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Racial Disparities in Gestational Age-Specific Infant Mortality Among College-Educated Women

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An abstract of
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Abstract

Racial Disparities in Gestational Age-Specific Infant Mortality Among College-Educated Women

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Objective: To evaluate whether differences in gestational age-specific mortality explain racial disparities in infant mortality seen among non-anomalous infants born to college-educated women in the United States.

Methods: In this population-based retrospective cohort study, we linked 2016 and 2017 birth cohort and infant death datasets from the National Center for Health Statistics (NCHS) of the Centers for Disease Control and Prevention (CDC). Our outcome of interest was infant death as a dichotomized variable. Our primary exposure was maternal race (non-Hispanic Black [NHB], non-Hispanic White [NHW]). We used multivariable logistic regression models to evaluate associations between maternal race and infant death for women with at least some college education, with and without adjustment for covariates (education level beyond high school, marital status, age, live birth order, timing of prenatal care).

Results: The sample included 2,961,752 liveborn infants (37.9%) born in 2016 or 2017; 14.4% of infants were born to college-educated NHB mothers and 85.7% were born to college-educated NHW mothers. Infants born to college-educated NHB mothers had twice the odds of death after controlling for maternal age, marital status, parity, prenatal care, and education (aOR: 2.017; 95% CI: 1.923 – 2.116). The adjusted odds ratios remained significant when stratifying by gestational age, with worse outcomes for infants born to NHB mothers at < 32 weeks (aOR: 1.411; 95% CI: 1.316 – 1.514), 37 – 40 weeks (aOR: 1.267; 95% CI: 1.161 – 1.382), and 41 weeks or greater (aOR: 1.367; 95% CI: 1.097 – 1.703). Comparing standardized gestational ages, infants born to NHB mothers had greater odds of death up to 1 standard deviation above the mean.

Conclusion: Despite education being a protective factor for infant mortality, racial disparities in infant mortality exist among highly educated women and cannot be explained by individual-level maternal characteristics or differential distribution of gestational age at birth among infants born to NHB and NHW women.

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Racial Disparities in Gestational Age-Specific Infant Mortality Among College-Educated Women

CHAPTER I: LITERATURE REVIEW

Infant mortality, defined as the death of an infant between birth and his or her first birthday,[1] is an important global indicator of sustainability and development.[2] The leading medical causes of infant deaths have remained largely unchanged over recent decades[3] and include congenital malformations, disorders related to short gestation and low birth weight, maternal complications, sudden infant death syndrome, and unintentional injuries.[3,4]

Infant mortality rates in the United States have declined since 1995.[4,5] The US infant mortality rate was 7.6 deaths per 1,000 live births in 1995,[5] compared to a recent historic low of 5.67 infant deaths per 1,000 live births in 2018.[4] However, when compared to other OECD nations, the US consistently ranks among the worst for infant mortality.[6] In 2017, the United States ranked 33rd for infant mortality, with rates only better than 5 other current OECD nations.[6] These differences are only partially explained by country-level variations in preterm birth rates and gestational-age specific mortality.[7] Other proposed factors include misclassification and underreporting of infant deaths and variations in definitions of live births and infant deaths, which limit global comparisons.[8] Gonzalez and Gilleskie in 2017 found that 33 to 50% of late fetal deaths, defined as from 22 weeks of gestation to birth, should be classified instead as early neonatal deaths, which begins at birth of the fetus and includes the first week.[8] In addition, the proportion of fetal deaths resulting from live births with low birth weights less than 1000 grams[9] or at very early gestational ages (< 22 weeks)[10] varies considerably internationally due to country-specific birth registration practices.[9,10] Differential classification results in lower infant mortality rates because low birth weight or early gestational age deaths may be automatically excluded for certain countries[9] and fetal deaths that are reported as late, instead of as early neonatal deaths, are not included in the calculation of infant mortality rates.[8]

Despite the recent decline in infant mortality rates in the United States, troubling racial disparities persist.[4,11] Infants born to non-Hispanic Black women had the highest mortality rates with 10.75 infant deaths per 1,000 live births in 2018, compared to 4.63 infants deaths per 1,000 live births for infants born to non-Hispanic White women.[4] This racial gap has remained stable over 5 decades.[12]

Higher maternal education is associated with lower overall infant mortality rates,[13] yet racial disparities are still present among infants born to college-educated women.[14] In fact, racial disparities in infant mortality are greater in the high-education subpopulation, than in the less-educated subpopulation.[13] The relative risk for infant mortality is 1.63 (95% CI 1.51 – 1.75) for females and 1.61 (95% CI 1.52 – 1.69) for males born to lower-educated African Americans, compared to European Americans.[13] In contrast, the relative risk for infant mortality is 2.46 (95% CI 2.21 – 2.71) for females and 2.57 (95% CI 2.36 – 2.81) for males born to African American versus European in the more educated subgroup.[13]

Racial differences in infant mortality among college-educated women may reflect differential distribution of very low birth weight (VLBW) infants.[14,15] VLBW infants are those that weigh less than 1500 grams at delivery, are almost always born preterm, and are more prevalent among infants born to Black women, as compared to White women, even after controlling for socioeconomic and behavioral factors,[15] and college education.[14] Thus, it is important to consider whether the racial disparity in infant mortality among infants born to college-educated mothers is attributable to factors leading to preterm birth or overall risk or both.

