This is to certify that the
dissertation entitled

AN INVESTIGATION OF RACIAL DISPARITIES IN
INFANT MORTALITY ACROSS THE UNITED STATES:
THE ROLES OF
SOCIO-DEMOGRAPHIC FACTORS,
BIRTH AND FETAL DEATH REGISTRATION
AND PERINATAL REGIONALIZATION

presented by

Crystal Pirtle Tyler

has been accepted towards fulfillment
of the requirements for the

Doctoral degree in Epidemiology

Major Professor's Signature

5/13/09

Date

AN INVESTIGATION OF RACIAL DISPARITIES IN INFANT MORTALITY ACROSS THE UNITED STATES: THE ROLES OF SOCIO-DEMOGRAPHIC FACTORS, BIRTH AND FETAL DEATH REGISTRATION AND PERINATAL REGIONALIZATION

By

Crystal Pirtle Tyler

A DISSERTATION

Submitted to
Michigan State University
in partial fulfillment of the requirements
for the degree of

DOCTOR OF PHILOSOPHY

EPIDEMIOLOGY

2009

ABSTRACT

AN INVESTIGATION OF RACIAL DISPARITIES IN INFANT MORTALITY ACROSS THE UNITED STATES: THE ROLES OF SOCIO-DEMOGRAPHIC FACTORS, BIRTH AND FETAL DEATH REGISTRATION AND PERINATAL REGIONALIZATION

By

Crystal Pirtle Tyler

Objective: To determine the effect of racial inequalities in sociodemographic factors, state fetal death registration requirements and reporting of non-viable births and perinatal regionalization, defined as birth hospital level and neonatal intensive care unit (NICU) transfer, on nationwide variation in racial disparities in infant mortality (IM).

Methods: National Center for Health Statistics (NCHS) live birth and linked infant death records from 2000-2002, U.S. Bureau of the Census, 2000 Census of Population and Housing, and Michigan Department of Community Health live birth and linked infant death vital records from 1996-2006 were used to examine absolute (black IM / white IM) and relative (black IM – white IM) racial disparities in IM rates.

Results: Absolute and relative U.S. disparity measures were 6.99 per 1,000 live births and 2.42, respectively. The absolute disparity measure was highly correlated with black IM ($r = 0.91$) but not white IM ($r = -0.03$), while the relative measure was correlated with both black IM ($r = 0.57$) and white IM ($r = -0.51$). Compared to racial inequalities in other infant, maternal and state risk factors, inequalities in the proportion of very low birthweight births were most correlated with disparities in IM. Mortality rates and racial disparities were the highest among states with birthweight only fetal death reporting criteria and among states with the highest proportion of non-viable births recorded in birth certificates (RR=1.22; 95% CI=1.17-1.37). The largest proportion of this difference

was accounted for by births $\leq$ 22 weeks gestation (RR=1.71; 95% CI=1.43-2.04). The case study in Michigan found that the majority of infants were born at a level 3 hospital. The highest IM rates were seen among extremely preterm infants born at level 1 hospitals compared to their level 3 counterparts (level 1 = 465.3 per 1,000 live births; level 3 = 363.9 per 1,000 live births) and among extremely preterm level 1 white births compared to their black counterparts (white = 506.1 per 1,000 live births ; black = 383.3 per 1,000 live births). Extremely preterm black infants who were born at a level 1 hospital and subsequently transferred to the NICU had a significantly decreased risk of infant death, compared to their white counterparts (RR=0.41; 95% CI=0.26-0.66).

Conclusion: Racial inequalities in the proportion of very low birthweight and very preterm infant births along with state differences in reporting very low birthweight and very preterm births were consistently associated with national variation in IM disparities. Racial inequalities in perinatal regionalization did not account for higher infant or neonatal mortality rates among black infants. A uniform definition of fetal death should be adopted to reduce systematic differences in the reporting of live births and fetal deaths, especially among deaths $\leq$ 22 weeks gestation. Efforts should be made to reduce rates of extremely preterm and extremely low birthweight births where mortality rates and racial disparities in risk of adjusted mortality were the highest and state disparities were more correlated.

