THE INFANT MORTALITY RACIAL DISPARITY IN NORTH CAROLINA:

CONTRIBUTING SOCIAL/BEHAVIORAL AND BIOMEDICAL RISK FACTORS

by

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Abstract

Objectives. This study examined a number of social/behavioral and biomedical factors as potential mediators of the association between race and infant mortality, with maternal education as an effect modifier.

Methods. Birth certificate data from singleton, non-Hispanic white and African American births to North Carolina residents in 2009 were used to calculate odds of infant mortality adjusting for race and potential mediators, stratified by maternal education.

Results. The racial disparity between white and African American infants was reduced but remained significant after adjusting for mediators, and the disparity increased with increasing level of maternal education.

Conclusions. Social/behavioral and biomedical factors contribute to the association between race and infant mortality. However, additional factors likely influence the racial disparity, particularly among mothers with higher levels of education.

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Though great progress has been made in reducing infant mortality rates in the United States over the past century, infant mortality remains a major concern. Infant mortality rates in the US are higher than in many other developed countries; in 2008, the US ranked 31st among Organization for Economic Cooperation and Development (OECD) countries in infant mortality.[1] The US infant mortality rate has been identified as a leading health indicator by Healthy People 2020, with a corresponding objective to decrease the rate to 6.0 infant deaths per 1,000 live births.[2] In the period ranging from 2006 to 2008, the US infant mortality rate was 6.68 per 1,000 live births.[3] In North Carolina, infant mortality rates are consistently higher than the national average. North Carolina's infant mortality rate for the same period (2006-2008) was 8.29 per 1,000 live births.[3] Within both North Carolina and the US as a whole, a disparity in infant mortality rates between non-Hispanic African Americans and non-Hispanic whites is also troubling. For 2006-2008, the ratio of the African American infant mortality rate to the white American infant mortality rate was 2.35, and in North Carolina the ratio was 2.37.[3]

Both the North Carolina infant mortality rate and infant mortality racial disparity are addressed in Healthy North Carolina 2020, a set of objectives similar to Healthy People 2020 developed by a steering committee facilitated by the North Carolina Institute of Medicine.[4] The 2020 targets set by the committee are 6.3 infant deaths per 1,000 live births, and a disparity ratio of 1.92. At the time these targets were established, the state's infant mortality rate was 8.2 and the disparity ratio 2.45 (2008 data).[4] Since then, the state's infant mortality rate has declined to 7.0 deaths per 1,000 live births and the disparity ratio to 2.40 (2010 data).[5-6] Despite these recent reductions in overall infant mortality, rates in North Carolina remain higher than the US average. A better understanding of the interplay of factors that influence the disparity in infant mortality rates may provide additional clues as to how to address this problem and reduce infant mortality in the broader population.

Much of the extant literature on racial disparities in infant mortality focuses on preterm birth (delivery at less than 37 completed weeks of gestation) and low birthweight (less than 2500 grams), two of the adverse pregnancy outcomes most frequently associated with mortality. Infants who are born preterm or low birthweight have a much greater risk of mortality that increases with earlier gestational age and lower birthweight,[3] and there are significant racial disparities in these outcomes in the US, with a greater prevalence of preterm birth and low birthweight among non-Hispanic African American infants compared to non-Hispanic white infants.[7-11] An analysis of US Vital Records from 2000-2006 found that infants of non-Hispanic African American mothers had nearly 4 times the mortality rate attributed to short gestation and low birthweight as white Americans.[11] Other studies suggest that the racial disparity is influenced by birthweight- and gestational age-specific mortality in addition to birthweight and gestational age distributions.[7] For example, 0.2% of singleton births to US white mothers and 0.8% of singleton births to African American mothers were less than 28 weeks gestation in the period from 1995-2000; this gestational age group accounted for 31.3% of white infant deaths and 48.4% of African American infant deaths.[7] Theories as to why these disparities occur include differing access to health care and medical technology by race, and the cumulative stress hypothesis, wherein stressors over the life course (including racial discrimination) accumulate and increase susceptibility to deliver prematurely.[7,9,12-13] However, the causes of preterm birth and low birthweight are highly varied.[13-14] Recent studies suggest that preterm birth and low birthweight, though strongly associated with infant mortality, are not causes of mortality but rather indicators of unmeasured conditions that affect both prematurity or birthweight and mortality.[8,14-17] With this in mind, this study will attempt to examine some of the conditions associated with these outcomes and their relationships to mortality, without explicitly assessing the contributions of preterm birth and low birthweight.

There are a number of factors that are thought to contribute to the relationship between race and infant mortality. The aim of this study is to examine a combination of potential mediators of this association: social and behavioral factors including paternal involvement, prenatal care, interpregnancy interval, and maternal smoking and alcohol use during pregnancy; and biomedical factors including infant birth order, maternal age, diabetes, hypertension, and anemia. Additionally, this study will consider education as a moderator of the racial disparity in infant mortality.

Social and Behavioral Risk Factors

Paternal Involvement. Paternal involvement during pregnancy may serve to moderate maternal stress through provision of social and emotional support, and conversely, lack of paternal involvement may increase maternal stress, leading to an increased risk of poor birth outcomes.[18] Marital status has often been associated with infant mortality and adverse outcomes, but fewer studies have attempted to analyze paternal involvement or absence, which today may be a more pertinent measure of paternal support.[18-19] A recent study of births in Florida examined paternal involvement as defined by the presence of information about the father on the birth certificate, and found that paternal absence increased racial disparities in infant mortality between non-Hispanic white and non-Hispanic African American infants.[18] Similarly, an earlier study of births in Georgia found that the absence of fathers' names on birth certificates was associated with a greater risk of infant mortality (Relative Risk [RR] 2.0, 95% Confidence Interval [CI] 1.6-2.4), and that the risk was similar across sociodemographic groups.[19]