Most racial disparities between infants born to non-Hispanic Black or non-Hispanic White women are attributed to preterm related causes.[16] Black race is associated with twice the odds of preterm birth, compared with White race.[17] When assessing the relative contribution of preterm birth and gestational age-specific mortality rates to disparities in infant mortality rates, differences in preterm birth rates accounted for 78% of the difference.[16] These findings result from a complex interaction of racial differences in sociodemographic, geographic, health,[18] biological, and genetic factors.[19] Co-authors Kramer and Hogue developed a conceptual model to better explain the association between race and the outcome of very preterm birth, an extreme category of preterm birth, defined as birth at 32 weeks of gestation or less.[20] In this model, primary proximate biologic pathways that directly impact very preterm birth include uteroplacental vascular dysfunction, placental and maternal hypothalamic-pituitary-adrenal-axis dysfunction, and maternal-fetal inflammation.[20] Maternal stress (acute, chronic, or early-life), preconception health status, and genotype/epigenetic modification of risk, are intermediaries between race and these biologic pathways, and are affected by interpersonal and institutionalized racism.[20] Their literature findings depict how differential exposures to psychosocial stress, from conditions such as poverty, discrimination, abuse, and high-crime environments, result in immune and neuroendocrine dysfunction and contribute to racial disparities in very preterm births.[20]

Differences in gestational age-specific mortality rates account for the remaining 22% of disparities in infant mortality rates for infants born to non-Hispanic Black women compared to those born to non-Hispanic White women, primarily at later gestational ages (34 weeks or more).[16] The nature of this disparity, at earlier gestational ages, varies depending on how infant mortality rates are examined.[21-23] In a retrospective study of infant deaths in California from

2007-2012, Anderson and co-authors found that Black infants born at 22 – 25 weeks had significantly *lower* mortality than non-Hispanic White infants (OR 0.76, 95% CI 0.62 – 0.94).[21] In contrast, non-Hispanic Black infants born at 32 – 34 weeks and 35 – 36 weeks were significantly *more* likely to die than non-Hispanic White infants (OR 1.64, 95% CI 1.15 – 2.32; OR 1.57, 95% CI 1.00 – 2.24, respectively).[21] Chen and co-authors performed a similar evaluation using 2000 to 2004 birth cohort linked data from the National Center for Health Statistics and found that, when compared to non-Hispanic White infants, non-Hispanic Black infants had higher adjusted infant mortality rates at 28 – 31 weeks (RR 1.14, 95% CI 1.05 – 1.24), 34 – 36 weeks (RR 1.36, 95% CI 1.25 – 1.47), and ≥ 37 weeks (RR 1.54, 95% CI 1.48 – 1.59).[22] There were no statistical differences in infant mortality rates overall at 24 – 27 weeks and 32 – 33 weeks.[22]

Gestational age-specific infant mortality rates, such as for those preterm, might be explained by potentially rare and unmeasured confounding factors that are harmful to the fetus and cause the delivery itself.[24,25] Although gestational age at birth is a strong predictor of infant mortality, analyses which adjust for this factor may block its effects and produce biased results.[25] Wilcox and co-authors illustrate this point in a 2011 publication using an example of mortality risk for twins; adjusting for gestational age in this case resulted in the reversal of risk, suggesting an unlikely protective effect of twinning.[25] Hertz-Picciotto and Din-Dzietham recommend plotting infant mortality rates as a function of each *percentile* of gestational age at birth, rather than gestational age itself, in order to evenly distribute the population of births for each race along the curve.[23] When infant mortality rates were analyzed in this way, an apparent survival advantage seen for African Americans born at earlier gestational ages was no longer present.[23]

In fact, rates were uniformly higher across gestational age percentiles for African American infants, as compared to European American infants.[23]

Gestational age-specific infant mortality rates may overestimate the impact of gestational age itself until we better identify additional rare and unmeasured confounding factors which lead to the delivery itself.[24] Nevertheless, comparing gestational age-specific infant mortality is better than comparing birth weight-specific infant mortality rates.[26] The relationship between birth weight and mortality is not completely causal and may also reflect confounding factors.[27] Higher risk infants, such as those born to smokers, have lower mortality than lower risk infants, such as those born to nonsmokers, at the same birth weight.[27] There is also evidence to suggest that birth weight does not wholly explain the relationship between infant mortality and maternal education; other determinants such as gestational age may play a role.[13] Therefore, duration of pregnancy might be a better measure to compare infant mortality[26] and to understand racial disparities by maternal education.

PURPOSE

Data are lacking to examine whether differences in gestational age-specific mortality explain any of the racial disparities in infant mortality seen among infants born to college-educated women in the United States. The purpose of this study is to compare gestational age-specific mortality among non-anomalous infants born to college-educated non-Hispanic Black and non-Hispanic White women with singleton pregnancies in 2016 - 2017 in the United States.

PUBLIC HEALTH PURPOSE

To inform strategies that can be used to address racial disparities in infant mortality.

CHAPTER II: JOURNAL ARTICLE

ABSTRACT

Objective: To evaluate whether differences in gestational age-specific mortality explain racial disparities in infant mortality seen among non-anomalous infants born to college-educated women in the United States.

Methods: In this population-based retrospective cohort study, we linked 2016 and 2017 birth cohort and infant death datasets from the National Center for Health Statistics (NCHS) of the Centers for Disease Control and Prevention (CDC). Our outcome of interest was infant death as a dichotomized variable. Our primary exposure was maternal race (non-Hispanic Black [NHB], non-Hispanic White [NHW]). We used multivariable logistic regression models to evaluate associations between maternal race and infant death for women with at least some college education, with and without adjustment for covariates (education level beyond high school, marital status, age, live birth order, timing of prenatal care).

Results: The sample included 2,961,752 liveborn infants (37.9%) born in 2016 or 2017; 14.4% of infants were born to college-educated NHB mothers and 85.7% were born to college-educated NHW mothers. Infants born to college-educated NHB mothers had twice the odds of death after controlling for maternal age, marital status, parity, prenatal care, and education (aOR: 2.017; 95% CI: 1.923 – 2.116). The adjusted odds ratios remained significant when stratifying by gestational age, with worse outcomes for infants born to NHB mothers at < 32 weeks (aOR: 1.411; 95% CI: 1.316 – 1.514), 37 – 40 weeks (aOR: 1.267; 95% CI: 1.161 – 1.382), and 41 weeks or greater (aOR: 1.367; 95% CI: 1.097 – 1.703). Comparing standardized gestational ages, infants born to NHB mothers had greater odds of death up to 1 standard deviation above the mean.

Conclusion: Despite education being a protective factor for infant mortality, racial disparities in infant mortality exist among highly educated women and cannot be explained by individual-level maternal characteristics or differential distribution of gestational age at birth among infants born to NHB and NHW women.