DEDICATION

This work is dedicated to my husband, Marcus. Thank you so much for your patience and understanding throughout this process. I love you very much.

AKNOWLEDGEMENTS

I would first like to thank the chair of my dissertation committee, Dr. Nigel Paneth who encouraged and supported me with invaluable advice and kind words throughout this process. I would also like to thank my committee members: Dr. Sue Grady, Dr. Barbara Luke, Dr. Violanda Grigorescu and Dr. David Todem for their patience with my ongoing revisions. I would also like to thank Dr. Yona Cloonan for helping me conceptualize when my brain was tired and Dr. Nicole Talge for accepting me as a roommate for the final months before my defense. Finally, I would like to thank my family and friends who supported me throughout this process.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPREVIATIONS

Confidence Interval.....CI

Disparity Difference.....DD

Disparity Ratio.....DR

Extremely Preterm Birth.....EPTB

Infant Mortality.....IM

Low Birthweight.....LBW

Michigan Department of Community Health.....MDCH

National Center for Health Statistics.....NCHS

Neonatal Intensive Care Unit.....NICU

Neonatal Mortality.....NM

New York City.....NYC

Odds Ratio.....OR

Preterm Birth.....PTB

Relative Risk.....RR

Risk Difference.....RD

Sudden Infant Death Syndrome.....SIDS

Very Low Birthweight.....VLBW

Very Preterm Birth.....VPTB

United States.....US

CHAPTER 1: INTRODUCTION

Improving our understanding of the burden and epidemiology of racial differences in infant mortality (IM) is the primary focus of this research. A special emphasis will be placed on statewide variation in racial differences in IM rates at the national level by first focusing on differences between state level population characteristics and socioeconomic factors and second to differences in fetal death reporting policies and practices. A case study of perinatal regionalization in the State of Michigan and its impact on racial differences in IM rates will also be presented.

1.1 Overview of the Burden and Epidemiology of Infant Mortality

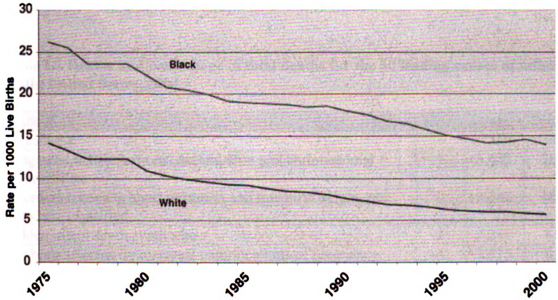
1.1.1 Definition of Infant Mortality

The National Center for Health Statistics defines IM as any death which occurs between birth and 364 days of age. The IM rate therefore is the number of deaths among infants less that 1 year of age divided by the total number of live births and is expressed per 1,000 live births. The U.S. IM rate in 2004 was 6.8 infant deaths per 1000 live births [1, 2].

As with many diseases and conditions in the United States, there are racial differences in IM rates. These racial differences are commonly referred to as disparities because the term embodies both inequality (ie. differences in the health status between two groups) and inequity (ie. systematic differences between two groups with different social advantage). Although IM rates have declined for all races during the 20th century, there are substantial disparities among racial groups [3]. Slower IM declines among blacks compared to whites have led to a 25% increases in disparities in the U.S. [1, 2]. For example, in 1980, the IM rate among whites in the United States was 8.7 per 1,000 live

births compared to an IM rate of 16.5 per 1,000 live births among blacks [4], meaning blacks were 1.90 times as likely as white infants to die during the first year of life. On the other hand in 2005, the white IM rate was 5.7 per 1,000 live births compared to the black IM rate of 13.6 per 1,000 live births, meaning blacks were 2.39 times as likely as whites to die during the first year of life (Figure 1) [5].

Figure 1.1. Trends in infant mortality rates (per 1,000 live births), United States 1975-2000.