Interpregnancy Interval. Short interpregnancy intervals (time between conception and the previous birth) less than 18 months have been associated with adverse perinatal outcomes, including preterm birth, low birthweight, small-for-gestational age, and perinatal death.[20-23] The nutrition depletion hypothesis, the most common theory to explain this relationship, states that a depleted maternal nutrient store may result from limited recovery time after a previous pregnancy.[21] A meta-analysis found that interpregnancy intervals less than 6 months were associated with increased risks of the greatest magnitude for preterm birth (Odds Ratio [OR] 1.40, 95% CI 1.24-1.58) and low birthweight (OR 1.61, 95% CI 1.39-1.86), and that interpregnancy intervals less than 18 months and greater than 59 months were also associated with a significantly increased risk of preterm birth and low birthweight.[20] Associations with infant mortality have not been examined as extensively, but a recent study of infants in Arizona found that short intervals of 18 months or less were associated with neonatal, though not postneonatal, death.[23] Differences in the distribution of interpregnancy intervals by race have been noted as well, with a greater proportion of short (12 months or less) intervals among non-Hispanic African American mothers compared to non-Hispanic white mothers, and the length of the interval associated with a similar increased risk of low birthweight and preterm birth among each race.[22]

Prenatal Care. Utilization of prenatal care provides the opportunity to identify risk factors for poor birth outcomes prior to delivery. High-risk pregnancies identified early can be closely monitored and referred to better-equipped facilities for delivery, if necessary.[12] The Kotelchuck Adequacy of Prenatal Care Utilization Index[24] categorizes prenatal care utilization as inadequate, intermediate, adequate, or adequate plus based on the timing of prenatal care initiation and the percentage of recommended visits (as recommended by the American College of Obstetricians and Gynecologists) for gestational age. A large, recent retrospective analysis of US singleton births found that inadequate and intermediate levels of prenatal care, compared to adequate care, were associated with an increased risk of infant death (OR 1.79, 95% CI 1.76-1.82), as well as increased risks of prematurity and stillbirth.[25] Racial disparities in prenatal care utilization in the US are thought to contribute, in part, to disparities in infant mortality.[12-13] In 2007, 5.0% of non-Hispanic white mothers (in 22 states using the 2003 standard version of the birth certificate) reported late or no prenatal care, compared to 11.7% of non-Hispanic African American women.[26] A high-risk pregnancy detected early and monitored may have a better chance of survival, and any severe anomalies detected early in pregnancy may lead to elective termination.[12-13] However, efforts to expand prenatal care have had limited success in reducing adverse outcomes, as women who seek out prenatal care tend to be of lower risk to begin with for a variety of reasons, including greater likelihood of intended pregnancy and higher income.[3,13]

Smoking. Many studies have linked maternal cigarette smoking to poor birth outcomes, including infant death.[27-29] A population-based study in Sweden found that smoking cessation reduces the risk of infant death, supporting a causal link between smoking and infant mortality.[28] Although the prevalence of smoking is declining, it remains a common and preventable cause of infant morbidity and mortality.[27,29] Smoking may result in mortality directly, and indirectly through morbidities such as preterm birth, intrauterine growth restriction, placental conditions, and SIDS.[29] An analysis of US births in 2002 concluded that between 5.0-7.3% of preterm-related infant deaths were attributable to smoking.[27] In 2008, the mortality rate for infants of smokers in the US was 9.68 deaths per 1,000 live births, compared to 5.68 for those of non-smokers.[3] However, smoking may contribute little to disparities in infant mortality. There are differences in prenatal smoking behaviors by race, with a higher prevalence typically among non-Hispanic white women - 16.3% in 21 states reporting in 2007 - compared to 10.1% among non-Hispanic African American women.[26]

Alcohol Use. Prenatal alcohol use is another well-documented behavioral risk factor for adverse birth outcomes and a known teratogen. Fetal alcohol syndrome (FAS), first described in the 1970s, may result from drinking during pregnancy and is characterized by growth retardation, neurodevelopmental abnormalities, and facial anomalies.[30] A small cohort study in Canada found that infants diagnosed with FAS experienced a mortality rate 3.5 times higher than the rate expected in the general population.[31] Prenatal exposure to alcohol has also been associated with fetal death, SIDS, congenital malformations, lower Apgar scores, and low birthweight.[30,32] During the postneonatal period, infants who were exposed to alcohol in utero are more likely to experience colic, irritability, and sleep disorders, which may increase their risk of postneonatal death when combined with maternal neglect and other behaviors characteristic of mothers that continue to drink after pregnancy.[32] Effects of prenatal alcohol consumption on disparities in infant mortality remain unclear. In 2002, the most recent year for which national birth certificate data on alcohol use is publically available, 0.8% of non-Hispanic white women and 0.9% of non-Hispanic African American women reported drinking during pregnancy; however, alcohol use tends to be underreported on the US birth certificate.[33] A study using a stratified random sample of hospital births in 20 US cities found that non-Hispanic white women were more likely to report any drinking during pregnancy – 17.0% compared to 9.7% of non-Hispanic black African American.[34] Conversely, frequent drinking was reported among a greater proportion of non-Hispanic African American women (2.9%) than non-Hispanic white women (1.8%).[34]

Biomedical Risk Factors

Birth Order. Birth order typically has a U-shaped association with infant mortality, wherein first order births experience a higher risk of mortality than second order births, and third and higher order births also experience a greater risk (compared to second order births) that increases with each birth order.[35-36] For US infants born in 2008, the mortality rate for first order births was 6.65 deaths per 1,000 live births, compared to 5.74 for second order births, 6.35 for third order births, and climbing to 10.16 for fifth or higher order births.[3] This relationship exists among all racial groups, though the birth rates at each birth order differ by race.[10,36] In 2009, non-Hispanic white women had higher second order birth rates than non-Hispanic African American women, but lower first order, third and higher order birth rates.[10]