INTRODUCTION

Infant mortality, defined as the death of an infant between birth and his or her first birthday,[1] is an important global indicator of development.[2] Despite recent declines in infant mortality rates –since 1995– in the United States, troubling racial disparities persist.[4,11] Infants born to non-Hispanic Black women had the highest mortality rates with 10.75 infant deaths per 1,000 live births in 2018, compared to 4.63 infant deaths per 1,000 live births for infants born to non-Hispanic White women.[4] This racial gap has remained stable over 5 decades.[12]

When assessing the relative contributions of preterm birth and gestational age-specific mortality rates to racial disparities in infant mortality rates, differences in preterm birth rates account for 78% of the difference.[16] Differences in gestational age-specific mortality rates account for the remaining 22% of disparities in infant mortality rates for infants born to non-Hispanic Black women compared to those born to non-Hispanic White women, primarily at later gestational ages (34 weeks or more).[16]

Higher maternal education is typically protective against maternal mortality and traditionally associated with lower overall infant mortality rates,[13] yet racial disparities are still present among infants born to college-educated women.[14] In fact, racial disparities in infant mortality are greater in the high-education subpopulation than in the less-educated subpopulation.[13]

The purpose of this study is to evaluate whether differences in gestational age-specific mortality explain the racial disparities in infant mortality seen among non-anomalous infants born to college-educated non-Hispanic Black and non-Hispanic White women in the United States.

METHODS

This was a population-based retrospective cohort study using the 2016 and 2017 birth cohort linked/infant death data sets from the Centers for Disease Control and Prevention (CDC) National Center for Health Statistics (NCHS). These data are based on linked birth and infant death certificates for infants under 1 year of age who died in the 50 United States, the District of Columbia, Puerto Rico, and Guam.[4] In 2017, 99.6% of infant death records were successfully linked to their 2016 birth records.[5] In 2018, 99.3% of infant death records were successfully linked to 2017 birth records.[4] These are publicly available de-identified datasets and do not meet criteria for human subjects' research by the Emory University Institutional Review Board.

We created birth cohort files and combined data for infants born in 2016 and 2017.[28,29] We restricted our study sample to singleton, non-anomalous, births ending at 20 weeks of gestation or greater from U.S. born and U.S. residing women ages 20 years or older; infants born at unknown gestational ages were excluded. Maternal race is self-reported and was restricted to women who identified as non-Hispanic White or non-Hispanic Black races only; those who selected more than one racial category or with unknown racial identities were excluded. We also restricted our study sample to those with known educational status and at least some college credit.

Our outcome of interest was infant death as a dichotomized variable. Our primary exposure was maternal race (non-Hispanic Black, non-Hispanic White). We used the following covariates in the adjusted analyses:

1. **Maternal education** (some college credit but not a degree, associate's degree, bachelor's degree, master's degree, doctorate). Previous literature has established an association between education and infant mortality; infants born to mothers with lower educational attainment are more like to experience death.[13,30] Educational attainment is also associated with both race and gender; a larger proportion of Whites complete college than Blacks.[31] There is also a female advantage in college completion that is most striking among Blacks.[31]
2. **Marital status** (married, unmarried, unknown). Infant mortality rates are higher for unmarried women as compared to married women for both Black and White women.[32] Marital status is also associated with race; Black women have lower rates of marriage than other racial and ethnic groups.[33]
3. **Age** (20 – 24, 25 – 29, 30 – 34, 35 – 39, 40 – 44, 45 – 49, 50 – 54). Younger (<20) and older (40-54) maternal ages are risk factors for increased infant mortality.[30] Previous literature establishes the differential distributions of maternal age at first birth, when examined by racial group.[34] This suggests that race is associated with age at delivery.
4. **Live birth order** (1, 2, 3, 4, 5, 6, 7, 8 or more, unknown). Birth order is associated with infant mortality; among White infants, higher birth order is associated with increased mortality, but this relationship varies for other races.[35] Second or later-born infants are also at increased risk for injury-related mortality during the first year of life, compared to first-born infants.[36] Birth order is related to parity; previous literature has established

associations between race and parity with Black women being more likely to have higher parity as compared to Whites.[37]

5. **Timing of prenatal care initiation** (1^{st} – 3^{rd} month, other). Inadequate prenatal care utilization is a risk factor for adverse perinatal outcomes including infant death.[38] Race is also associated with prenatal care utilization; Black women are more likely to receive late or no prenatal care as compared to White women.[39]

We examined differences in the characteristics between the exposure groups using chi-square tests. We compared the frequency distributions of infant death by gestational age between exposure groups graphically. We chose to also explore models using standardized gestational ages to account for the influence of racial differences in delivery timing. For example, non-Hispanic White women are more likely to have early-term inductions[40] and non-medically indicated inductions of labor at term,[41] while non-Hispanic Black race is a risk factor for late preterm inductions.[40] Therefore, excess non-Hispanic Black infants being delivered at the extremes of gestational age may contribute to racial disparities in infant mortality. Assuming a difference in distribution of infant deaths by gestational age for non-Hispanic Black and non-Hispanic White women, we created a standardized gestational age variable, in which the mean for each exposure group was set to zero and standard deviation set to 1. To evaluate the association between infant death and maternal race, we built several logistic regression models:

Gestational age-specific mortality

We built crude and adjusted-multivariable binomial logistic regression models based on gestational age at birth (completed weeks). The four subgroups included < 32 weeks, 32 – 36 weeks, 37 – 40 weeks, and 41 weeks or greater. We repeated this analysis using 4 standardized gestational age categories, including *more* than 2 standard deviations *below* the mean, 1 – 2 standard deviations *below* the mean (inclusive of those exactly 2 standard deviations below the mean), from 1 standard deviation *below* the mean to 1 standard deviation *above* the mean (inclusive of those exactly 1 standard deviation below the mean), 1 standard deviations *above* the mean or more (inclusive of those exactly 1 standard deviation above the mean).

Overall mortality

We built adjusted multivariable binomial and quadratic logistic regression models for overall infant death, using non-standardized and standardized gestational ages. We included binomial models that adjusted for gestational age alone. We also included quadratic models with both gestational age and (gestational age)^2 terms given the presence of higher infant mortality rates at the extremes of gestational ages.[42-44]

All statistical analyses were performed using SAS 9.4 (SAS Institute, Cary, NC). We also conducted sensitivity analyses to determine whether inclusion of anomalous fetuses affected the association between infant death and maternal race.

