounding due to unmeasured interpersonal racism experienced by Blacks in these occupations. Finally, we are limited to the 30 states in our sample. Comparing the indicator ratio means and ranges from study states and all available states, we find they are quite similar. States excluded from the sample were equally distributed across the three tertiles for high school graduation, voter registration and voting indicator ratios. For the bachelor's degree and managerial occupation indicator ratios, excluded states were more likely to be in the lowest tertile. Excluded states were more likely to be from the middle or highest tertile of the incarceration indicator ratios.

Despite these limitations, the study has several strengths. Our primary strength is the utilization of individual hospital discharge records rather than ecologic data which allows us to examine the individual risk of SMM associated with birthing in states with high levels of structural racism. Our use of several indicators representing multiple domains allows us to explore a range of pathways through which structural racism may affect SMM. Further, the large sample of 1.3 million births is more than adequately powered to detect associations with an outcome as rare as SMM. By using an expanded method of identifying deliveries we decreased the chance of incorrectly excluding deliveries with SMM.

Conclusion

Black persons had a higher risk of SMM during delivery than White persons potentially contributing to higher rates of maternal mortality observed in this population. White persons had significantly lower risk of SMM in states highest in racial inequality, measured by incarceration and high school graduation rates. Race-specific differences in associations between criminal justice, education and employment domains of structural racism suggest areas of focus for public health policies aimed at the reduction of racial disparities in SMM. Future research should focus on refinement of measures of structural racism and develop measures which capture the ways that different domains interact to create and maintain systemic racial inequities.

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Table 1. Domains of Structural Racism: State Level Indicator Variable Calculations and Data Sources

Domain	Indicator	Numerator (calculated separately for Whites and Blacks in each state)	Denominator (calculated separately for Whites and Blacks in each state)	Data Source, Year	States in sample with indicator data available
Criminal Justice	Incarceration	Number of persons age 18+ incarcerated in state prisons	Number of persons age 18+	U.S. Bureau of Justice Statistics, National Prisoner Statistics, 2009-2011	30
Political participation	Voter registration	Number of persons age 18+ registered to vote	Number of persons age 18+	U.S. Census Bureau, 2010	28 (not available for IA, OR)
	Voting	Number of persons age 18+ who voted	Number of persons age 18+	U.S. Census Bureau, 2010	28 (not available for IA, OR)
Educational attainment	Bachelor's degree	Number of persons age 25+ with a bachelor's degree or higher	Number of persons age 25+	U.S. Census Bureau, American Community Survey, 2010	30
	4-Yr Cohort High School Graduation Rate	Number of students graduating high school	Number of entering 9 th grade students 4 years previously	U.S. Department of Education, School Year 2010-2011	28 (not available for KY, OK)
Employment	Managerial occupation	Number of persons with managerial occupation	Number of persons in the civilian employed population age 16+	U.S. Census Bureau, American Community Survey, 2012	30

Table 2. Patient and Hospital Characteristics by Presence of Severe Maternal Morbidity (SMM)

	All deliveries	Deliveries with SMM	Deliveries without SMM
	(n=1,311,160)	(n=21,376)	(n=1,289,784)
	n (%)	n (%)	n (%)
Age (mean, SD)	27.8 (6.1)	28.1 (6.6)	27.8 (6.1)
Race			
Black	303,943 (23.2)	7,738 (36.2)	296,205 (23.0)
White	1,007,217 (76.8)	13,638 (63.8)	993,579 (77.0)
Primary payor			
Medicare/Medicaid	521,028 (39.7)	10,110 (47.3)	510,918 (39.6)
Private	721,123 (55.0)	9,989 (46.7)	711,134 (55.1)
Self-pay	25,614 (2.0)	559 (2.6)	25,055 (1.9)
Other	43,395 (3.3)	718 (3.4)	42,677 (3.3)
Geographic Region			
Northeast	233,626 (17.8)	3,795 (17.8)	229,831 (17.8)
Midwest	263,130 (20.1)	3,909 (18.3)	259,221 (20.1)
South	594,943 (45.4)	10,731 (50.2)	584,212 (45.3)
West	219,461 (16.7)	2,941 (13.8)	216,520 (16.8)
Hospital teaching status			
Teaching	608,241 (47.3)	11,423 (54.4)	596,818 (47.2)
Non-teaching	676,891 (52.7)	9,588 (45.6)	667,303 (52.8)

Table 3. Descriptive Statistics for State Structural Racism Indicator Ratios¹ in Study States and All Available States.