Maternal Age. The youngest and oldest mothers tend to have the highest rates of preterm birth and low birthweight infants, potentially mediating higher infant mortality rates as well.[10-11,37-38] Older mothers are more likely to have chronic conditions, including hypertension, which may increase their risk.[10] Proposed mechanisms for the relationship between younger maternal age and risk of adverse birth outcomes include young gynecologic age associated with predisposition to subclinical infection during pregnancy and pregnancy before growth has ceased associated with competition with the fetus for nutrients and inadequate weight gain.[37-38] Socioeconomic disadvantages may also explain some of the association; younger mothers are more likely to be of lower income, less educated, and are less likely to obtain prenatal care early in pregnancy.[38] In the US, birth rates by maternal age differ by race, and the incidence of adverse birth outcomes by age also differ by race.[10,39] In 2009, the birth rate for non-Hispanic African American young women age 15-19 was 59.0 births per 1,000 women, compared to a rate of 25.6 per 1,000 women age 15-19 for non-Hispanic whites.[10] Younger and older African American women also had higher rates of preterm birth and low birthweight compared to younger and older white women.[10] Furthermore, an analysis of North Carolina resident births to non-Hispanic whites and African Americans from 1999-2003 found that disparities in birth outcomes tended to increase with age, with African Americans experiencing higher rates of adverse outcomes (low birthweight and infant mortality) at every age.[39] Other US studies have come to similar conclusions, supporting the hypothesis of differential stress accumulation over the lifecourse.[13]

Diabetes. Diabetes mellitus (types 1 and 2) during pregnancy is associated with a number of adverse perinatal outcomes, including congenital anomalies (particularly cardiovascular malformations), preterm birth, low birthweight, large for gestational age at birth, and mortality.[40-44] A study of births in Finland concluded that infants of mothers with diabetes experienced more than two times the risk of death compared to infants of mothers without diabetes (OR 2.87, 95% CI 1.79-4.61), and that congenital malformations explained the majority of excess risk.[41] Within the US, a case-control study of infants with cardiovascular malformations (CVM) found that preconceptional diabetes was strongly associated with malformations (OR 4.7, 95% CI 2.8-7.9).[42] Additionally, case infants (diagnosed with CVM) of diabetic mothers experienced greater mortality than case infants without diabetic mothers – 39% compared to 17.8%, and those that died were more likely to have other anomalies, and to have been born preterm and/or low birthweight.[42] Chronic diabetes during pregnancy is rare, but statistically significant differences in prevalence by race have been noted. Using the New York City Birth Files, Rosenberg and colleagues found that 0.4% of non-Hispanic African American births and 0.3% of non-Hispanic white births were to mothers with diabetes ($p<.001$).[43] Whether these differences influence disparities in infant mortality, however, is uncertain. Infants of all races with diabetic mothers were more likely to be born preterm and/or low birthweight; however, the risk for white infants was higher than that for African American infants.[43]

Hypertension. Chronic hypertension is a well-documented risk factor for poor pregnancy outcomes, and its prevalence has increased over the past two decades in part due to rising obesity rates and childbearing at older ages.[10,46-47] Preeclampsia, placental abruption, fetal growth restriction, preterm birth, and perinatal death have been found to occur more frequently among infants of mothers diagnosed with hypertension.[46-48] Primary hypertension is the most common form of chronic hypertension among pregnant women, but secondary hypertension resulting from other medical conditions (diabetes, for example) is responsible for about 10% of cases, potentially compounding risk in those women.[46] Within the US, non-Hispanic African American women have experienced the largest increase in rates of chronic hypertension during pregnancy, which could influence disparities in infant outcomes.[10] In 2009, 25.7 per 1,000 live births were to mothers with chronic hypertension among non-Hispanic African American infants, compared to a rate of 12.3 per 1,000 live births among non-Hispanic white infants.[10] A study examining disparities in maternal hypertension among North Carolina live births found that rates by race were more similar (8.36% of non-Hispanic white births and 8.65% of non-Hispanic African American births), but that the risk for hypertension during pregnancy among African American mothers relative to white mothers increased steadily with age.[48] However, the North Carolina study also included pregnancy-induced hypertension and eclampsia in its calculations, which differ etiologically from chronic hypertension.

Anemia. Maternal anemia (defined by low hemoglobin concentration) is associated with low birthweight, preterm birth, and increased risk of neonatal mortality.[48-49] Iron-deficiency anemia is the most common form, but anemia can also be caused by other conditions such as sickle cell disease.[49] Women of reproductive age are most at risk for iron-deficiency because of blood loss from menstruation, and a substantial amount of iron is also required for pregnancy.[49] Iron-deficiency anemia detected early in pregnancy is associated with preterm birth and inadequate weight gain, though anemia during the 3rd trimester is not.[49] The extent to which iron deficiency itself may explain associations between anemia and adverse birth outcomes is unclear, however; supplementation with iron during pregnancy does not appear to improve outcomes of low birthweight and preterm birth.[48] Rates of anemia reported during pregnancy differ by race and by other sociodemographic characteristics as well. In 2002, the rate of maternal anemia among non-Hispanic African American infants in the US was 40.7 cases per 1,000 live births, compared to a rate of 21.5 per 1,000 live births for non-Hispanic whites.[33] Teenage mothers (all races) were the age group most likely to report anemia during pregnancy.[33]

Education and Racial Disparities in Infant Mortality

Within the US, infant mortality rates tend to decrease with increasing levels of maternal education.[50] However, racial disparities in infant mortality are greater among higher educated groups.[13,50-51] A study using the North Carolina birth files found odds ratios comparing African American to white infants of 1.5 (95% CI 1.4-1.7) among those whose mothers had less than 12 years of education, 1.9 (95% CI 1.8-2.1) among those with 12 years of education, and 2.5 (95% CI 2.3-2.8) among those with greater than 12 years of education.[51] A more recent US-based study found similarly that among infants whose mothers had less than 12 years of education, the relative risk of mortality for African Americans compared to European Americans was 1.61 for males and 1.63 for females; for those whose mothers had 12 or more years of education, the relative risk was 2.57 for males and 2.46 for females.[50] Compromised European American births (those in the lowest and highest extremes of the birthweight distribution) in the higher educated group appeared to experience declines in mortality compared to their counterparts in the low educated group, but this did not hold true for the compromised African American births.[50] A number of possible explanations for this effect of maternal education on the infant mortality disparity have been postulated. Both income and health status tend to improve with increasing education, but at higher levels of education may be much more varied, with racial differences persisting.[51] Cumulative stress might also differ by race more at higher educational levels, perhaps due to differences in social support.[13,51]