1.1.2 Causes of Infant Mortality

The leading causes of IM among United States infants in 2004 are listed in Table 1. In descending order, causes include: congenital malformations, conditions related to short gestation, sudden infant death syndrome, maternal complications of pregnancy, accidents, maternal complications of the placenta, respiratory distress syndrome, bacterial sepsis, neonatal hemorrhage, and diseases of the circulatory system [6]. These 10 leading causes of death accounted for 69% of all infant deaths in 2004. Studies have shown that vital statistics data may underreport or incorrectly report variables such as cause of death [7] and recommend cautious interpretation [8]. Common problems with cause of death data include the reversal of underlying vs. proximate causes or if the cause of death is unknown, sudden infant death syndrome (SIDS) is frequently used. For this reason, Krous et al (2004) describe SIDS as a "term that has been used to describe unexpected deaths of infants or young children when subsequent interventions fail to demonstrate a definite cause of death" [9].

Table 1.1 Deaths and percentage of total deaths for the 10 leading causes of infant death: United States, 2004.

Cause of Death*	Rank	Deaths	Percent
All causes†	--	27,936	100.0
Congenital malformations, deformation and chromosomal abnormalities	1	5,622	20.1
Disorders related to short gestation and low birthweight, not elsewhere classified	2	4,642	16.6
Sudden infant death syndrome	3	2,246	8.0
Newborn affected by maternal complications of pregnancy	4	1,715	6.1
Accidents (unintentional injuries)	5	1,052	3.8
Newborn affected by maternal complications of the placenta, chord and membranes	6	1,042	3.7
Respiratory distress of newborn	7	875	3.1
Bacterial sepsis of newborn	8	827	3.0
Neonatal hemorrhage	9	616	2.2
Diseases of the circulatory system	10	593	2.1

*Based on the International Classification of Diseases, Tenth Revision, 1992
†Data from the NCHS [6]

Differences in cause of death rates differ by race with black infants more likely to die from disorders related to short gestation and SIDS and white infants more likely to die from congenital malformations (Table 2).

Table 1.2. Racial differences in cause specific infant mortality rates: United States, 2004.

Cause of Death*	Mortality Rate†			
	Total	White	Black	RR†
All causes	677.5	566.1	1,359.6	2.4
Congenital malformations, deformation and chromosomal abnormalities	137.1	129.3	167.4	1.3
Disorders related to short gestation and low birthweight, not elsewhere classified	112.1	77.1	297.2	3.9
Sudden infant death syndrome	54.6	54.0	110.9	2.1
Newborn affected by maternal complications of pregnancy	41.5	32.2	103.1	3.2
Accidents	25.6	25.6	46.8	1.8

* Cause of death information is based on the International Classification of Diseases, Tenth Revision, 1992. Data are from the National Vital Statistics Reports [6].
† Mortality rate per 1,000 live births
‡ RR=relative risk (Black to White).

1.1.3 Timing of Death

Depending on the time at which IM occurs, it can be categorized as neonatal mortality or postneonatal mortality. Neonatal mortality is defined as infant death between 1 and 27 days and is primarily related to maternal exposures and conditions arising in pregnancy. As a result, low birthweight (<2500 grams) and very low birthweight births (<1500 grams) account for the majority of deaths during this time period [10]. Since birthweight is a representation of gestational age and growth in-utero, prematurity and intrauterine growth restriction are two factors which contribute significantly to neonatal mortality [11]. At times, neonatal mortality is further dissected into early neonatal mortality, defined as deaths between 1 and 6 days of life.

Postneonatal mortality is defined as infant death between 28 and 364 days of life. Postneonatal mortality in developed countries primarily results from sudden infant death syndrome, infections and homicide [12], but can also result from the late effects of congenital malformations and preterm delivery. Although maternal exposures and conditions may contribute to postneonatal mortality rates, these rates primarily reflect infant exposures and experiences after birth. Postneonatal mortality may also include effects of postponing deaths which would have occurred during the neonatal period but were delayed because of medical intervention.

1.1.4 Maternal Behavioral Influences

There are a number of maternal factors that are associated with an increased risk of IM, including little or no prenatal care, low socioeconomic position, alcohol use and tobacco use during pregnancy [6]. These risk factors act independently and interactively to influence antecedents to IM such as reduced fetal growth and premature birth, the latter of which can lead to a twofold risk in IM [10].

