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Structural Racism and Odds for Infant Mortality Among Infants Born in the United States 2010

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Abstract

Objectives While ecological studies indicate that high levels of structural racism within US states are associated with elevated infant mortality rates, studies using individual-level data are needed.

To determine whether indicators of structural racism are associated with the individual odds for infant mortality among white and black infants in the US.

Methods We used data on 2,163,096 white and 590,081 black infants from the 2010 US Cohort Linked Birth/Infant Death Data Files. Structural racism indicators were ratios of relative proportions of blacks to whites for these domains: electoral (registered to vote and voted; state legislature representation), employment (civilian labor force; employed; in management; with a bachelor's degree), and justice system (sentenced to death; incarcerated). Multilevel logistic regression was used to determine whether structural racism indicators were risk factors of infant mortality.

Results Compared to the lowest tertile ratio of relative proportions of blacks to whites with a bachelor's degree or higher—indicative of low structural racism—black infants, but not whites, in states with moderate (OR = 1.12, 95% CI = 0.94, 1.32) and high tertiles (OR = 1.25, 95% CI = 1.03, 1.51) had higher odds of infant mortality.

Conclusions Educational and judicial indicators of structural racism were associated with infant mortality among blacks. Decreasing structural racism could prevent black infant deaths.

Keywords Structural racism · Infant mortality · Racial disparities · Birth cohort

Introduction

The infant mortality rate (IMR: number of deaths before age one per 1,000 live births) and neonatal mortality rate (NMR: number of deaths within the first 28 days of life per 1,000 live births) influence a nation's life expectancy [1]. In 2016, the US IMR was 5.9, significantly higher than the Organization for Economic Co-operation and Development (OECD) average of 4 [2]. In the US, a striking racial disparity exists, with IMR significantly higher among blacks than among whites [3]. Although the gap in infant mortality rate between black and white infants decreased from 2005 to 2015, the gap has since increased [4]. More specifically, the excess black infant deaths fell from 8.6 to 6.6 deaths per 1000 between 2005 and 2012, but rose to 6.9 in 2015 [4].

Leading causes of infant mortality include congenital malformations, chromosomal abnormalities, disorders related to short gestation or low birthweight, accidents, and sudden infant death syndrome [5–9]. The majority of neonatal deaths, specifically, are precipitated by respiratory distress; maternal complications of pregnancy; intrauterine hypoxia and birth asphyxia; complications of the placenta, umbilical cord, or other membranes; or neonatal hemorrhage [9]. Economic and social conditions influence the health of mothers and newborns, and have been associated with IMRs [10]. Individual, familial, home, neighborhood, and state characteristics, e.g.,

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health policies and access to healthcare, are important determinants [11].

For example, socioeconomic characteristics and social conditions significantly affect infant health [11]. Low household income, maternal education, and employment status are risk factors for infant mortality [11]. Variability in opportunity could explain the racial disparity in infant mortality in the US [11]. However, evidence suggests that disparities in birth outcomes persist for babies born to black women compared to those of white women across all levels of income, including for college-educated women [12–15].

Structural racism has been associated with adverse health outcomes including stress, depression, and heart disease [16–18]. As a construct, it describes how social systems, institutions, policies, and practices, together with historical trends, reinforce and perpetuate inequality [18]. Education, housing, the economy, criminal justice, and political systems can foster a culture of discrimination against minorities. This system might disproportionately incarcerate minorities at higher rates through discriminatory policing practices or harsh school and community policies. Structural racism could harm mothers and their infants, especially among marginalized groups.