On a national level, data from vital registries have contributed to many analyses of births and infant deaths. An abundance of the literature has examined trends in infant mortality and subsets of implicated risk factors, particularly in relation to preterm birth and low birthweight. Some, but fewer, studies have focused on mortality risk within the context of several potentially modifiable social/behavioral and biomedical measures available in birth record data. This study will contribute to the knowledge on this topic by examining recent data on a number of these measures together in North Carolina in an attempt to explain the racial disparity in infant mortality rates at the state level.

Methods

Subjects

The 2009 North Carolina birth files contain birth certificate information for all North Carolina live births in 2009.[52] The 2009 and 2010 North Carolina linked birth/infant death files contain birth and death certificate information for all North Carolina infants that died in 2009 and 2010, respectively.[53-54] Infants in the 2009 linked birth/infant death files were born in either 2008 or 2009, and infants in the 2010 linked files were born in 2009 or 2010. Using these files, the 2009 birth data was merged with the 2009-2010 linked birth/infant death data for all infants born in 2009 that subsequently died, in order to create a complete 2009 birth cohort with death certificate information for those infants who died. The dataset contains information on the entire population of North Carolina births in 2009; no sampling procedures were used. Of the 129,444 infants born in North Carolina in 2009, a total of 96,574 were selected for analysis. Analyses were restricted to North Carolina resident, singleton, non-Hispanic white and non-Hispanic African American infants.

Subjects with no information on maternal education present in the birth certificate (N = 370) were excluded from analyses stratified by education, for a total of 96,204 subjects in the stratified analysis model. There were 124 subjects missing data on interpregnancy interval (97 were missing either the month or year of last live birth, and 27 date values were excluded because they did not precede the subject’s date of birth), 1,815 subjects were missing data on adequacy of prenatal care utilization, 761 were missing data on alcohol use, 204 were missing data on smoking, 258 were missing data on diabetes, hypertension, and anemia, and 1 subject was missing data on maternal age.

Measures

The main outcome variable analyzed was infant mortality, defined as death within a year of live birth. Neonatal mortality (death before 28 days) and postneonatal mortality (death between 28 days and one year) were examined as outcomes as well. Education, a moderator, was categorized as less than 12 years (less than high school), 12 years (high school education or equivalent), or greater than 12 years (any education beyond high school). Self-reported maternal race/ethnicity (non-Hispanic white or non-Hispanic African American) was the primary independent variable of interest. Additional independent variables included the social/behavioral risk factors derived from birth certificate data – paternal involvement, prenatal care, short interpregnancy interval, maternal smoking and alcohol use during pregnancy; and the biomedical risk factors – infant birth order, maternal age, diabetes, hypertension, and anemia. Gestational age (completed weeks of gestation, a continuous variable), and birthweight (weight at delivery in grams, a continuous variable) were also examined in descriptive analyses, but were not included in the inferential analysis models.

Social/behavioral factors. Paternal involvement was dichotomized as yes or no, and a father was classified as involved if at least one of the paternal variables from the public-use birth data files (age, education, race, and ethnicity) was non-missing. In the state of North Carolina, the husband's name is entered on the birth certificate if the infant's mother is married; if the mother is unmarried (or married to someone other than the infant's father), an affidavit of paternity must be completed to add the father's name to the birth certificate.[55] Previous research has found that presence of paternal information on the birth certificate is correlated with other measures of paternal involvement.[18,56] Prenatal care was categorized according to the Kotelchuck Index, which is included in the public-use birth files. Standard categories are "inadequate" (care initiated after 4 months or fewer than half of recommended visits for gestational age were attended), "intermediate" (care was initiated by 4 months and 50-79% of recommended visits were attended), "adequate" (care was initiated by 4 months and 80-109% of recommended visits were attended), and "adequate plus" (care was initiated by 4 months and 110% or more of recommended visits were attended).[24] Interpregnancy intervals were calculated by subtracting the date of last live birth reported on the birth certificate from the subject's estimated date of conception (date of birth minus gestational age).Because only the month and year of last live birth are reported, dates of last live birth were constructed using the first day of the month. Intervals were categorized as short if they were <18 months, and not short if the interpregnancy interval was 18 months or greater or the infant was a first birth. Maternal smoking and alcohol use were dichotomized as yes or no; mothers who reported smoking any number of cigarettes per day or smoking an unknown amount were considered smokers, and those who reported any number of alcoholic drinks consumed per week or drinking an unknown amount of alcohol were considered to have used alcohol.

Biomedical factors. Birth order was categorized as 1st, 2nd, 3rd, and 4th or higher, and calculated by subtracting the mother's number of prior terminations (abortions and/or fetal deaths) from her total number of pregnancies. Three categories were constructed for maternal age: <20 years, 20-39 years, and 40+ years of age. Maternal diabetes (type 1 or 2), hypertension (chronic), and anemia (low hemoglobin due to any cause) were all dichotomized as yes or no, and considered present if the condition was noted at any time during pregnancy.