Table: Original Variable Names[28,29]

Original Variable Name	**Description**
RESTATUS	Residence Status
MRACEHISP	Mother's Race/Hispanic Origin
NO_CONGEN	No congenital anomalies
MEDUC	Mother's Education
DPLURAL	Plurality
COMBGEST	Gestation (weeks)
MBSTATE_REC	Mother's Nativity

DMAR	Marital Status
MAGER9	Mother's Age
LBO_REC	Live Birth Order
PRECARE5	Month Prenatal Care Began

RESULTS

There were 3,945,875 live births in 2016 and 3,864,754 live births in 2017 recorded in the United States. After application of the exclusion criteria, the final study sample included 1,501,060 infants born in 2016 and 1,460,692 infants born in 2017, for a combined cohort of 2,961,752 liveborn infants (37.9%) (Figure 1). Within the final study sample, 424,918 (14.4%) infants were born to college-educated non-Hispanic Black mothers and 2,536,834 (85.7%) were born to college-educated non-Hispanic White mothers. Maternal characteristics for these groups varied by race (Table 1). Non-Hispanic Black mothers were more likely to: be younger and unmarried; have less than an associate's degree and higher parity; initiate prenatal care after the 3rd month and deliver a preterm or low birth weight infant.

There were 3,157 (0.7%) infant deaths among infants born to college-educated non-Hispanic Black mothers and 6,642 (0.3%) infant deaths among infants born to college-educated non-Hispanic White mothers. These deaths differed by gestational age and race, with a greater percentage of infant deaths among those born at less than 30 weeks to non-Hispanic Black mothers than to non-Hispanic White mothers, but a greater percentage of infant deaths among those born after 30 weeks to non-Hispanic White mothers than to non-Hispanic Black mothers (Figure 2).

Compared with infants born to college-educated non-Hispanic White mothers, those born to non-Hispanic Black mothers had almost three times the odds of death (OR: 2.851; 95% CI: 2.733 - 2.975) (Table 2). Even after controlling for maternal age, marital status, parity, prenatal care, and education, infants born to college-educated non-Hispanic Black mothers had twice the odds of death (aOR: 2.017; 95% CI: 1.923 – 2.116) (Table 2). Except for infants born between 32-36 weeks of gestation, the adjusted odds ratios remained significant when stratifying by gestational age, with worse outcomes for infants born to non-Hispanic Black mothers at < 32 weeks, 37 – 40 weeks, and 41 weeks or greater.

When comparing standardized gestational ages with infants born to non-Hispanic White mothers as the referent category, infants born to non-Hispanic Black mothers had greater odds of death up to 1 standard deviation above the mean (Table 3). The magnitude of the adjusted odds ratio was higher as the value moved further from the mean, with a maximum adjusted odds ratio of 2.842 (95% CI: 2.661 – 3.036) for gestational ages more than two standard deviations *below* the mean (Table 3).

After adjusting for standardized gestational age in the regression equation, infants born to non-Hispanic Black mothers had approximately 2.7 (95% CI: 2.552 – 2.821) and 2.9 (95% CI: 2.731 – 3.025) the odds of dying compared to infants born to non-Hispanic White mothers in the binomial and quadratic models, respectively (Table 4).

Sensitivity analyses (Table 5) including anomalous births were consistent with findings from the primary analyses, with increased odds of death among infants born to college-educated non-Hispanic Black women, compared to those born to college-educated non-Hispanic White women (aOR 1.885; 95% CI: 1.801 – 1.973).

DISCUSSION

Our analysis demonstrates persistent and significant racial disparities in infant mortality among a highly educated population. Infants born to these non-Hispanic Black women have twice the odds of death as compared to those born to their non-Hispanic White counterparts. These findings are not completely explained by differences in the extent of college education, maternal age, marital status, parity, and timing of prenatal care initiation.

We explored two pathways whereby these disparities in infant mortality may be occurring. First, it is well-known that infants born to African American mothers are at greater risk of being born at very low birth weight (<1500g)[15] or low birth weight (<2500g),[45] when compared to infants born to White mothers. Further, disorders related to short gestation and low birth weight are the leading cause of death for infants born to non-Hispanic Black women, with mortality rates of 247.5 per 100,000 live births in 2018, compared to 62.1 among infants born to non-Hispanic White women.[5] Previous studies attributed racial disparities in infant mortality among women with college degrees to differences in the risk of very low or low birth weight.[13,14] The risk of low birth weight improves with maternal education, but less so for non-Hispanic Black women.[13] In our study cohort, which also utilizes nationally representative data, but for more recent years, we also found higher percentages of low birth weight infants among non-Hispanic Black women. For women with complete information on birth weight, the adjusted odds for very low birth weight and low birth weight infants were 3.240 (95% CI: 3.149 - 3.334) and 2.238 (95% CI: 2.210 - 2.267), respectively, comparing non-Hispanic Black to White women.

The second pathway we explored was mortality *within* gestational age categories (i.e. < 32, 32 – 36, 37 – 40, 41+ completed weeks). We found that racial disparities persisted when examining mortality within gestational age categories. Adjusted odds ratios for mortality were largest for the extreme gestational age categories (<32 and 41+) at 1.4, comparing non-Hispanic Black to White women. This differs from previous analyses which reported *decreased* mortality for infants born to non-Hispanic Black mothers[21] or no significant difference[22] at the lowest gestational age categories, likely attributed to a difference in categorization. Similar to our analysis, these studies reported greater risk or odds of death among non-Hispanic Black infants at 32 weeks and greater.[21,22]

Racial disparities persisted in models comparing standardized gestational ages, with adjusted odds ratio values ranging from 1.4 for gestational ages 2 standard deviations below the mean and higher, up to 2.8 for gestational ages more than 2 standard deviations below the mean. These findings suggest that the racial disparities in infant mortality cannot be explained only by the differential distribution of gestational age at birth among infants born to non-Hispanic Black and non-Hispanic White women.