Indicator	States included in study sample			All available states		
	States (n)	Mean Ratio (SD)	Ratio Range	States (n)	Mean Ratio (SD)	Ratio Range
Incarcerated	30	7.39 (3.24)	3.64 – 15.26	50	7.56 (3.16)	3.31 – 15.26
Voter Registration	28	1.12 (0.15)	0.88 – 1.59	33	1.13 (0.18)	0.88 – 1.70
Voting	28	1.14 (0.17)	0.89 – 1.53	33	1.16 (0.20)	0.89 – 1.79
Bachelor’s Degree	30	1.75 (0.29)	1.00 – 2.26	45	1.69 (0.29)	0.93 – 2.26
High School Graduation Rate	28	1.25 (0.11)	1.10 – 1.65	47	1.24 (0.14)	1.01 – 1.71
Managerial Occupation	30	1.84 (0.28)	1.16 – 2.58	42	1.79 (0.34)	1.08 – 2.63

¹Calculated as the ratio of the proportion of the state’s White population with the indicator to the proportion of the state’s Black population with the indicator, except Incarceration ratios which were calculated as the state’s proportion of Black incarcerated adults to the state’s proportion of White incarcerated adults. Therefore, ratios greater than 1 always indicate structural racism.

Table 4. Presence of Severe Maternal Mortality during Delivery by Category* of State Structural Racism Indicators

Indicator	All deliveries (n=1,311,160) n (%)	Deliveries with SMM (n=21,376) n (%)	Deliveries without SMM (n=1,289,784) n (%)
Incarceration			
Low	434,174 (33.1)	7,683 (35.9)	426,491 (33.1)
Moderate	475,112 (36.2)	7,513 (35.2)	467,599 (36.2)
High	401,874 (30.7)	6,180 (28.9)	395,694 (30.7)
Voter Registration			
Low	368,013 (28.8)	6,509 (31.1)	361,504 (28.8)
Moderate	539,829 (42.3)	9,156 (43.7)	530,673 (42.2)
High	369,945 (29.0)	5,284 (25.2)	364,661 (29.0)
Voting			
Low	413,880 (32.4)	6,839 (32.7)	407,041 (32.4)
Moderate	506,200 (39.6)	8,776 (41.9)	497,424 (39.6)
High	357,707 (28.0)	5,334 (25.5)	352,373 (28.0)
Bachelor's Degree			
Low	339,177 (25.9)	5,723 (26.8)	333,454 (25.9)
Moderate	614,170 (46.8)	9,785 (45.8)	604,385 (46.9)
High	357,813 (27.3)	5,868 (27.5)	351,945 (27.3)
High School Graduation Rate			
Low	387,165 (31.0)	6,732 (33.3)	380,433 (31.0)
Moderate	340,463 (27.3)	5,737 (28.4)	334,726 (27.3)
High	519,723 (41.7)	7,723 (38.3)	512,000 (41.7)
Managerial Occupation			
Low	459,185 (35.0)	7,231 (33.8)	451,954 (35.0)
Moderate	478,250 (36.5)	7,568 (35.4)	470,682 (36.5)
High	373,725 (28.5)	6,577 (30.8)	367,148 (28.5)

*Categories defined by tertile of indicator ratios, higher tertiles represent higher structural racism.

Figure 1. Structural Racism Indicator Ratio Categories for States in Study Sample. Ratios calculated as the proportion of the state's White population with the indicator to the proportion of the state's Black population with the indicator, except Incarceration ratios which were calculated as the state's proportion of Black incarcerated adults to the proportion of White incarcerated adults. See Table 4 for details of indicator calculations. States categorized as low, moderate, or high based on tertiles of state indicator ratios. Gray states were excluded or did not have indicator data available. Maps created on mapchart.net