Analyses

Descriptive statistics were first calculated in order to examine differences in each independent variable by race. The chi-square test of independence was used to test for significant differences in categorical variables, and the two-sample t-test was used to examine gestational age and birthweight differences by race. Data were then analyzed in three phases: 1) a set of logistic regression models examining the crude associations between each independent variable and infant mortality; 2) a multivariate logistic regression model examining the relationship between race and infant mortality, adjusting for social/behavioral and biomedical mediators; and 3) a multivariate logistic regression model examining the relationship between race and infant mortality, adjusting for all mediators and stratified by maternal education status. Analyses were conducted using STATA software (version 12).[57]

Results

For the entire cohort of North Carolina births in 2009 (N=129,444), the infant mortality rate was 7.63 deaths per 1,000 live births. After all exclusions, the infant mortality rate among singleton, non-Hispanic white and non-Hispanic African American infants (N=96,574) was 6.99 deaths per 1,000 live births. For non-Hispanic African Americans in the study population (N=28,991), the infant mortality rate was 12.38 deaths per 1,000 live births, and for non-Hispanic whites (N=67,583) the rate was 4.68 deaths per 1,000 live births – an infant mortality disparity ratio of 2.65. The neonatal mortality rate among all infants in the study population was 4.71 deaths per 1,000 live births; there were 2.96 neonatal deaths per 1,000 live births among white infants and 8.80 neonatal deaths per 1,000 live births among African American infants. The postneonatal mortality rate was 2.28 deaths per 1,000 live births for all study infants, 1.72 deaths per 1,000 live births for white infants, and 3.59 deaths per 1,000 live births for African American infants.

Rates of paternal involvement, short interpregnancy interval, prenatal care utilization, smoking, birth order, maternal age, maternal hypertension, and maternal anemia were significantly different for African American compared to white infants (Table 1). The rate of prenatal smoking was higher among mothers of non-Hispanic white infants, but rates of no paternal involvement, short interpregnancy interval, inadequate prenatal care utilization, high birth order, teen maternal age, hypertension, and anemia were higher among non-Hispanic African American births. The rate of maternal alcohol use was slightly higher among African American births, but the difference by race was not statistically significant. On average, gestational age and birthweight were also lower for African American infants compared to white infants (Table 1).

Table 1. Characteristics of non-Hispanic white and African American North Carolina live births by race, 2009

	Non-Hispanic White N (%)	Non-Hispanic African American N (%)	p-value
Paternal Involvement			
Yes	60,818 (90.0)	17,735 (61.2)	p < 0.001
No	6,765 (10.0)	11,256 (38.8)	
Short Interpregnancy Interval			
Yes	4,420 (6.6)	2,966 (10.3)	p < 0.001
No	63,087 (93.5)	25,977 (89.8)	
Prenatal Care Utilization			
Inadequate	3,624 (5.5)	3,881 (13.7)	p < 0.001
Intermediate	4,189 (6.3)	2,097 (7.4)	
Adequate	29,545 (44.5)	9,816 (34.6)	
Adequate Plus	29,000 (43.7)	12,607 (44.4)	
Smoking			
Yes	9,135 (13.6)	2,756 (9.5)	p < 0.001
No	58,305 (86.5)	26,174 (90.5)	
Alcohol Use			
Yes	279 (0.4)	137 (0.5)	p = 0.21
No	66,698 (99.6)	28,699 (99.5)	
Birth Order			
1	30,653 (45.5)	11,938 (41.2)	p < 0.001
2	22,188 (32.9)	8,331 (28.8)	
3	9,708 (14.4)	4,946 (17.1)	
4+	4,858 (7.2%)	3,742 (12.9)	
Maternal Age			
< 20 years	5,789 (8.6)	5,110 (17.6)	p < 0.001
20-39 years	60,111 (89.0)	23,373 (80.6)	
40+ years	1,682 (2.5)	508 (1.8)	
Maternal Diabetes			
Yes	2,057 (3.1)	891 (3.1)	p = 0.85
No	65,300 (97.0)	28,068 (96.9)	
Maternal Hypertension			
Yes	886 (1.3)	817 (2.8)	p < 0.001
No	66,471 (98.7)	28,142 (97.2)	
Maternal Anemia			
Yes	2,198 (3.3)	2,001 (6.9)	p < 0.001
No	65,159 (96.7)	26,117 (95.6)	
Gestational Age (wks)			
M (SD)	38.91 (2.29)	38.29 (2.99)	p < 0.001
Birthweight (grams)			
M (SD)	3366.44 (560.71)	3093.10 (629.68)	p < 0.001

African American births in the study population were more likely than white births to result in infant death (OR = 2.67, 95% CI 2.29-3.11), both neonatal (OR = 2.99, 95% CI 2.48-3.60) and postneonatal (OR = 2.09, 95% CI 1.61-2.73). In the first set of logistic regressions, crude associations between all independent variables and infant mortality, neonatal mortality, and postneonatal mortality were calculated (Table 2). Lack of paternal involvement, inadequate prenatal care, and maternal hypertension were the potential mediators with the strongest unadjusted associations with infant mortality. In the neonatal death crude analyses, the strongest significant associations were with lack of paternal involvement, inadequate prenatal care utilization, and adequate plus prenatal care utilization, while in the postneonatal death crude analyses the strongest significant associations were with inadequate prenatal care, maternal smoking, and maternal hypertension. The regression models in the second phase of analyses, which adjusted for all potential mediators, reduced the effect of race on infant mortality, neonatal mortality, and postneonatal mortality, but race remained significant in each of these models (Table 3).