The adequacy of prenatal care received by the mother, based on number and timing of prenatal care visits relative to infant gestation, is associated with IM in a number of ways. The American College of Obstetricians and Gynecologists recommend that all pregnant women initiate prenatal care in the first trimester and continue care at specified intervals throughout pregnancy [13]. Research into the role of prenatal care in IM risk primarily centers around whether prenatal care itself plays a part in reducing IM risk or if reduction in IM risk is due to characteristics of mothers who initiate prenatal care early [14]. For example, Poma (1999) found that infants whose mothers did not receive prenatal care were significantly more likely to die than infants who received adequate prenatal care (OR=4.07; 95% CI=3.74-4.43). Poma et al also found that mothers who did not receive prenatal care were more likely to have other risk factors such as smoking and medical complications [15]. Racial patterns prenatal care closely mirror those of IM rates with blacks more likely than whites to have inadequate or late prenatal care. Furthermore, when IM is examined by trimester of prenatal care initiation, blacks have the highest rates of IM, regardless of timing of prenatal care [6].

Risky maternal behaviors such as smoking and alcohol use also put the infant at increased IM risk. Infants born to women who smoke during pregnancy have a 40% higher IM risk than infants whose mother didn't smoke [16]. Smoking can contribute to IM risk through SIDS, fetal growth restriction and premature rupture of membranes. The risk of each of these factors increases with the number of cigarettes smoked [16]. The race specific effect of smoking is difficult to understand because it differentially influences IM risk across different racial groups. For example, among children of white women, smoking during pregnancy is associated with an 85% increase in IM risk, while it is only associated with a 53% risk among children of black women who smoke [17]. This racial difference in risk could be due to racial differences in the causal pathway from smoking to IM.

Maternal moderate and heavy alcohol use are associated with poor pregnancy outcomes such as fetal alcohol syndrome fetal growth restriction and preterm delivery [18]. Self-reported alcohol use during pregnancy indicate that while overall rates are low (0.8% in 2002) and similar between blacks and whites (0.9% and 0.8%, respectively) [19]. One of the best protections that a mother can offer against poor pregnancy outcomes such as low birthweight, preterm birth and IM is to actively plan for pregnancy and enter into pregnancy with as few medical and behavioral risk factors as possible.

1.1.5 Importance of Understanding Racial Disparities in Infant Mortality: Racial Composition

A health disparity is the quantity that separates a group from a specified reference point on a particular measure of health that is expressed in terms of a rate, percentage, mean or some other quantitative measure [20]. The term health disparity is almost exclusively used in the United States, while the terms 'health inequity' and 'health inequality' are more commonly used outside of the United States [21]. Reasons for this difference in terminology primarily center on whether a judgment of what is avoidable and unfair is included, and how these judgments are made.

In the U.S. public health field, use of the term 'health disparity' generally takes on the implication of injustice, but can still be separated from general inequalities in health. A health disparity should be viewed as a chain of events characterized by differences in environment, access to or quality of care or health status [21]. Whitehead defines seven determinants of health disparities as a) natural, biological variation; b) health damaging behavior that is freely chosen; c) the transient health advantage of one group over another when one group is first to adopt a health promoting behavior (as long as other groups have the means to catch up fairly soon); d) health damaging behavior in which the degree of choice of lifestyles is severely restricted; e) exposure to unhealthy, stressful living and working conditions; f) inadequate access to essential health services and other basic services; g) natural selection, or health related social mobility, involving the tendency for sick people to move down the social scale [22]. The first three categories in this classification are usually viewed as unavoidable and fair, while the last four categories are viewed as avoidable and unfair. Racial inequalities in either of the categories (but especially the last four) are the prime focus of health disparity research.

In addition to worldwide variation in terminology, concrete definitions and methods, which are critical to the health disparity research field, are the center of much debate. In general health disparities are measured by comparing the health of one population (disadvantaged) with the health of another population (referred to as the reference population). Although a reference point can be arbitrarily chosen based on researcher preference, choice of reference has important implications for intervention and policy. Comparisons can either be made to groups (between- or within-group measures), relative to a summary measure (population mean or standard deviation), or based on a standard (ie. Healthy People 2010 goal) [20]. When between-group comparisons are made, the reference can be the group with the largest number of people. This could be beneficial because the largest group would have the most stable rate. Between-group comparisons could also be made the 'best' rate as the reference point (best could be defined as the highest or lowest rate depending on the outcome). Best rate comparisons may be convenient because comparisons with all other groups would be in the same direction. For within group comparisons, the reference is based on an internal scale of measurement. This method could account for culturally relevant differences between groups, but only provides an indirect measure of health disparity. In large, diverse populations, the mean of the population could be used as a reference for a small group. The mean would be less subject to variation over time, but it could be subject to outlying population rates. Finally, a health standard or target could be used as a reference because it doesn't have sources of random variation associated with it. Despite the reference choice, it has to be clearly specified in order for the disparity measure to have meaning.