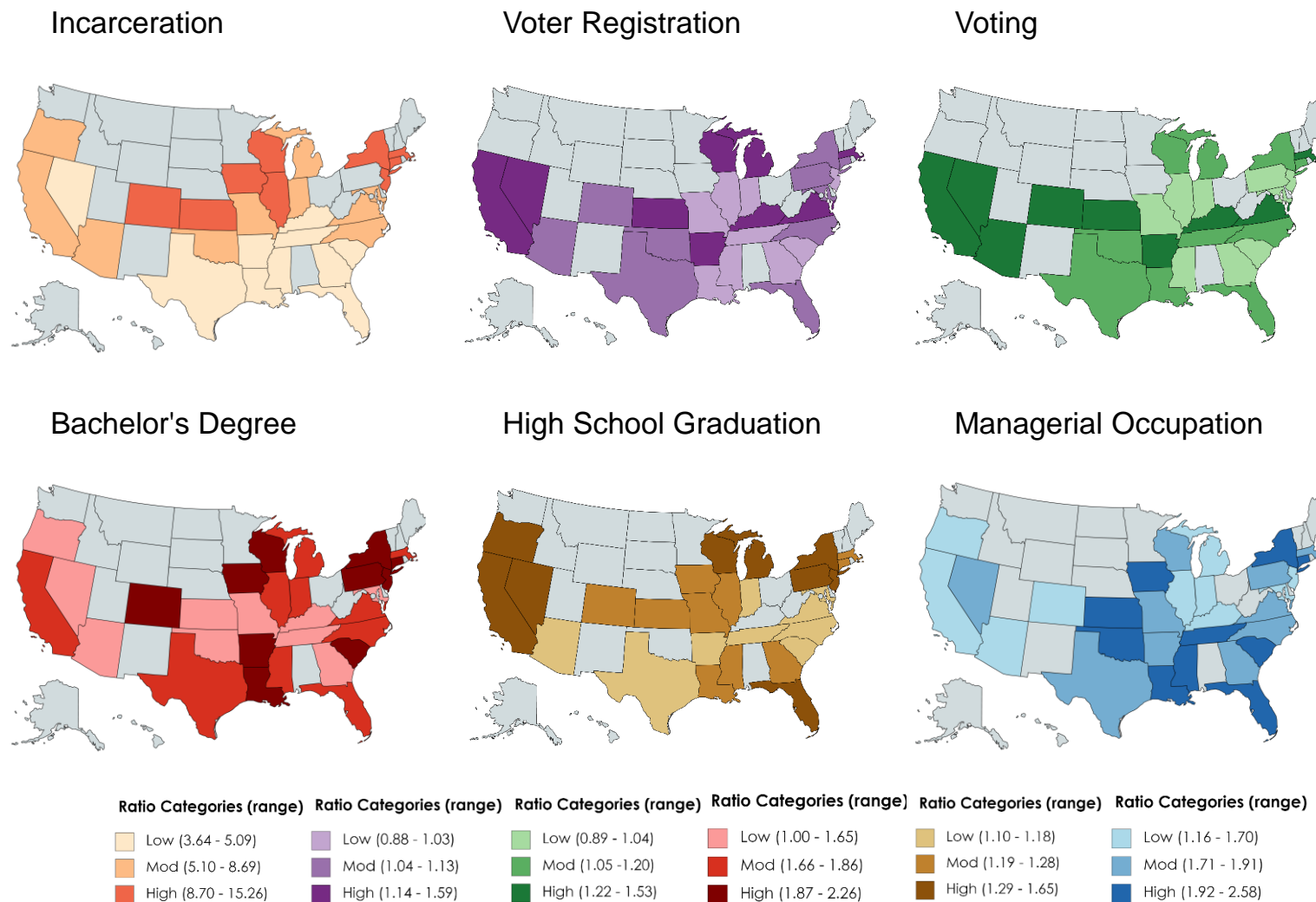


Table 5 Odds Ratio for Severe Maternal Morbidity by Race and Tertile of State Structural Racism Indicator Ratios. Each Indicator Modeled Separately. Nationwide Inpatient Sample 2009-2011, Selected States.