In the final phase of analyses, the models adjusting for potential mediators were also stratified by maternal education level. The results for associations between race and mortality at each level of education (less than high school, high school, and greater than high school) are presented in Table 4. For infant death and neonatal death, the magnitude of association with race was stronger with increasing levels of education; for postneonatal death, the association with race was weakest in the least educated group and strongest in the high school educated group. Crude analyses not adjusted for potential mediators (not shown) showed similar patterns, with a greater magnitude of association between race and infant mortality. In adjusted analyses, the associations between African American race and each outcome (infant, neonatal, and postneonatal death) were all non-significant in the group with less than high school education. In crude analyses, the association between race and neonatal death was significant in the group with less than high school education. For those with less than a high school education, mediators that remained significant in the adjusted infant death model were inadequate prenatal care (OR 2.13, 95% CI 1.34-3.39), adequate plus prenatal care (OR 1.67, 95% CI 1.11-2.53) and a birth order of 3 (OR 1.76, 95% CI 1.08-2.88); the same predictors remained significant in the neonatal death model (inadequate prenatal care OR 2.33, 95% CI 1.27-4.31; adequate plus prenatal care OR 2.01, 95% CI 1.17-3.45; 3rd birth order OR 2.09, 95% CI 1.10-3.98), and no predictors were significant in the postneonatal death model. Among those with a high school education, adequate plus prenatal care (infant death OR 2.05, 95% CI 1.51-2.79; neonatal death OR 2.42, 95% CI 1.66-3.53) and first birth order (infant death OR 1.49, 95% CI 1.07-2.08; neonatal death OR 2.10, 95% CI 1.37-3.22) remained significantly associated with both infant death and neonatal death. Older maternal age (OR 2.19, 95% CI 1.01-4.78) and hypertension (OR 2.05, 95% CI 1.12-3.76) also remained significantly associated with infant death, lack of paternal involvement with neonatal death (OR 1.44, 95% CI 1.03-2.03) and no predictors (other than race) remained significantly associated with postneonatal death in this group. In the group with maternal education greater than high school, inadequate and adequate plus prenatal care were significantly associated with infant mortality (inadequate prenatal care OR 2.17, 95% CI 1.25-3.76; adequate plus prenatal care OR 2.20, 95% CI 1.63-2.98) and neonatal mortality (inadequate prenatal care OR 3.04, 95% CI 1.59-5.82; adequate plus prenatal care OR 2.75, 95% CI 1.87-4.06), while smoking (OR 2.61, 95% CI 1.30-5.25) and anemia (OR 2.33, 95% CI 1.06-5.14) remained significantly associated with postneonatal mortality.

Table 2. Odds ratios and 95% confidence intervals from unadjusted logistic regression models examining factors associated with infant mortality, North Carolina live births 2009

	Infant Death OR (95% CI)	Neonatal Death OR (95% CI)	Postneonatal Death OR (95% CI)
Race			
White	1	1	1
African American	2.67 (2.29-3.11)	2.99 (2.48-3.60)	2.09 (1.61-2.73)
Paternal Involvement			
Yes	1	1	1
No	2.18 (1.86-2.56)	2.33 (1.92-2.83)	1.87 (1.40-2.50)
Short Interpregnancy Interval			
Yes	1.41 (1.10-1.81)	1.37 (1.01-1.86)	1.49 (0.97-2.27)
No	1	1	1
Prenatal Care Utilization			
Inadequate	3.25 (2.52-4.19)	3.56 (2.57-4.91)	2.79 (1.85-4.21)
Intermediate	1.23 (0.84-1.81)	1.43 (0.89-2.30)	0.75 (0.40-1.43)
Adequate	1	1	1
Adequate Plus	2.17 (1.80-2.62)	2.64 (2.08-3.35)	1.51 (1.11-2.05)
Smoking			
Yes	1.53 (1.25-1.87)	1.26 (0.97-1.64)	2.12 (1.54-2.91)
No	1	1	1
Alcohol Use			
Yes	1.40 (0.52-3.77)	1.04 (0.26-4.19)	2.15 (0.53-8.68)
No	1	1	1
Birth Order			
1	1.27 (1.05-1.54)	1.61 (1.27-2.05)	0.81 (0.59-1.11)
2	1	1	1
3	1.46 (1.15-1.85)	1.64 (1.22-2.21)	1.20 (0.82-1.77)
4+	1.77 (1.36-2.30)	2.07 (1.49-2.87)	1.35 (0.87-2.11)
Maternal Age			
< 20 years	1.57 (1.28-1.93)	1.54 (1.20-1.98)	1.64 (1.15-2.33)
20-39 years	1	1	1
40+ years	1.12 (0.68-1.84)	1.24 (0.70-2.21)	0.86 (0.32-2.31)
Maternal Diabetes			
Yes	1.17 (0.78-1.76)	0.93 (0.54-1.62)	1.68 (0.91-3.08)
No	1	1	1
Maternal Hypertension			
Yes	2.34 (1.59-3.45)	2.17 (1.33-3.53)	2.67 (1.41-5.04)
No	1	1	1
Maternal Anemia			
Yes	1.06 (0.74-1.52)	0.90 (0.56-1.45)	1.39 (0.79-2.43)
No	1	1	1

Table 3. Odds ratios and 95% confidence intervals from adjusted logistic regression models examining potential mediators of the association between race and infant mortality, North Carolina live births 2009

	Infant Death OR (95% CI)	Neonatal Death OR (95% CI)	Postneonatal Death OR (95% CI)
Race			
White	1	1	1
African American	2.23 (1.88-2.65)	2.41 (1.95-2.98)	1.90 (1.41-2.55)
Paternal Involvement			
Yes	1	1	1
No	1.31 (1.09-1.58)	1.41 (1.12-1.77)	1.13 (0.82-1.57)
Short Interpregnancy Interval			
Yes	1.23 (0.93-1.61)	1.30 (0.93-1.83)	1.09 (0.69-1.71)
No	1	1	1
Prenatal Care Utilization			
Inadequate	2.04 (1.55-2.69)	2.20 (1.55-3.13)	1.81 (1.17-2.80)
Intermediate	1.11 (0.75-1.63)	1.31 (0.81-2.11)	0.84 (0.43-1.64)
Adequate	1	1	1
Adequate Plus	2.05 (1.70-2.48)	2.49 (1.96-3.17)	1.44 (1.05-1.96)
Smoking			
Yes	1.46 (1.18-1.82)	1.19 (0.90-1.59)	2.01 (1.43-2.81)
No	1	1	1
Alcohol Use			
Yes	0.82 (0.26-2.59)	0.92 (0.23-3.76)	0.68 (0.09-4.95)
No	1	1	1
Birth Order			
1	1.22 (0.99-1.50)	1.57 (1.22-2.04)	0.75 (0.53-1.06)
2	1	1	1
3	1.26 (0.99-1.61)	1.38 (1.01-1.89)	1.11 (0.75-1.64)
4+	1.27 (0.96-1.68)	1.47 (1.03-2.08)	1.01 (0.63-1.62)
Maternal Age			
< 20 years	1.21 (0.96-1.53)	1.03 (0.77-1.38)	1.68 (1.13-2.50)
20-39 years	1	1	1
40+ years	1.05 (0.62-1.80)	1.15 (0.61-2.16)	0.87 (0.32-2.37)
Maternal Diabetes			
Yes	1.07 (0.70-1.64)	0.82 (0.46-1.46)	1.63 (0.88-3.03)
No	1	1	1
Maternal Hypertension			
Yes	1.66 (1.09-2.55)	1.62 (0.96-2.75)	1.74 (0.85-3.59)
No	1	1	1
Maternal Anemia			
Yes	0.80 (0.54-1.18)	0.63 (0.37-1.08)	1.14 (0.65-2.01)
No	1	1	1