Structural racism has been operationalized in several ways. An index of concentration at the extremes (ICE) was developed to measure spatial social polarizations of deprived and privileged socioeconomic groups in one measure [19]; this was later expanded to include race and income disparities [20]. With multiple dimensions, ICE characterizes the extremes of disparities between groups within a particular area. ICE measures of structural racism have been used to describe zip code regions and census tracts. For larger geographical units (e.g., counties and states), structural racism can be measured by the degree of racial inequality across socioeconomic and judicial domains, e.g., prison incarceration rates, educational attainment, unemployment, occupational status, and median household income [21]. These measures have been captured through a ratio of relative proportions of black to white population values for each indicator [21]. Furthermore, social epidemiologists contend that structural racism may act on various levels within a state that are more proximal to the individual, such as city- or county-level characteristics such as racial residential segregation, or concentrated disadvantage [21].

Previous research suggests that structural racism harms the health of black but not of white Americans [21–24]. Studies have revealed an association between structural racism and infant health. Using data from ten states and the District of Columbia, researchers observed a significant relationship between indicators of structural racism and odds for babies to be born small for gestational age [22]. In ecological studies examining the risk of infant mortality, structural racism was correlated with rising infant mortality rates [21]. However, most research has used only population-level data, leaving analyses vulnerable to the ecological fallacy. We address this gap by exploiting rich, individual-level mortality data to determine the relationship between indicators of structural racism and odds for infant and neonatal mortality among infants born in the US in 2010, and to determine if structural racism explains any observed racial disparity.

Methods

Data Sources

Infant and maternal data were obtained from the 2010 U.S. Linked Birth/Infant Death (LBID) files, provided by the National Center for Health Statistics (NCHS). State laws require certificates to be completed for all births, and federal law mandates national collection and publication of births and other vital statistics. The National Vital Statistics System compiles these data and is the result of the cooperation between NCHS and the states. LBID contains information on sociodemographic characteristics, place of birth, and risk factors for infant health. In 2010, over 98% of LBID records were linked to their corresponding birth certificates. Foreign residents, those with missing information or with records indicating mismatch between state of birth and state residence, were excluded from analyses. Infants were followed until their first birthday.

Structural racism indicators came from several sources, and were linked to vital records by state Federal Information Processing Standard code. The Prison Policy Intiative [25] provided 2010 estimates of prison incarceration and juvenile custody rates by race and state, based on records of the US Bureau of Justice Statistics and the US Office of Juvenile Justice and Delinquency Prevention [25, 26]. Data on representation in state legislatures for the year 2009 were provided by the National Black Caucus of State Legislatures and the National Conference of State Legislatures. Data for the remaining indicators came from the Census Bureau's American Community Survey 3-year estimates for 2007–2010. Ethical approval was obtained from the University of Nevada, Reno's Institutional Review Board.

Measures

Outcome

Since different risk factors and mechanisms might play a different role in odds for neonatal and infant mortality, we looked at two outcomes [9]. Infant mortality (death within 365 days of birth) and neonatal mortality (death within 28 days of birth) were our outcomes of interest. Roughly two-thirds of infant

deaths occur within the first month, with nearly all deaths related to low birthweight and premature birth [9].

State-Level Structural Racism Indicators

Our exposure of interest was structural racism within each US state, a measure constructed in previous work [21, 22]. State-level indicators included prison incarceration and juvenile custody rates; sentencing rates and capital punishment; educational attainment (proportion of population aged 25+ with bachelor's degree or higher); unemployment (proportion of civilian labor force not currently employed); professional occupational status (proportion employed in management, business, science, and arts occupations); and median household income. Structural racism was operationalized as the ratio of relative proportions of blacks to whites for each indicator. For the black representation, we divided the percentage of total seats occupied by black legislators in each state by percentage of that state's population that was black, based on 2010 US Census data.

All structural racism ratios were categorized as low, moderate, or high, based on tertiles. For example, we used the distribution of each of the indicators across the US states to identify thresholds at the 33rd and 66th percentiles to categorize the states into low, moderate, and high. For indicators, such as the ratio of relative proportions of blacks to whites with a bachelor's degree or higher or proportion employed in management, the categories were reverse coded so that the greater tertile category is indicative of greater structural racism. We treated race (black, white) as a moderator and controlled for state-level characteristics (proportion black, proportion in poverty, median income, population size, and census region), and individual-level characteristics (mother's age, marital status, education, nativity, and infant's birth order).