	Model A ¹		Model B ²		Model C ³	
	OR	95% CI	OR	95% CI	OR	95% CI
Maternal Race						
White	<i>Ref</i>		<i>Ref</i>		<i>Ref</i>	
Black	1.66*	(1.56, 1.77)	1.57*	(1.48, 1.67)	1.57*	(1.48, 1.67)
Incarceration						
Low	<i>Ref</i>		<i>Ref</i>		<i>Ref</i>	
Moderate	0.89	(0.76, 1.05)	0.89	(0.76, 1.04)	0.95	(0.82, 1.11)
High	0.79*	(0.64, 0.96)	0.78*	(0.64, 0.94)	0.88	(0.69, 1.11)
Linear Trend Test	p = 0.019		p = 0.011		p = 0.277	
Voter Registration						
Low	<i>Ref</i>		<i>Ref</i>		<i>Ref</i>	
Moderate	0.95	(0.79, 1.15)	0.93	(0.77, 1.12)	1.00	(0.87, 1.16)
High	0.88	(0.72, 1.08)	0.88	(0.73, 1.08)	0.98	(0.82, 1.17)
Linear Trend Test	p = 0.229		p = 0.216		p = 0.809	
Voting						
Low	<i>Ref</i>		<i>Ref</i>		<i>Ref</i>	
Moderate	1.06	(0.86, 1.29)	1.03	(0.84, 1.25)	1.04	(0.88, 1.24)
High	1.03	(0.86, 1.24)	1.04	(0.87, 1.25)	1.16	(0.96, 1.40)
Linear Trend Test	p = 0.732		p = 0.375		p = 0.120	
Bachelor's Degree						
Low	<i>Ref</i>		<i>Ref</i>		<i>Ref</i>	
Moderate	0.93	(0.79, 1.09)	0.93	(0.80, 1.08)	0.93	(0.81, 1.07)
High	0.91	(0.72, 1.16)	0.90	(0.72, 1.13)	0.93	(0.77, 1.13)
Linear Trend Test	p = 0.444		p = 0.653		p = 0.466	
High School Graduation						
Low	<i>Ref</i>		<i>Ref</i>		<i>Ref</i>	
Moderate	0.92	(0.77, 1.10)	0.91	(0.76, 1.08)	0.93	(0.80, 1.09)
High	0.82†	(0.72, 0.95)	0.80*	(0.71, 0.90)	0.86*	(0.76, 0.97)
Linear Trend Test	p = 0.006		p < 0.001		p < 0.001	
Managerial Occupation						
Low	<i>Ref</i>		<i>Ref</i>		<i>Ref</i>	
Moderate	0.89	(0.74, 1.06)	0.89	(0.74, 1.06)	0.84*	(0.72, 0.98)
High	0.95	(0.78, 1.16)	0.96	(0.79, 1.16)	0.89	(0.75, 1.04)
Linear Trend Test	p = 0.631		p = 0.657		p = 0.155	

OR: Odds Ratio, CI: Confidence Interval. ¹Adjusted for maternal age, race. ²Adjusted for Model A covariates, primary payor, hospital teaching status. ³Adjusted for Model B covariates, percent of the state's population identifying as Black, percent state population below poverty. In all models, states categorized as low, moderate, or high structural racism based on tertiles of state structural racism indicator ratios.

†p<0.05; †p<0.01; *p<0.001

Table 6. Odds Ratio for Severe Maternal Morbidity and Tertiles of Structural Racism Indicator Ratios, Stratified by Maternal Race. Each Indicator Modeled Separately. Nationwide Inpatient Sample 2009-2011, Selected States.