Table 4. Odds ratios and 95% confidence intervals for race from adjusted logistic regression models stratified by education, North Carolina live births 2009

	Infant Death OR (95% CI)	Neonatal Death OR (95% CI)	Postneonatal Death OR (95% CI)
< High School	1.27 (0.89-1.80)	1.35 (0.87-2.11)	1.13 (0.64-2.01)
High School	2.10 (1.59-2.77)	1.96 (1.39-2.75)	2.36 (1.47-3.80)
> High School	2.92 (2.21-3.86)	3.66 (2.62-5.11)	1.75 (1.05-2.93)

Discussion

Non-Hispanic African American infants born in 2009 were 2.67 times as likely as non-Hispanic white infants to experience mortality in their first year of life, and the infant mortality rate among these births was 2.65 times higher than the rate among white infants – an excess of 223 deaths among the non-Hispanic African American North Carolina births in the study population. Most of the social/behavioral and biomedical risk factors examined were more prevalent among non-Hispanic African American births compared to non-Hispanic white births, with the exception of smoking, first order births, and older maternal age. Risk factors with significant associations with infant mortality in crude analyses included paternal involvement, short interpregnancy interval, inadequate and adequate plus prenatal care, smoking, first, third, and fourth and higher order births, teen maternal age, and hypertension. Paternal involvement, inadequate, and adequate plus prenatal care utilization were most strongly associated with neonatal births, while inadequate prenatal care, smoking, and hypertension were most strongly associated with postneonatal mortality. Several factors appear to mediate the association between race and infant mortality. After adjustment for all potential mediators and race, paternal involvement, inadequate and adequate plus prenatal care, smoking, and hypertension remained significantly associated with infant mortality. The magnitude of association between race and mortality was diminished but remained significant, suggesting that additional factors influence this racial disparity. Paternal involvement, inadequate and adequate plus prenatal care, and first, third, and fourth and higher order births remained significantly associated with neonatal mortality, while inadequate and adequate plus prenatal care, smoking, and teen maternal age remained significantly associated with postneonatal mortality, indicating that the factors examined may influence mortality risk differently during early and late infancy.

Education moderated the association between race and infant mortality, with the racial disparity increasing as education level increased. This pattern held true for neonatal mortality, but not for postneonatal mortality – the high school educated group experienced the greatest racial disparity in postneonatal death, followed by those with education beyond high school. Groups with lower levels of education may experience similar risks regardless of race, including many of the social/behavioral and biomedical factors examined in this study, such as young maternal age, inadequate prenatal care, lack of paternal involvement, and substance use during pregnancy, in addition to other sociodemographic factors. At higher levels of education, risk factors appear to be experienced differentially by race, which would contribute to increased disparities in infant outcomes.

Other studies examining factors that contribute to the racial disparity in infant mortality have also found that maternal behavioral and biomedical factors only partially explain the difference in risk of mortality between non-Hispanic white and African American infants.[58-59] In an analysis of US births and cause-specific infant deaths from 1989-2001, Frisbie and colleagues examined a similar set of risk factors available in birth record data and found that risk of mortality for non-Hispanic African American infants compared to white infants remained significantly higher for all causes of death except congenital anomalies after adjusting for all covariates (excluding gestational age and birthweight).[59] A study of nationally representative survey data was able to examine potential behavioral, health-related, birth outcome, and sociodemographic mediators of the association between race and infant mortality beyond the variables available in birth records, and found that behavioral factors explained only a small portion of black/white differentials in mortality while sociodemographic factors contributed substantially.[58] Maternal smoking, for instance, is a behavioral risk factor that is less prevalent among African American women compared to white women, with lower rates of smoking in this group presumably acting as a protective factor. However, studies have found that African American women are less likely to quit smoking and tend to initiate smoking later than white women, and among the middle-aged, African American women actually have higher smoking rates than white women.[60-61] Taking sociodemographic differentials into account in this case may help to explain overall persisting disparities and the lack of a racial disparity in infant mortality among those with less than a high school education.

Previous studies, including an analysis of North Carolina births from 1988-1993[51], have also found that the racial disparity in infant mortality between non-Hispanic white and African American infants increases with increasing education. Authors of the North Carolina study proposed a number of explanations for this pattern, including greater racial disparities in income at higher education levels, and the stress of changing social classes.[51] For those who grew up in less educated surroundings and pursued a higher education, the potential for disjunction from other family/community members and reduced social support could contribute to increased psychological stress.[51] Stress stemming from societal influences such as institutional and interpersonal racism may play a role as well.[12-13,62] In a recent study, Gage and colleagues found that while overall infant mortality declined with increasing education (for all races), mortality did not improve among compromised (extremely high and low birthweight) African American births with increasing education but did improve among compromised European American births.[50]

The primary contribution of this analysis is the investigation of a comprehensive set of risk factors using recent birth certificate data from the state of North Carolina. This study includes a large population representing all non-Hispanic white and African American births in North Carolina in 2009. Findings confirm that social/behavior and biomedical risk factors influence, but do not fully explain, infant mortality disparities within this population. The results of this study also confirm earlier findings that education moderates the association between race and infant mortality in North Carolina[51], and extends these findings by examining patterns in neonatal and postneonatal mortality as well.