While a number of disparity measures exist, each is based on its own assumptions and therefore requires its own scientific interpretation [23-25]. A number of potential disparity measures have been proposed but a clear consensus on the best type of measurement (relative or absolute) is best has not been achieved [5, 20, 23-27]. Disparity ratios (DR) are a commonly used relative measure for quantifying inequality between two groups [20, 24-26, 28, 29]. In this research, the DR is the ratio of black IM to white IM and its meaning can vary depending on the rates of those groups. For example, a high DR can be due to a high black IM rate, a low white IM rate, or a combination of the two. In contrast, a low DR can be due to a low black IM rate, a high white IM rate or a combination of the two. In 1980, the black/white disparity ratio in IM was 1.90 and in 2005, the black/white disparity ratio was 2.39, but in order to gain meaning from these DRs it is important to know the race-specific composition of the ratios and if it varies over time.

The absolute disparity difference (DD) is the difference between the black IM rate and the white IM rate (ie. black IM – white IM). The DD reflects the actual (absolute) size of the disparity by indicating how large a proportion of the disadvantaged group is affected by the outcome. It can also be used to make comparisons across health indicators, regardless of unit of measurement [5, 20, 24]. From 1980 to 2005, the black-white DD in IM was similar (ie. 7.8 excess deaths per 1,000 live births and 7.9 excess deaths per 1,000 live births, respectively). When comparing the relative to the absolute measure, the DR depends heavily on the baseline level of the measure of interest, while the DD depends heavily on the overall rate of disease. Larger DDs are seen when overall rates of disease are average and smaller differences are seen at the extremes [24, 26]. With the 1980 and 2005 IM rates, the same absolute decrease in white and black mortality rates affects the DR but not the DD. Equally, the same proportion increase in white and black mortality rates would be reflected in a change in the DD, but not in the DR. In general, absolute and relative measures lead to similar results when applied to the same measure at one point in time, but can lead to different conclusions when comparisons are made at multiple points over time [21]. In an ideal situation, both the difference and ratio would be measured simultaneously to enable the most meaningful interpretation of health disparity data.

Currently, we don't know if racial disparities in IM are composed of high black IM rates, low white IM rates, or both. We also don't know if there is geographic variation in the racial composition of disparities in IM across the U.S. In order to effectively reduce racial disparities in IM, it will be important to determine the underlying race-specific rates that comprise these disparities.

1.2 Three Key Exposures in Relation to Infant Mortality

State-level differences in IM have been apparent since the 1950s [30], with regional and statewide variations within and between racial groups [4, 6, 29, 31-36]. While studies have shown that southern states average the highest overall IM rates [29], racial/ethnic disparities in IM are greatest among states in the north central region of the U.S. [6]. In 2004, state-level DRs ranged from 1.42-3.48 with black infants nearly four times as likely as their white counterparts to die during the first year of life in some states. Little is understood about the cause of these state-level differences in IM rates and disparities. States vary in population risk characteristics, prevalence of LBW, and geographic obstacles to delivery in care [4]; but these factors have not been well examined in relation to disparities. The areas of sociodemographic factors, reporting of fetal and infant deaths and perinatal regionalization have received little attention in relation to state-level variation in IM disparities; especially in relation to the racial composition of disparities.