Statistical Analysis

Individual- and state-level characteristics were examined. Infants with missing information were excluded from the analyses. Since mothers and infants were nested within states, we used multilevel logistic modeling to test the association between each state-level structural racism indicator and infant and neonatal mortality. For simplicity, we stratified analyses by mother's race (white vs. black). We tested interaction terms for each indicator of structural racism and black race to determine if racial differences were statistically significant. Interaction terms that included educational attainment ratios were significant when the odds for infant and neonatal mortality were tested.

To investigate the potential effect of structural racism on the likelihood of infant and neonatal mortality, we adopted a step-up approach and conducted three sets of analyses [27]. For each indicator, we first estimated the null model to compute the 95% plausible value range, which measures variability in likelihood of infant and neonatal mortality. It allows us to compute a plausible range of proportions of births ending in infant and neonatal mortality across states. Significant variability by state indicates that state-level factors explain some variability in odds for mortality. Second, crude analyses were conducted to test the association between each of the structural racism indicators and the likelihood of infant and neonatal mortality. Finally, we ran models adjusting for state-level and individual-level socioeconomic characteristics.

Results

Characteristics

In 2010, 2,163,096 white (54.0%) and 590,081(14.7%) black infants were born in the US. Mothers and infants were excluded from this study if they had missing information (n = 18,837; 0.7%), moved out of state (n = 72,408; 2.6%), or were foreign residents (n = 963; 0.03%). Excluded babies were more likely to have mothers who were black, single, and older. When stratified by race, similar characteristics were associated with the likelihood of being excluded from the investigation, with the exception of marital status. Among black infants, those who had single mothers (OR = 0.88, 95% CI = 0.83, 0.93) were significantly less likely to be excluded from the analyses in comparison to those whose mothers were married. Conversely, among white infants, single mothers (OR = 1.22, 95% CI = 1.18, 95% CI = 1.27) were significantly more likely to be excluded from the study in comparison to mothers who were married. Compared to those born in New England, those born in the South Atlantic, Mountain, and Pacific census regions were more likely to be excluded, while those from the Mid-Atlantic, East North Central, West North Central, and West South Central were less likely to be excluded. Compared to infants who were first-born, those excluded were also less likely to be second- or third-born, but more likely to be fourth-born or later.

Characteristics of the infants and their mothers can be found in Table 1. Of all 2010 births, 38.6% of mothers were single, 92.1% were US-born, and 12.4% did not complete high school. Average maternal age was 27.7 years (SD = 6.0). A significantly greater proportion of black mothers were single, foreign-born, and educated below high school level, compared to white mothers.

Variability in socioeconomic characteristics was considerable across states (Table 1). The state-level median income was $51,385, with a standard deviation (SD) of $8,376 and a range of $37,838 to $70,976. Values of structural racism indicators also varied widely across states. For example, the average ratio of relative proportions of blacks to whites with a college degree in a state was 0.65 (SD = 0.26) and ranged

Table 1 Characteristics of white and black mothers who gave birth to infants and of US states and the District of Columbia in 2010