Reliability of predictor variables is a limitation of this study inherent in the use of birth certificate data, and could potentially result in misclassification. Additionally, misclassification of interpregnancy interval in particular is possible. Because all dates of last live birth were assigned as the first day of the reported month (only month and year are available on the birth certificate), some short interpregnancy intervals may have been misclassified into the 18+ months category, which could bias this variable's association with infant mortality toward the null. Several of the other birth certificate variables examined in this study have been compared with data from other sources, such as cohort studies and representative surveys, to assess their reliability. While many variables have been found to agree between sources, the reliability of some variables has been consistently questioned. An assessment of a number of variables on the North Carolina birth certificate, compared to data from a prospective cohort study (the

Pregnancy, Infection, and Nutrition cohort), found maternal race, education, age, birthweight, and gestational age to be adequately reliable.[63] Variables concerning health behaviors (cigarette smoke, alcohol consumption) and medical conditions (anemia, gestational diabetes, and pregnancy-induced hypertension) had lower agreement between sources, particularly alcohol consumption, gestational diabetes, and anemia.[63] Other studies have found alcohol use on the birth certificate to be underreported when compared to survey data.[33] Low prevalence of gestational diabetes and alcohol consumption also contributed to the poor agreement of these variables between sources in the Vinikoor analysis;[63] alcohol use was of similarly low prevalence in the present study, which is likely why it was not significantly associated with infant mortality despite overwhelming evidence that alcohol use during pregnancy is a major risk factor for poor infant outcomes.[30-32,34] While gestational diabetes and pregnancy-induced hypertension were not examined in the present study, the lack of established reliability of these variables could indicate poorer reliability of chronic diabetes and hypertension reported on the birth certificate.

Other limitations include potential confounding due to the observational nature of the study, and the use of maternal education as a proxy for socioeconomic status. Interpregnancy intervals, for instance, may be confounded by gestational age and outcome of last live birth. Shorter pregnancies will equate to shorter interpregnancy intervals for multiparous mothers, and associations between short intervals and mortality could be spurious if mortality is due to preterm birth.[23] A previous infant death may also precede a short interpregnancy interval, and be indicative of higher risk pregnancy.[23,64] This study did not adjust for gestational age (due to the possibility that it is not on the causal pathway to mortality) or previous birth outcome (not available in the birth files) in multivariate analyses; however, analyses that have taken these variables into account have found that significant associations between interpregnancy interval and mortality remain after adjustments.[23,64] Additionally, prenatal care utilization may be confounded by risk of the pregnancy. Studies have found that the adequate plus group tends to have poorer birth outcomes compared to the adequate group because of the inclusion of high-risk patients that attend extra prenatal care visits, a finding replicated in the present analysis.[25] Adequate plus categorization is also easier to achieve at earlier gestations due to fewer recommended visits earlier in pregnancy.[25] Lastly, maternal education was used as a proxy for socioeconomic status, due to the availability of this information in the birth files. Younger mothers, who are already considered an at risk group, are by default categorized as having less than a high school education, which could inflate the mortality risk in this group. However, a separate stratified analysis restricted to mothers age 20 and older (not shown) resulted in the same risk and racial disparity patterns as the primary analysis, suggesting that the primary stratified analysis presented was not sensitive to maternal age.

The findings from this study and related research provide valuable information on how to best target resources to reduce infant mortality and the infant mortality racial disparity. It is clear from this study that while behavioral interventions and addressing biomedical risk factors during pregnancy may be beneficial, there are additional factors at play that should be explored further. Future research should attempt to examine the influence of socioeconomic status more precisely, perhaps through the use of additional proxy measures such as payment source for delivery (private insurance, Medicaid, self-pay, other), an item now collected on the North Carolina birth certificate beginning in August 2010.[65] Representative surveys, such as the 1988 National Maternal and Infant Health Survey analyzed by Finch and colleagues,[58] are another method of obtaining detailed sociodemographic information, including income, as well other measures not present on the birth certificate. Illicit drug use, for example, is likely even more harmful to the developing fetus than alcohol or tobacco (particularly when used in combination with alcohol or tobacco), and past survey data found its prevalence to be 1.8% among non-Hispanic white women who had recently given birth and 7.2% among non-Hispanic African American women, potentially contributing to disparities in infant outcomes.[34] Examining risk factors beyond the prenatal period from a life-course perspective, as several studies have done,[66-68] as well as the exploration of societal influences such as racial discrimination, may also help to explain racial disparities in the context of cumulative stress and the weathering hypothesis.[69] Though this approach would also require survey or cohort data, linking this information to that available in birth records is possible. Additionally, inclusion of births to Hispanic women would also add to the research examining race/ethnicity and infant mortality, particularly because Hispanic birth outcomes in North Carolina tend to be similar to those for non-Hispanic white women, despite differing socioeconomic characteristics.[70]

While the results of this study provide some evidence of mediation of the relationship between race and infant mortality through a combination of social/behavioral and biomedical factors, the factors examined do not fully explain the disparity in infant mortality between non-Hispanic African Americans and non-Hispanic whites. The findings suggest that maternal education moderates the association between race and infant mortality, such that groups with higher levels of education experience greater racial disparities in infant mortality. Controlling for a wide range of social/behavioral and biomedical factors does not eliminate the significant effect of race on risk of infant mortality among those with a high school education and beyond, indicating that there are additional factors contributing to the relationship between race and infant mortality that need to be explored.

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