1.2.1 Social Influences

Socioeconomic factors such as education and income, differences in cultural norms and practices, and institutionalized racism [37], are thought to be major contributors to racial disparities in IM. Nearly parallel reductions in IM rates among all racial groups coupled with increases in racial disparities, suggest that factors which influence racial disparities in IM may differ from factors associated with IM rates over time. For example, black infants are more likely to be born preterm or with a low birthweight than white infants [38], which accounts for a large proportion of the black/white disparity in infant mortality. But, while conditions related to short gestation account for a large proportion of IM, black low birthweight infants have improved survival, compared to their white counterparts [39]. In contrast, normal birthweight black infants are considerably more likely to die before the age of one than their white counterparts [12].

Black/white differences in IM persist even after classification on socioeconomic risk factors. In 1992, Schoendorf et al found that black infants born to college educated mothers have higher IM rates than white infants with similarly educated mothers [37].

Furthermore, infants of black college educated women have higher IM rates than do infants of white women with less than a high school education [37].

Since the early 20th century, researchers have observed a link between standard of living and morbidity and mortality [40]. The general theory states that social factors, such as societal transitions in economic conditions, urbanization, improved sanitation, and improvement in the status of women, have been primarily responsible for reducing mortality rates [41]. A number of researchers have speculated that socioeconomic and political empowerment may have a beneficial impact on maternal health status, and that the disparity in IM is a reflection of underlying political inequality [41, 42]. Based on this hypothesis, if differences in mortality are reflections of powerlessness, where certain groups (ie. minorities) have economic and political power, mortality rates should be lower. Bird and Bauman (1995) found that a substantial portion of the variance in state level IM is accounted for by state structural characteristics such as the proportion black, proportion with greater than a high school degree and proportion with income below the poverty level [33]. Furthermore, this same study found that structural variables accounted for more variance in state level IM rates than health services variables such as the number of physicians, proportion without health insurance and proportion receiving late or no prenatal care. States vary in structural sociodemographic characteristics; although racial inequalities in these factors have not been well examined in relation to racial disparities in infant mortality. In addition, comparisons of different disparity measures have not been made in relation to state level disparities in IM. The interaction of socioeconomic factors with race poses a challenge when separating the effect of these factors on racial disparities in IM. Identifying populations at high risk of IM requires simultaneously examining race and socioeconomic factors.

Critiques of state level, ecologic analyses of the effects of social factors on health outcomes usually cite ecologic fallacies (ie. the conceptual model being tested corresponds to the individual but the data used are in aggregate or group form), residual confounding (ie. partial or incomplete control for variables of interest) or over controlling (ie. controlling mediators in the causal pathway) as methodological issues. While these critiques are relevant to a number of research questions, not all ecologic rsearch studies attempt to make individual inferences based study results (ie. Bird et al, 1995) [33]. Furthermore, as with individual level analyses, ecologic analyses require methods to ensure proper statistical control (ie. not adjusting for mediators on the causal pathway).

1.2.2 Reporting Differences

Variation in the completeness and accuracy of reporting fetal and infant deaths can influence racial disparities in both fetal and infant mortality rates [43]. Although all states require the reporting of a live birth regardless of the length of gestation or weight, there is considerable variation in reporting criteria for fetal deaths.

The 1992 revision of the Model State Vital Statistics Act and Regulations recommended the following definition of fetal death: "...death prior to the complete expulsion or extraction from its mother of a product of human conception...after such expulsion or extraction the fetus does not breathe or show any evidence of life... " [44]. Imprecision in recognizing or acknowledging very brief and faint signs of life may lead to systematic variations in reporting a delivery as a live birth and subsequent infant death versus a fetal death [43]. Because there is only a recommended definition of fetal death, systematic variation appears in state reported rates of very low birthweight fetal deaths. Studies have examined the effect of reporting differences on proportion low birthweight [45, 46], racial differences in perinatal mortality [43], and neonatal mortality [36]. Although there is conflicting evidence on the effect of reporting differences on state-level differences in perinatal outcomes, Wingate (2006) found that there may be underreporting of very low birthweight fetal deaths and recommended further analyses to establish if black fetal death rates are underreported [43]. Due to the systematic differences in state reporting of perinatal deaths, it is reasonable to suspect that misclassification of low birthweight infants as fetal deaths by certain areas (or vice versa) , could lead to state differences in overall IM rates and/or racial disparities in IM.