The persistence of Black-White disparities in the distribution of low birth-weight infants, short gestation, and gestation-specific infant mortality – despite high educational attainment – has not been adequately explained by differences in traditional measures of geographic, sociodemographic, and health characteristics between these populations.[18] This highlights the potential role of other factors such as societal inequities and early health deterioration (‘weathering’) which are influenced by ongoing discrimination of African Americans in the U.S.[46,47] Supporting this hypothesis, a previous study of racial differences in low birth weight found nativity differences in birth weight patterns such that infants born to African-born Black women were more comparable to those born to US-born White women than those born to US-born Black women.[48] Moreover, a follow-up study that examined intergenerational birth weight patterns found racial differences based on nativity status of the first generation.[49] Mean birth weight increased more for US and European-born White women than US born African American women and decreased for foreign-born African American women.[49]

Social contextual factors may be more influential mediators of racial disparities than genetic factors.[47,48] In particular, factors that are unique to the minority experience within the United States, including negative consequences from barriers to equitable health care access, employment, housing, economic opportunity, excess stress, environmental pollutants, violence, and lack of social support may be unmeasured confounders that explain the identified differences in infant mortality.[47] For example, Collins and co-authors demonstrated increased odds for lifetime exposure to interpersonal racism among women who delivered very low birth weight infants, compared to controls, across various sociodemographic, biomedical, and behavioral risk categories.[50] In this study, the association was strongest among college-educated women.[50]

Disparities in health care quality associated with implicit or explicit bias may also explain differences in gestation-specific infant mortality. Greenwood et al. examined the impact of physician-newborn racial concordance on infant mortality and found improvements in mortality among Black infants when treated by Black physicians,[51] thus proposing the idea of disparate care as a contributing factor to racial disparities in infant mortality. This idea has been explored in previous publications which have identified disparities in access to effective clinical treatment,[52,53] quality care including appropriate staffing and hospital acuity level,[53] and perceptions of neglect, judgment and systemic barriers[54]; in most cases, these health care differences negatively impact Black infants.[53]

We also noted racial disparities among infants with congenital anomalies in our sensitivity analyses. Infants with congenital anomalies comprised 0.5% of all infants born in the

United States from 2016 to 2017 and 0.2% and 0.4% of infants born to college-educated non-Hispanic Black women and non-Hispanic White women, respectively, in our sample population. When including this population in the analysis, the magnitude of the disparity in infant mortality decreased, and notably, the *upper limit* of the 95% CI for the odds ratio *including* infants with congenital anomalies was comparable to the *lower limit* of the 95% CI for the odds ratio that *excluded* infants with congenital anomalies. Infant mortality among infants with congenital anomalies was initially lower in non-Whites during the 1970s, but became higher in non-White populations by the 1990s,[55] and has steadily increased over time.[56] In 2018, mortality rates due to congenital malformations were 111.3 per 100,000 live births for non-Hispanic White women, compared to 156.9 for non-Hispanic Black women in the US.[4] Mortality rates overall were 463 per 100,000 live births for infants born to non-Hispanic Whites and 1,074.8 for infants born to non-Hispanic Blacks.[4] Differences in funding for and access to pregnancy termination or prenatal testing and diagnosis[56] may explain why the odds of dying are still higher among infants born to non-Hispanic Black mothers, despite a higher prevalence of anomalies among infants born to non-Hispanic White mothers. Black women are more likely than White women to have Medicaid- associated funding restrictions for pregnancy termination of anomalous fetuses.[56] However, because congenital malformations are the leading cause of death among infants born to non-Hispanic White women,[4] while disorders of short gestation contribute more for infants born to non-Hispanic Black women,[4] the magnitude of Black-White disparities in infant mortality among only infants with congenital anomalies may be lower than that seen when comparing all infants.

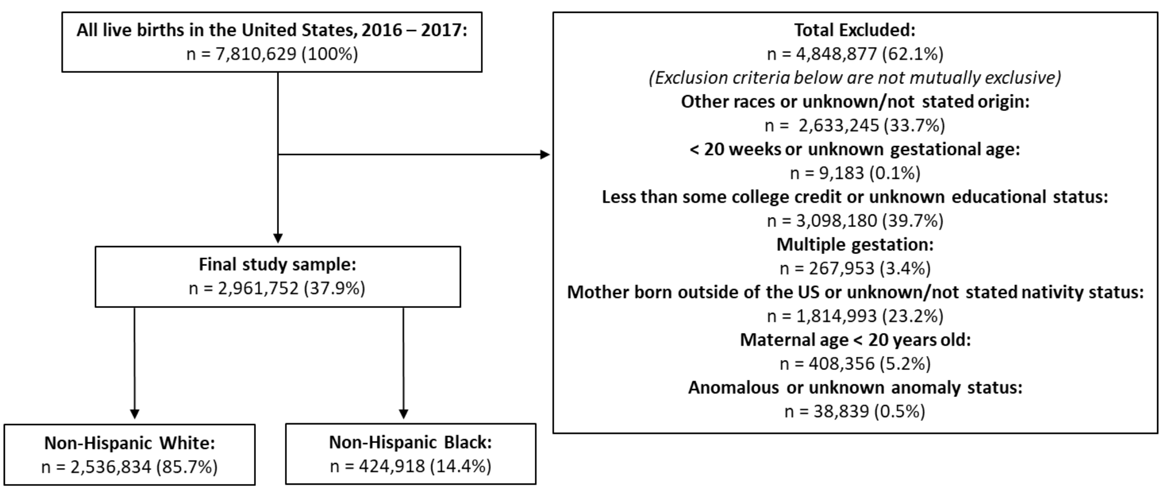
We acknowledge the presence of limitations in our analyses. First, race is self-reported for mothers and the data utilized in our analyses follow the 1997 Office of Management and