	All mothers		White mothers		Black mothers
Characteristic	*n*	%	*n*	%	*n*
Marital status					
Single	1,027,194	38.6	609,127	29.2	418,067
Couple	1,634,287	61.4	1,477,742	70.8	156,545
Nativity	2,661,481		2,086,869		574,612
Foreign born	210,405	7.9	131,526	6.3	78,879
US born	2,451,076	92.1	1,955,343	93.7	495,733
Education					
Less than high school	329,539	12.4	207,374	9.9	122,165
High school	692,051	26.0	493,453	23.6	198,598
Post high school	1,639,891	61.6	1,386,042	66.4	253,849
Birth order					
1st born	904,096	34.0	726,461	34.8	177,635
2nd born	746,952	28.1	606,890	29.1	140,062
3rd born	463,517	17.4	364,617	17.5	98,900
4th or more	546,916	20.5	388,901	18.6	158,015
Census division					
New England	115,893	4.4	102,734	4.9	13,159
Mid Atlantic	335,100	12.6	259,984	12.5	75,116
South Atlantic	554,455	20.8	363,943	17.4	190,512
East North Central	465,166	17.5	376,880	18.1	88,286
East South Central	205,381	7.7	149,232	7.2	56,149
West North Central	221,537	8.3	197,484	9.5	24,053
West South Central	304,156	11.4	224,309	10.7	79,847
Mountain	185,977	7.0	174,092	8.3	11,995
Pacific	273,816	10.3	238,211	11.4	35,605
Mortality					
Infant (within 12 months)	16,463	0.62	10,145	0.49	6318
Neonatal (within 28 days)	10,526	0.40	6528	0.31	3998
	Mean	SD	Mean	SD	Mean
Mother's age (years)	27.7	6.0	28.2	5.9	25.9
State-level characteristic	Mean	SD	Min	Max	
Population	5,699,069	6,572,937	563,626	37,253,956	
Median income	$51,385.18	$8,376.04	$37,838.00	$70,976.00	
Proportion African-American	12.1	11.1	0.8	52.2	
Proportion living in poverty	14.8	3.1	8.3	22.4	
Registered to vote (total) ratio	0.92	0.16	0.51	1.15	
Registered to vote (citizens) ratio	0.92	0.12	0.6	1.14	
Voted (total) ratio	0.91	0.18	0.53	1.21	
Voted (citizens) ratio	0.92	0.13	0.58	1.16	
Labor force ratio	0.99	0.10	0.70	1.24	
Employed ratio	0.91	0.11	0.59	1.25	
Management ratio	0.65	0.26	0.19	1.70	
Professional ratio	0.78	0.20	0.17	1.10	
Higher education ratio	0.65	0.16	0.28	1.10	
Black representation ratio	0.65	0.43	0	1.77	
Death row ratio	4.33	3.47	0	12.19	
Incarcerated ratio	6.27	2.34	2.5	11.80	

Table 1 (continued)

Characteristic	All mothers		White mothers		Black mothers
	n	%	*n*	%	*n*
Juvenile custody ratio	8.41	4.28	0	24.89	
Black disenfranchisement ratio	7.73	6.28	0	24.87	
Median household income ratio	0.64	0.09	0.39	0.85	

from 0.28 to 1.10. The average relative proportion ratio of blacks to whites with a college degree ranged from 0.28 (high structural racism) in Washington, DC, to 1.10 (low structural racism) in North Dakota.

Infant and Neonatal Mortality

Among births in our sample, 16,463 (0.62%) resulted in infant death and 10,526 (0.40%) in neonatal death. Proportions of these deaths were significantly higher among blacks than among whites (Table 1), and varied across states. In 2010, the overall predicted probabilities for infant and neonatal mortality were 0.57% and 0.37%, respectively. The plausible value range for each was 0.38–0.86% and 0.25–0.54%, respectively, indicating considerable variation in cumulative incidence across states. The overall predicted variability and plausible value range for infant and neonatal mortality were significantly higher among blacks (infant mortality 1.08; 0.82–1.43; neonatal mortality 0.69; 0.50–0.95) than among whites (infant mortality 0.47; 0.32–0.71; neonatal mortality 0.30; 0.21–0.42). The proportion of infant deaths was highest in the South Atlantic states ($n = 1{,}643$; 0.80%) and lowest in New England ($n = 503$; 0.43%).