1.2.3 Perinatal Regionalization

Extremely preterm infants born in hospitals with neonatal intensive care units (NICU) or transferred to such centers immediately after birth have lower mortality and morbidity rates than comparable infants born in other settings [47]. The process of perinatal regionalization involves a "regionally coordinated system focusing on levels of hospital-based perinatal care" and has been shown to improves outcomes for both mothers and newborns [48]. Perinatal regionalization incorporates the use of maternal and/or infant transport services to ensure that low birthweight or at-risk infants are inborn or promptly transferred to appropriate facilities (preferably with NICUs), regardless of where their mother initially sought obstetrical care [49]. This system evolved to increase the number of mothers and infants who had access to neonatologists, obstetricians and pediatricians. Furthermore perinatal regionalization offered improved health care for mothers and infants and has been adopted by many states and hospital systems [50].

In 1976, the March of Dimes Committee on Perinatal Health designated three levels of perinatal care. The three basic levels as described in the latest American Academy of Pediatrics (AAP)/American College of Obstetricians and Gynecologists (ACOG) guidelines are as follows: level 1 hospitals are able to treat newborns without obstetric complications and do not have a NICU; level 2 hospitals are able to treat moderately ill newborns and they may or may not have a NICU; level 3 hospitals always have a NICU and are able to treat the highest risk infants [48]. Recently, level 2 and level 3 hospitals have been further categorized by factors such as the volume of extremely preterm infants and/or the number of NICU beds [51]. Alternatively some states, such as Michigan, recognize only two levels of care, bypassing the intermediate (level 2) category [52].

The effectiveness of perinatal regionalization can be determined by examining the proportion of extremely preterm, low birthweight infants which are born at a level 3 hospital or by examining the proportion of extremely preterm, low birthweight infants which are transferred to a NICU after birth [53-56].

Throughout the 1990s, increases in the number of smaller, community NICUs with 1 or 2 neonatologists has led to breakdowns in the cooperative relationships between the less specialized level 1and level 2 hospitals and the most specialized level 3 facilities [57]. Furthermore, decreases in state funding of the regionalized transport of mothers and infants as well as decreases in insurance funding of level 3 care (when less expensive level 2 care is available) has led to de-regionalization in many states (ie. Michigan). This de-regionalization is thought to have the largest effect on lower socioeconomic groups with limited access to level 3 hospitals [39]. With the disproportionate representation of racial/ethnic minorities in lower socioeconomic groups, perinatal de-regionalization could impact on racial disparities in infant and neonatal mortality rates. In addition, state-level differences in regionalization funding could account for state differences in preterm or low birthweight IM rates. While some studies have examined the effect of perinatal regionalization IM rates, it is not clear whether racial differences in IM can be partially explained by differences in access to medical care for high risk neonates.

1.3 Significance of Study

Understanding IM in general and racial disparities in IM in particular is necessary in order to reduce these disparities. There is a lack of research examining the effect of racial inequalities in social factors, statewide reporting and perinatal regionalization on racial disparities in IM. Furthermore few examine these factors with respect to national variation in IM disparities. This study focuses on the burden and epidemiology of disparities in IM by examining on three important and timely exposures with the purpose of influencing state and national policy. The distinction between this research and that of others is the focal point of states as the unit of analysis. States were chosen as the primary focus for three key reasons: first, racial disparity in IM is a population level concept and a critique of relative versus absolute disparities can not be done on an individual level. Second, in order to examine reasons for national variation in IM rates and racial disparities in IM, an examination of characteristics in aggregate allows for patterns, which may not be apparent in individual level analyses, to be seen. Finally, the use of states as the unit of analysis allows for a direct pathway between research and the population level implementation of policy. In order to effectively reduce racial disparities in IM it is important to determine what is causing the state-level differences in the racial composition of disparities in IM.

1.4 Specific Aims

In order to improve understanding of major contributions to national variation in IM rates and racial disparities in IM, the aims of this dissertation research are as follows:

- Specific Aim 1: Determine the influence of racial inequalities in infant, maternal and state sociodemographic factors on racial disparities in IM. Both relative and absolute disparity measures will be used to determine if results are influenced by disparity measurement techniques.
- Specific Aim 2: Determine the effect of fetal death registration requirements and reporting of largely non-viable births on state level differences in infant, early and late neonatal, postneonatal, and fetal mortality rates and racial disparities in mortality rates.
- Specific Aim 3: Examine the effect of perinatal regionalization (ie. hospital level at birth and NICU access) on racial disparities in preterm infant and neonatal mortality in Michigan.