Budget (OMB) standards for racial categories[4] and bridging methods to select one racial category for those who select multiple races,[57] thus creating the potential for misclassification bias. Previous analyses of the bridging method utilized by NCHS demonstrated minimal impact on the Black and White single-race populations in the United States with increases of 2.5 and 0.5%, respectively,[57] compared to the single-race populations. We excluded those mothers reporting more than one race and did not utilize the bridged-race variable. Given the minimal change in population count comparing bridged-race Black and White populations to that of the single-race populations, it is unlikely that our odds ratio estimates would be significantly affected. We utilized maternal racial identity as a proxy for the corresponding infant's racial categorization, which may also bias mortality rate comparisons.[58] Second, differential reporting of exclusion criteria covariates by race, such as education, gestational age, and presence of congenital anomalies, could lead to selection bias given Black respondents are more likely to have incomplete or missing data.[59] Third, in 2014, the National Center for Health Statistics transitioned to utilizing the obstetric estimate of gestation at delivery which takes into account perinatal factors and assessments beyond the previously utilized last menstrual period (LMP).[60] Comparing gestational age estimates using this method to that using LMP suggests minimal difference when examined by race and ethnic group ($\leq$ 0.2 weeks), but overall lower levels of preterm, late-term, and post-term births.[60] These findings suggest potential limitations when comparing our results to literature that relies on a different method for determining gestational age. Lastly, classification of maternal educational attainment on birth certificates has changed over time, from a years-of-education-based designation in 1989 to a degree-attainment-based item in 2003.[61] There was enough difference in classifying educational attainment between these two versions that the National Center for Health Statistics recommends against longitudinal comparisons across the versions.[62] While this is a limitation in comparing results from our study to those of earlier studies, it is not a limitation within this study. By 2016, all reporting areas used the 2003 version.

In spite of these limitations, our analysis presents nationally representative evidence that the significant racial disparities in infant mortality cannot be wholly explained by individual-level maternal characteristics or gestational age at birth. The impact of historical adverse reproductive health experiences on the current health status and outcomes for Black women is difficult to quantify and may require different investigative approaches such as community-based participatory research[63] and adapted socioecological models.[64]

TABLES AND FIGURES

Figure 1. Flow Diagram of Study Sample, Infants born in the US 2016 – 2017



Data are n (%) with percentage rounded to the nearest 0.1

Table 1. Maternal Characteristics by Race, Infants born in the US 2016 – 2017 (n = 2,961,752)

Characteristic	Non-Hispanic Black (n = 424,918)	Non-Hispanic White (n = 2,536,834)	*p*
Birth Year			<.001
2016	212,148 (49.9)	1,288,912 (50.8)	
2017	212,770 (50.1)	1,247,922 (49.2)	
Deaths by birth year			<.786
2016	1,631 (51.7)	3,412 (51.4)	
2017	1,526 (48.3)	3,230 (48.6)	
Age (years)			<.001
20 – 24	103,238 (24.3)	290,073 (11.4)	
25 – 29	143,391 (33.8)	788,785 (31.1)	
30 – 34	109,074 (25.7)	948,303 (37.4)	
35 – 39	56,415 (13.3)	431,961 (17.0)	
40 – 44	12,057 (2.8)	72,516 (2.9)	
45 – 49	707 (0.2)	4,804 (0.2)	
50 – 54	36 (0.0)	392 (0.0)	
Marital Status			<.001
Married	148,928 (35.1)	2,002,856 (79.0)	
Unmarried	265,884 (62.6)	453,930 (17.9)	
Unknown	10,106 (2.4)	80,048 (3.2)	
Education			<.001
Some college credit, but not a degree	238,913 (56.2)	731,642 (28.8)	
Associate's degree	61,689 (14.5)	351,880 (13.9)	
Bachelor's degree	81,261 (19.1)	924,003 (36.4)	

Master's degree	35,884 (8.4)	417,187 (16.5)	
Doctorate	7,171 (1.7)	112,122 (4.4)	
Prenatal Care Initiation			<.001
1st – 3rd month	304,815 (71.7)	2,168,579 (85.5)	
4th month or later	103,973 (24.5)	319,524 (12.6)	
(including no prenatal care)			
Unknown or not stated	16,130 (3.8)	48,731 (1.9)	
Live Birth Order			<.001
1	155,577 (36.6)	1,033,268 (40.7)	
2	131,928 (31.1)	888,350 (35.0)	
3	76,819 (18.1)	395,547 (15.6)	
4	34,453 (8.1)	137,886 (5.4)	
5	13,839 (3.3)	43,694 (1.7)	
6	5,510 (1.3)	16,744 (0.7)	
7	2,453 (0.6)	7,019 (0.3)	
8 or more	2,212 (0.5)	7,817 (0.3)	
Unknown or not stated	2127 (0.5)	6,509 (0.3)	
Gestational Age (completed weeks)			<.001
< 32	12,305 (2.9)	23,655 (0.9)	
32 – 36	46,650 (11.0)	165,441 (6.5)	
37 – 40	318,379 (74.9)	1,964,639 (77.4)	
≥ 41	47,584 (11.2)	383,099 (15.1)	
Birth weight			<.001
< 1500	10,132 (2.4)	15,876 (0.6)	
1500 – 2499	36,361 (8.6)	93,818 (3.7)	

≥ 2500 Not stated	378,172 (89.0) 253 (0.1)	2,425,748 (95.6) 1,392 (0.1)	