Associations Between Structural Racism and Infant and Neonatal Mortality

The relationship between structural racism and infant mortality (Tables 2, 3, 4, and 5) and neonatal mortality (Tables 6, 7, 8, and 9) were determined. Among whites born in 2010, those in states from the second (OR = 1.13, 95% CI 1.05, 1.23) and third (OR = 1.11, 95% CI 1.02, 1.21) tertiles of median income ratio were significantly more likely to experience infant death compared to those born in the lowest tertile states (Table 4). Conversely, whites born in states with the lowest tertile of ratio of black to white voters in the state (higher structural racism) were significantly less likely to experience neonatal death (OR = 0.87, 95% CI 0.77, 0.96) compared to whites born in the highest tertile states (Table 6).

Among black infants born in 2010, those in the states with the second (OR = 1.12, 95% CI 0.94, 1.32) and third (OR = 1.25, 95% CI 1.03, 1.52) lowest tertiles of ratio of proportion of blacks with a college degree, which is indicative of higher structural racism, were more likely to experience infant mortality in comparison to those born in the highest tertile states (Table 4). Similarly, black infants in the states from the second (OR = 1.24, 95% CI 0.98, 1.57) and third (OR = 1.35, 95% CI 1.04, 1.76) tertiles of ratio of proportion of blacks with a college degree were at greater odds of neonatal mortality (Table 8).

Higher state-level relative proportion ratio of blacks to whites sentenced to death (higher structural racism) was associated with elevated risk for infant and neonatal mortality among both whites and blacks (Tables 5 and 9). However, the interaction term was not significant, revealing no significant heterogeneity by race in the relationship between the capital punishment indicator of structural racism and infant/neonatal mortality.

Discussion

Our findings suggest that state-level structural racism related to education and incarceration is a risk factor for infant and neonatal mortality. When education was used as an indicator, adverse effects were found among blacks but not among whites after controlling for individual-level characteristics such as mother's age and education, and state-level factors such as median income and percent in poverty. When the capital punishment indicator was used, an adverse association with infant and neonatal mortality for black and white babies was found.

These results corroborate a recent ecological study that found that decreased racial inequity in educational attainment was associated with an almost 10% reduction in the black infant mortality rate measured at the population level [21]. Our findings also echo those from an observational study suggesting that racial disparities in education and income were related to increased odds for babies being born small for gestational age [22]. In addition, we observed that blacks born in states with higher relative proportions of blacks to whites sentenced to death (elevated structural racism) were at greater risk for infant mortality compared to blacks born in states with low relative proportions of blacks to whites sentenced to death. This current study improves upon previous work by employing individual-level mortality data to determine the relationship between structural racism and odds for infant

Table 2 The adjusted association between political participation indicators of structural racism and infant mortality stratified by white and black American infants born in 2010

	Whites	Blacks	Whites	Blacks	Whites	Blacks	Whites	Blacks	Whites	Blacks
Area-level exposures	OR 95% CI	OR 95% CI	OR 95% CI	OR 95% CI	OR 95% CI	OR 95% CI	OR 95% CI	OR 95% CI	OR 95% CI	OR 95% CI
Registered to vote ratio (all)										
Low (ref)	1.00	1.00								
Moderate	1.05 (0.97, 1.12)	1.03 (0.92, 1.14)								
High	1.03 (0.95, 1.11)	1.03 (0.91, 1.15)								
Registered to vote ratio (citizens)			1.00							
Low (ref)			1.04 (0.96, 1.11)	1.00						
Moderate			1.00 (0.92, 1.08)	1.01 (0.91, 1.12)						
High				1.04 (0.91, 1.18)						
Voted ratio (all)										
Low (ref)					1.00	1.00				
Moderate					1.03 (0.96, 1.10)	1.04 (0.93, 1.15)				
High					0.98 (0.88, 1.08)	1.01 (0.85, 1.19)				
Voted ratio (citizen)										
Low (ref)							1.00	1.00		
Moderate							1.00 (0.94, 1.06)	1.06 (0.96, 1.15)		
High							0.93 (0.85, 1.01)	1.02 (0.87, 1.18)		
Black representation										
Low (ref)									1.00	1.00
Moderate									1.02 (0.94, 1.11)	0.88 (0.81, 0.97)
High									0.98 (0.90, 1.07)	1.03 (0.90, 1.18)