	White persons						Black persons					
	Model A ¹		Model B ²		Model C ³		Model A ¹		Model B ²		Model C ³	
	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI
Incarceration												
Low	Ref		Ref		Ref		Ref		Ref		Ref	
Moderate	0.92	(0.78, 1.09)	0.92	(0.78, 1.07)	0.99	(0.83, 1.18)	0.96	(0.81, 1.13)	0.94	(0.81, 1.10)	1.00	(0.89, 1.12)
High	0.79[†]	(0.66, 0.94)	0.78[†]	(0.66, 0.93)	0.89	(0.70, 1.12)	0.90	(0.70, 1.17)	0.86	(0.66, 1.12)	0.95	(0.70, 1.29)
Linear Trend Test	p = 0.008		p = 0.005		p = 0.310		p = 0.429		p = 0.259		p = 0.750	
Voter Registration												
Low	Ref		Ref		Ref		Ref		Ref		Ref	
Moderate	0.99	(0.83, 1.18)	0.97	(0.81, 1.15)	1.05	(0.92, 1.21)	0.94	(0.78, 1.14)	0.91	(0.76, 1.08)	0.93	(0.79, 1.10)
High	0.92	(0.75, 1.12)	0.92	(0.76, 1.11)	1.03	(0.86, 1.23)	0.82	(0.66, 1.02)	0.82	(0.67, 1.01)	0.88	(0.70, 1.05)
Linear Trend Test	p = 0.389		p = 0.367		p = 0.764		p = 0.085		p = 0.057		p = 0.129	
Voting												
Low	Ref		Ref		Ref		Ref		Ref		Ref	
Moderate	1.06	(0.89, 1.28)	1.04	(0.86, 1.25)	1.05	(0.91, 1.22)	1.01	(0.82, 1.26)	0.98	(0.79, 1.21)	0.99	(0.78, 1.22)
High	1.06	(0.88, 1.27)	1.06	(0.88, 1.27)	1.19	(1.00, 1.43)	0.95	(0.78, 1.16)	0.97	(0.79, 1.18)	1.04	(0.80, 1.35)
Linear Trend Test	p = 0.564		p = 0.522		p = 0.052		p = 0.637		p = 0.758		p = 0.792	
Bachelor's Degree												
Low	Ref		Ref		Ref		Ref		Ref		Ref	
Moderate	0.93	(0.80, 1.10)	0.93	(0.80, 1.09)	0.93	(0.81, 1.08)	0.95	(0.82, 1.10)	0.93	(0.83, 1.05)	0.94	(0.82, 1.08)
High	0.88	(0.70, 1.10)	0.88	(0.71, 1.09)	0.90	(0.75, 1.10)	1.00	(0.78, 1.28)	0.96	(0.75, 1.22)	0.97	(0.78, 1.22)
Linear Trend Test	p = 0.265		p = 0.234		p = 0.306		p = 0.990		p = 0.735		p = 0.840	
High School Graduation												
Low	Ref		Ref		Ref		Ref		Ref		Ref	
Moderate	0.93	(0.79, 1.09)	0.91	(0.78, 1.07)	0.93	(0.82, 1.06)	0.98	(0.78, 1.21)	0.95	(0.76, 1.17)	0.95	(0.77, 1.18)
High	0.81[†]	(0.72, 0.92)	0.79[*]	(0.71, 0.89)	0.85[†]	(0.77, 0.94)	0.91	(0.74, 1.12)	0.86	(0.70, 1.06)	0.91	(0.74, 1.11)
Linear Trend Test	p = 0.001		p < 0.001		p = 0.002		p = 0.378		p = 0.151		p = 0.332	
Managerial Occupation												
Low	Ref		Ref		Ref		Ref		Ref		Ref	
Moderate	0.92	(0.76, 1.10)	0.92	(0.76, 1.10)	0.87	(0.75, 1.01)	0.82[*]	(0.70, 0.98)	0.83[*]	(0.69, 0.99)	0.78[†]	(0.67, 0.93)
High	0.97	(0.80, 1.17)	0.97	(0.80, 1.17)	0.90	(0.76, 1.06)	0.89	(0.74, 1.08)	0.90	(0.76, 1.08)	0.83[*]	(0.71, 0.97)
Linear Trend Test	p = 0.723		p = 0.736		p = 0.209		p = 0.250		p = 0.265		p = 0.035	

OR: Odds Ratio, CI: Confidence Interval. ¹Adjusted for maternal age, ²Adjusted for maternal age, primary payor, hospital teaching status, ³Adjusted for Model B covariates and percent of the state's population identifying as Black, percent state population below poverty. In all models, states categorized as low, moderate, or high for each structural racism indicator based on tertiles of state structural racism indicator ratios. Interaction terms for maternal race and tertiles of structural racism indicators were significant for managerial occupation and high school graduation rate (p<0.01 for both) all other interactions were non-significant.

[†]p<0.05; ^{*}p<0.01; ^{*}p<0.001

Appendix A. CDC index of SMM indicators and corresponding ICD-9 Codes

Diagnosis	ICD-9 Codes
Acute myocardial infarction	410.xx
Acute renal failure	584.x, 277.8
Adult respiratory distress syndrome	518.5, 518.81, 518.82, 518.84, 799.1
Amniotic fluid embolism	673.1x
Aneurysm	441.xx
Cardiac arrest/Ventricular fibrillation	427.41, 427.42, 427.5
Disseminated intravascular coagulation	286.6, 286.9, 666.3x
Eclampsia	642.6x
Heart failure during procedure or surgery	669.4x, 997.1
Puerperal cerebrovascular disorders	430, 431, 432.x, 433.xx, 434.xx, 436, 437.x, 671.5x, 674.0x, 997.2, 999.2
Pulmonary edema	428.1, 518.4
Severe anesthesia complications	668.0x, 668.1x, 668.2x
Sepsis	038.xx, 995.91, 995.92, 670.2
Shock	669.1x, 785.5x, 995.0, 995.4, 998.0
Sickle cell anemia with crisis	282.62, 282.64, 282.69
Thrombotic embolism	415.1x, 673.0x, 673.2x, 673.3x, 673.8x
Procedure	
Blood transfusion	99.0x
Conversion of cardiac rhythm	99.6x
Hysterectomy	68.3x-68.9
Temporary tracheostomy	31.1
Ventilation	93.90, 96.01-96.05, 96.7x