Data are n (%) with percentage rounded to the nearest 0.1

Figure 2. Distributions of Infant Deaths by Gestational Age and Maternal Race

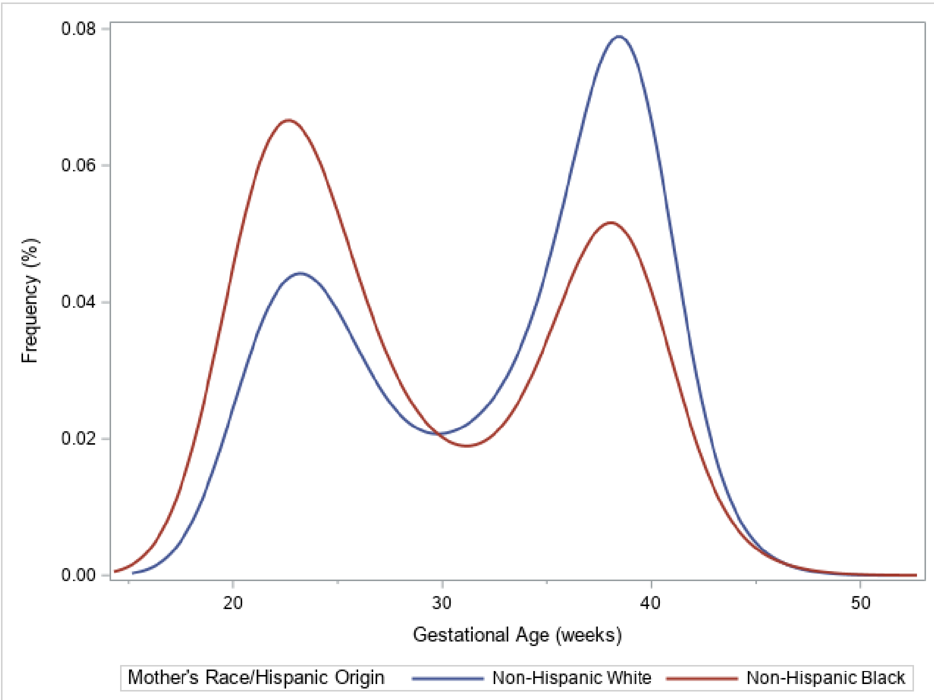


Table 2. Crude and Adjusted Odds Ratios for Infant Mortality by Maternal Race and Gestational Age

	Gestational Age (completed weeks)				
	All	**< 32**	**32 - 36**	**37 - 40**	**41+**
n (%)					
Non- Hispanic Black	424,918 (14.4)	12,305 (34.2)	46,650 (22.0)	318,379 (14.0)	47,584 (11.1)
Non- Hispanic White	2,536,834 (85.7)	23,655 (65.8)	165,441 (78.0)	1,964,639 (86.1)	383,099 (89.0)
Crude OR **(95% CI)**	**2.851** (2.733 - 2.975)	**1.399** (1.312 - 1.492)	**1.207** (1.072 - 1.359)	**2.072** (1.915 - 2.241)	**2.190** (1.790 - 2.680)

Adjusted OR* **(95% CI)**	**2.017** (1.923 - 2.116)	**1.411** (1.316 - 1.514)	0.984 (0.864 - 1.120)	**1.267** (1.161 - 1.382)	**1.367** (1.097 - 1.703)

Data are n (%) with percentage rounded to the nearest 0.1

Reference = infants born to non- Hispanic White mothers

*Adjusted for maternal education (some college credit, but not a degree, associate's degree, bachelor's degree, master's degree, doctorate) , marital status (married, unmarried, unknown), age (20 – 24, 25 – 29, 30 – 34, 35 – 39, 40 – 44, 45 – 49, 50 – 54) , live birth order (1, 2, 3, 4, 5, 6, 7, 8 or more, unknown), and timing of prenatal care initiation (1st – 3rd month, other)

Bold OR values indicate statistical significance (p <.05)

Table 3. Crude and Adjusted Odds Ratios for Infant Mortality by Maternal Race and Standardized Gestational Age

	Standardized Gestational Age			
	GA < -2	**-2 ≤ GA < -1**	**-1 ≤ GA < 1**	**GA ≥ 1**
n (%)				
Non- Hispanic Black	15,376 (18.3)	23,169 (16.2)	365,987 (14.2)	20,386 (13.5)
Non- Hispanic White	68,898 (81.8)	120,198 (83.8)	2,216,650 (85.8)	131,088 (86.5)
GA range (weeks)				
Non- Hispanic Black	20 – 32	33 – 35	36 – 41	42 – 47
Non- Hispanic White	20 – 34	35 – 36	37 – 41	42 – 47
Crude OR **(95% CI)**	**2.913** (2.743 - 3.093)	**1.840** (1.566 - 2.162)	**2.256** (2.099 - 2.425)	**1.939** (1.449 - 2.594)
Adjusted OR* **(95% CI)**	**2.842** (2.661 - 3.036)	**1.386** (1.160 - 1.655)	**1.386** (1.279 - 1.502)	1.326 (0.967 - 1.818)

Column values indicate the number of standard deviations away from the standardized mean

Data are n (%) with percentage rounded to the nearest 0.1

Reference = infants born to non-Hispanic White mothers

*Adjusted for maternal education (some college credit, but not a degree, associate's degree, bachelor's degree, master's degree, doctorate) , marital status (married, unmarried, unknown), age (20 – 24, 25 – 29, 30 – 34, 35 – 39, 40 – 44, 45 – 49, 50 – 54) , live birth order (1, 2, 3, 4, 5, 6, 7, 8 or more, unknown), and timing of prenatal care initiation (1st – 3rd month, other)

Bold OR values indicate statistical significance ($p < 0.05$)

Table 4. Gestational Age- Adjusted Odds Ratios for Infant Mortality by Maternal Race

	Overall	**+GA***	**+(GA and GA^2)†**	**+standardized GA‡**	**+standardized (GA and GA^2)§**
Crude OR (95% CI)	**2.851** (2.733 - 2.975)	**1.256** (1.196 - 1.318)	**1.272** (1.209 - 1.339)	**3.213** (3.070 - 3.362)	**3.487** (3.329 - 3.653)
Adjusted OR|| (95% CI)	**2.017** (1.923 - 2.116)	1.048 (0.994 - 1.104)	1.031 (0.976 - 1.090)	**2.683** (2.552 - 2.821)	**2.875** (2.731 - 3.025)

Reference = infants born to non- Hispanic White mothers

GA = gestational age

*+GA indicates that gestational age is added to the regression model

†+(GA and GA^2) indicates that both gestational age and the square of the gestational age variable are added to the regression model

‡+standardized GA indicates that the standardized gestational age variable (mean set to 0 and standard deviation set to 1) is added to the regression model

§+standardized (GA and GA^2) indicates that the standardized gestational age variable (mean set to 0 and standard deviation set to 1) and the square of the standardized gestational age variable are added to the regression model

||Adjusted for maternal education (some college credit, but not a degree, associate's degree, bachelor's degree,

master's degree, doctorate) , marital status (married, unmarried, unknown), age (20 – 24, 25 – 29, 30 – 34, 35 – 39, 40 – 44, 45 – 49, 50 – 54) , live birth order (1, 2, 3, 4, 5, 6, 7, 8 or more, unknown), and timing of prenatal care initiation (1st – 3rd month, other)