Table 3 The adjusted association between labor indicators of structural racism and infant mortality stratified by white and black American infants born in 2010

	Whites		Blacks		Whites		Blacks		Whites		Blacks		Whites		Blacks	
Area-level exposures	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI
Labor force ratio																
Low (ref)	1.00		1.00													
Moderate	0.98	(0.89, 1.06)	1.00	(0.88, 1.12)												
High	0.97	(0.87, 1.07)	1.04	(0.87, 1.23)												
Employed ratio																
Low (ref)					1.00		1.00									
Moderate					0.99	(0.91, 1.07)	1.00	(0.88, 1.13)								
High					1.01	(0.90, 1.13)	0.99	(0.83, 1.17)								
Management ratio																
Low (ref)									1.00		1.00					
Moderate									1.01	(0.92, 1.09)	0.90	(0.81, 0.98)				
High									1.00	(0.92, 1.08)	0.99	(0.90, 1.10)				
Professional employment ratio																
Low (ref)													1.00		1.00	
Moderate													0.97	(0.90, 1.05)	0.96	(0.86, 1.06)
High													1.00	(0.91, 1.09)	1.05	(0.92, 1.19)

Table 4 The adjusted association between socioeconomic indicators of structural racism and infant mortality stratified by white and black American infants born in 2010

	Whites		Blacks		Whites		Blacks	
Area-level exposures	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI
Higher education attainment ratio								
Low (ref)	1.00		1.00					
Moderate	1.00	(0.89, 1.10)	1.12	(0.94, 1.32)				
High	1.03	(0.92, 1.15)	1.25	(1.03, 1.51)				
Household income ratio								
Low (ref)					1.00		1.00	
Moderate					1.13	(1.04, 1.22)	1.09	(0.96, 1.23)
High					1.11	(1.01, 1.20)	1.08	(0.93, 1.24)

and neonatal mortality. It is innovative in that it is, to our knowledge, the only study to examine how state-level structural racism across a variety of domains is associated with these adverse birth outcomes.

Racial disparities in maternal education were found to be a significant risk factor for infant and neonatal mortality among black babies. Although college completion rates in the US have risen, achievement gaps remain. As of 2015, nearly half of white women aged 25–35 had a college degree, while just 35% of their black counterparts had reached that same level [28]. These achievement gaps stem from policies rooted in anti-literacy laws from the days of slavery and to the once legally sanctioned segregated and unequal schools. Additionally, social norms and a lack of federal intervention in educational funding have kept higher education disproportionately attainable for whites [29]. In many parts of the US, the vestiges of discriminatory laws and entrenched attitudes have kept many blacks from pursuing a college degree even today [29]. For example, many primary schools still remain racially segregated as a result of residential segregation [30].

Affirmative action programs have been implemented to advance equality of educational opportunity for individuals from groups that have experienced systematic historical discrimination [31]. The current federal administration has abandoned its predecessor's urging of universities to consider race as a factor in diversifying campuses. As a result, these practices may no longer be in place to decrease racial disparities in college educational attainment, with potentially harmful consequences for maternal and infant health.

Limiting access to education might have serious health consequences not only for women themselves, but for their children as well. According to the WHO, education is the first step in ensuring that women realize their full potential; it is critical in empowering women with the knowledge, skills, and confidence necessary to fully participate in their health and well-being [32]. Education, over and above income and

Table 5 The adjusted association between judicial indicators of structural racism and infant mortality stratified by white and black American infants born in 2010

	Whites		Blacks		Whites		Blacks		Whites		Blacks	
	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI
Capital punishment ratio												
Low (ref)	1.00		1.00									
Moderate	1.09	(1.02, 1.16)	1.21	(1.11, 1.33)								
High	1.09	(1.00, 1.18)	1.15	(1.01, 1.31)								
Incarceration ratio												
Low (ref)					1.00		1.00					
Moderate					1.02	(0.91, 1.13)	1.06	(0.92, 1.22)				
High					1.06	(0.94, 1.19)	0.96	(0.80, 1.14)				
Disenfranchisement												
Low (ref)									1.00		1.00	
Moderate									0.99	(0.91, 1.97)	1.03	(0.90, 1.18)
High									0.93	(0.85, 1.01)	1.01	(0.88, 1.17)

Table 6 The adjusted association between political participation indicators of structural racism and neonatal mortality stratified by white and black American infants born in 2010

	Whites		Blacks		Whites		Blacks		Whites		Blacks		Whites		Blacks	
Political participation indicators	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI
Registered to vote ratio (all)																				
Low (ref)	1.00		1.00																	
Moderate	1.07	(0.96, 1.18)	1.09	(0.94, 1.25)																
High	1.02	(0.91, 1.12)	1.08	(0.91, 1.26)																
Registered to vote ratio (citizens)																				
Low (ref)					1.00		1.00													
Moderate					1.03	(0.93, 1.13)	1.08	(0.94, 1.24)												
High					0.95	(0.84, 1.05)	1.11	(0.93, 1.31)												
Voted ratio (all)																				
Low (ref)									1.00		1.00									
Moderate									1.04	(0.95, 1.14)	1.07	(0.92, 1.23)								
High									0.93	(0.81, 1.06)	1.05	(0.83, 1.30)								
Voted ratio (citizen)																				
Low (ref)													1.00		1.00					
Moderate													1.01	(0.93, 1.08)	1.06	(0.93, 1.20)				
High													0.87	(0.77, 0.96)	0.96	(0.78, 1.17)				
Black representation																				
Low (ref)																	1.00		1.00	
Moderate																	1.04	(0.93, 1.16)	0.83	(0.73, 0.94)
High																	0.97	(0.85, 1.10)	0.99	(0.83, 1.18)

Table 7 The adjusted association between labor indicators of structural racism and neonatal mortality stratified by white and black American infants born in 2010

	Whites		Blacks		Whites		Blacks		Whites		Blacks		Whites		Blacks	
Labor indicators	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI
Labor force ratio																
Low (ref)	1.00		1.00													
Moderate	0.98	(0.86, 1.11)	0.95	(0.80, 1.12)												
High	0.93	(0.81, 1.07)	0.90	(0.70, 1.14)												
Employed ratio																
Low (ref)					1.00		1.00									
Moderate					0.98	(0.87, 1.10)	0.95	(0.80, 1.12)								
High					1.00	(0.86, 1.17)	0.89	(0.70, 1.12)								
Management ratio																
Low (ref)									1.00		1.00					
Moderate									0.98	(0.86, 1.10)	0.85	(0.73, 0.97)				
High									1.01	(0.90, 1.13)	0.96	(0.82, 1.10)				
Professional employment ratio																
Low (ref)													1.00		1.00	
Moderate													0.94	(0.84, 1.05)	0.91	(0.78, 1.04)
High													0.94	(0.83, 1.06)	0.98	(0.81, 1.16)

occupation, might have a more beneficial impact on the health of women and their children. Addressing the parallel racial inequity in women's post-secondary educational attainment could result in a shrinking of the race-based disparity in infant mortality risk.

Several mechanisms through which structural racism might influence infant mortality risk have been proposed. Structural racism could limit blacks' access to resources necessary for optimal health. Resources include avenues to employment, healthcare and health services, and affordable and safe housing—all determinants of health that could impact birth outcomes [18]. Second, structural racism might directly and indirectly (through racial prejudice and discrimination) increase stress and anxiety [33]. One study examined structural racism in the form of racial segregation and its association with self-reported stress among a cohort of pregnant

Table 8 The adjusted association between socioeconomic indicators of structural racism and neonatal mortality stratified by white and black American infants born in 2010