Bold OR values indicate statistical significance ($p < 0.05$)

Table 5. Sensitivity Analysis: Crude and Adjusted Odds Ratios for Infant Mortality by Maternal Race and Gestational Age – including Infants with Congenital Anomalies

	Excluding Infants with Congenital Anomalies	**Including Infants with Congenital Anomalies**	**Restricting to Only Infants with Congenital Anomalies**
n (%)			
Non- Hispanic Black	424,918 (14.4)	426,504 (14.3)	1,042 (9.8)
Non- Hispanic White	2,536,834 (85.7)	2,549,585 (85.7)	9,641 (90.3)
Crude OR (95% CI)	**2.851** (2.733 - 2.975)	**2.607** (2.503 - 2.716)	**1.481** (1.230 - 1.784)
Adjusted OR* (95% CI)	**2.017** (1.923 - 2.116)	**1.885** (1.801 - 1.973)	**1.491** (1.221 - 1.821)

Data are n (%) with percentage rounded to the nearest 0.1

Reference = infants born to non-Hispanic White mothers

*Adjusted for maternal education (some college credit, but not a degree, associate's degree, bachelor's degree, master's degree, doctorate) , marital status (married, unmarried, unknown), age (20 – 24, 25 – 29, 30 – 34, 35 – 39, 40 – 44, 45 – 49, 50 – 54) , live birth order (1, 2, 3, 4, 5, 6, 7, 8 or more, unknown), and timing of prenatal care initiation (1st – 3rd month, other)

Bold OR values indicate statistical significance ($p < 0.05$)

CHAPTER III: CONCUSION AND PUBLIC HEALTH IMPLICATIONS

This study adds to the literature on health inequities by establishing that racial disparities in infant mortality persist even among college-educated women and cannot be completely explained by differences in sociodemographic characteristics or the gestational age at birth of their infants. Previous publications have proposed disparate health care quality,[52,54] societal inequities, and early health deterioration[46,47] as additional considerations. Future research should explore the role of factors that are unique to the minority experience on racial disparities in reproductive health outcomes.

Persistent social inequalities may create a "weathering" phenomenon resulting in adverse physical outcomes for African Americans which worsen over time.[47] For example, maternal *childhood* experiences such as socio-economic status and maltreatment are related to her offspring's birth weight[65]; therefore socioeconomic status at the time of giving birth may provide an incomplete picture of the woman's experience throughout life.[66] This may explain why higher socioeconomic status does not necessarily improve health outcomes for non-Hispanic Black women in the same way that it can be seen for their non-Hispanic White counterparts.[67] In our analysis, we also found that disparities in mortality persisted despite high educational attainment in our study population. Previous analyses attribute such findings to differences in the distribution of low birth weight infants[13,14]; mortality improves significantly in this population with increased education for European Americans but not for African Americans.[13]

The life course perspective, described by Lu et al, re-examines traditional risk factors for adverse outcomes, such as socioeconomic status, and health behaviors, in the context of a woman's life course.[66] In other words, a woman's reproductive potential is influenced by events throughout life such that these exposures and experiences are cumulative in nature and create an allostatic load that further impacts health outcomes.[66] Using data from the National Health and Nutritional Examination Survey to create an allostatic load score that included 10 health biomarkers, researchers found higher scores among Blacks, especially Black women.[68] The Black-White disparity in scores widened with increasing age and was greatest when comparing nonpoor individuals.[68] The biomarkers utilized to generate an allostatic load score are associated with stress-related diseases which might be mediated by racial differences in life conditions,[68] such as racism which is prevalent among non-Hispanic Black pregnant and postpartum women,[69] and associated with adverse reproductive outcomes.[50,70,71]

Research on racism and adverse health suggests several mechanistic pathways including increased psychosocial stressors, differential access to resources and economic opportunities, and unconscious bias of health care providers, resulting in inferior care.[71] A 2021 narrative review recommends incorporation of four domains of systemic racism in population-based studies to evaluate their contribution to reproductive health outcomes.[72] These domains include civil rights laws and legal racial discrimination—measured through geographic and temporal cohorts; residential segregation and housing discrimination—measured by the Area Deprivation Index (ADI) or Index of Concentration at the Extremes (ICE); police violence – measured by the survey of police-public encounters; and mass incarceration—measured using data on local and individual incarceration.[72]

Structured assessments of contributions to health care disparities across the life course can then be utilized to determine the impact of the duration of certain exposures, identify intergeneration effects, and determine the most opportune time to intervene in affected populations.[71] Beck et al proposed interventions to target three causal pathways that create racial disparities in preterm birth.[73] These pathways include increased risk, lower quality care, and socioeconomic disadvantage and can be mitigated by actions such as implicit bias education, screening for social determinants of health, access to quality prenatal and inter-conception care, early intervention and intensive education programs, and clinical-community partnerships.[73] One example of an effective intervention is the Carolina Abecedarian project which was an early childhood program targeting disadvantaged children from birth up to age 8 using social and cognitive curriculum-based interventions; long-term follow-up demonstrated lower prevalence of risk factors for cardiovascular and metabolic disease among participants in their mid-30s.[74] Another study demonstrated reductions in implicit bias for up to 8 weeks following education and a training program.[75] Lastly, a 10% increase in public health expenditures in Florida was associated with significant reductions in maternal mortality among Black women and reductions in the associated Black-White disparity, thus highlighting the importance of public health interventions.[76] However, data on effective interventions specific to disparities in reproductive health outcomes are lacking.

Despite accounting for differences in gestational age at birth and individual-level maternal characteristics in a highly educated population, our study demonstrates increased odds of death – up to nearly three times – for non-Hispanic Black infants, compared to non-Hispanic White infants. Additional research and interventions are needed to better explain the role of risk factors throughout the life course and minority-based experiences that may account for these risks. Reductions in the rates of sudden infant death syndrome, congenital malformations, and short gestation/low birth weight[77] have driven reductions in overall infant mortality since 1995,[4,5] yet the racial disparities gap has remained stable over this time period.[12] Unless we shift our research focus to unmask and eliminate their underlying causes, such disparities will continue to persist.

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