	Whites		Blacks		Whites		Blacks	
Socioeconomic indicators	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI
Higher education attainment ratio								
Low (ref)	1.00		1.00					
Moderate	0.99	(0.86, 1.14)	1.24	(0.97, 1.56)				
High	1.03	(0.88, 1.20)	1.35	(1.03, 1.76)				
Household income ratio								
Low (ref)					1.00		1.00	
Moderate					1.08	(0.96, 1.22)	1.14	(0.95, 1.35)
High					1.05	(0.91, 1.20)	1.13	(0.93, 1.38)

Table 9 The adjusted association between judicial indicators of structural racism and neonatal mortality stratified by white and black American infants born in 2010

	Whites		Blacks		Whites		Blacks		Whites		Blacks	
Judicial indicators	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI
Capital punishment ratio												
Low (ref)	1.00		1.00									
Moderate	1.13	(1.04, 1.22)	1.24	(1.08, 1.43)								
High	1.17	(1.06, 1.30)	1.20	(0.99, 1.46)								
Incarceration ratio												
Low (ref)					1.00		1.00					
Moderate					1.00	(0.86, 1.16)	0.90	(0.73, 1.12)				
High					1.04	(0.88, 1.23)	0.90	(0.70, 1.14)				
Disenfranchisement												
Low (ref)									1.00		1.00	
Moderate									0.99	(0.88, 1.10)	1.05	(0.87, 1.26)
High									0.88	(0.79, 0.98)	1.01	(0.84, 1.22)

American women. Researchers observed that some forms of segregation are associated with self-reported stress [33]. These adverse psychological mediators could potentially lead to greater risk for infant mortality.

We also found evidence that states with high structural racism in terms of death row ratio was a significant risk factor for infant and neonatal mortality among both races in our sample. Blacks are disproportionately represented on death row and among those executed. Blacks comprise 13% of the US population, but 42% of death row inmates and 35% of those put to death [34]. This discrepancy could be a marker of discrimination in policing or in sentencing, and warrants serious criminal justice reform. This form of structural racism can have detrimental effects on the psychological well-being of the public, especially among black mothers, thereby harming their physical health and that of their infants.

This study's findings must be interpreted with acknowledgment of several limitations. First, there could be residual confounding, since we did not have mothers' income information. Household income might act as a confounder of the relationship between structural racism and infant mortality. Since the data for this investigation were not initially gathered for research purposes, they could be subject to some misclassification. Nevertheless, the validity of the mortality data is very high. We acknowledge that there could be differences in mothers exposed to structural racism and those not exposed that might explain the relationship between structural racism and infant mortality. Finally, infants and mothers with missing information and those whose state at birth and current residence differed were excluded from the analyses, exclusions that might not be random, possibly leading to selection bias. Regardless of these limitations, the implications of this investigation are meaningful, and this study has many strengths. This investigation is one of the first to examine structural racism in several domains, and related to infant and neonatal mortality. It is also among the first to use nationally representative, individual-level outcome data.

In conclusion, this novel, multilevel study found that state-level structural racism in education and incarceration is significantly associated with increased odds of neonatal and infant mortality for blacks compared to whites after controlling for socioeconomic factors. While individual factors contribute to disparities in these outcomes, this study highlights how legal and contextual factors create enduring structural barriers to optimal health for blacks in the US. Our findings suggest that, in order to address racial disparities in health within the US, we need to directly address social inequalities that are a product of structural racism, such as unequal access to higher education. Future research should investigate the mechanisms through which structural racism influences infant health and should evaluate policies and interventions implemented to decrease this racial disparity. Studies should also include measures of structural racism on a spatio-temporal scale, perhaps at a smaller area-level unit (e.g., counties or cities), since focusing at the state-level might not capture nuanced variation.

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Compliance with Ethical Standards

Conflict of Interest The authors declare that they have no conflict of interest.

Ethical Approval This article does not contain any studies with human participants or animals performed by any of the authors.

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