1.5 Study Population and Data Sources

Vital statistics data has been used to track maternal and child health since the early 1900s [58]. National vital statistics data files are compiled from data provided through the Vital Statistics Cooperative Program and involves contracts between the National Center for Health Statistics (NCHS), all 50 states, the District of Columbia and New York City (which is separate from New York State for the purpose of death registration.

1.5.1 Aim 1 Study Population and Data Source

Specific Aim 1: Determine the influence of racial inequalities in infant, maternal and state sociodemographic characteristics on racial disparities in IM. Both relative and absolute disparity measures will be used to determine if results are influenced by disparity measurement techniques.

The source population for aim 1 included singleton live births and infant deaths from 2000-2002 among non-Hispanic, white (white) and non-Hispanic, black (black) infants aggregated to each of the 50 states, Washington DC, and New York City (n=52 areas;10,999,362 live births; 66,566 infant deaths). The study population included live births and infant deaths among non-Hispanic, white and non-Hispanic, black infants aggregated to each of the states who had complete ascertainment of all variables of interest and adequate race specific sample sizes within each state (n=41 areas; 10,586,415 live births; 64,502 infant deaths).

Numerator data on infant deaths were obtained from the NCHS U.S. Infant Death Data Set for the years 2000-2002. Infant death data includes deaths to all infants in a calendar year which can be linked to a birth certificate in the denominator file and consists of information reported on death certificates, regardless of age. Fetal deaths are not contained in mortality files. The death certificate includes demographic characteristics of the decadent, and underlying and contributing cause of death. The U.S. death-registration system encompasses 50 States, Washington DC, and New York City NYC (which is independent of New York State for the purpose of death registration). It is believed that more than 99% of the births and deaths occurring in this country are registered [59]. Coding is done by the NCHS and quality control for infant death data is done by computer edit checks, code validations, and comparisons of tabulated data with data for the previous year.

Denominator data on live births were obtained from the United States natality files, which include data reported on the birth certificate shortly after the birth of a live-born infant. All live-born infants in the United States are required to have a birth certificate, regardless of viability or subsequent outcome (ie. infant death). Birth certificates are filled out by the institution at which the birth occurred and are submitted to the state. Data included on the birth certificate are maternal and paternal demographics, maternal pregnancy and reproductive history, birthweight and gestational age at delivery, mode of delivery and medical complications during delivery.

The Linked Birth/Infant Death Dataset is produced by the National Center for Health Statistics (NCHS) [59]. Three years of cohort data were used in order to obtain sufficient case and live birth thresholds from which to produce stable IM rates (>19 deaths in the numerator). Cohort data links infants born in one year to subsequent deaths regardless to whether the death occurred during the birth year, or the following year [59]. Birth cohort data files were preferred for detailed analyses because they follow a given cohort of births for an entire year to ascertain mortality-specific information.

National birth and infant death records make use of state linked files for the identification of linked birth and infant death certificates and NCHS natality and mortality computerized statistical files. When the birth and death of an infant occurs in different states, copies of the records are exchanged by the state of death and the state of birth in order for the record to be linked. In addition, if a third state is identified as the state of residence at the time of birth or death, that state is also sent a copy of the appropriate certificate by the state when the birth or death occurred. The NCHS natality and mortality files, produced annually, include statistical data from birth and death certificates that are provided to NCHS by states under the Vital Statistical Cooperative Program. Data were coded according to uniform coding specifications, passed rigid quality control standards, were edited and reviewed and are the basis for official US birth and death statistics [59].

Additional data on sociodemographic characteristics of areas of residence were obtained from the U.S. Bureau of the Census, 2000 Census of Population of Housing (census). For each census dataset, summary file 3 (SF3) data were used to estimate state-level (level 050) characteristics relating to natality, education, employment, and poverty. Sampling was done by the housing unit and the sampling rate varied by census block to account for differing population densities. For the U.S. census, the overall sampling rate is 1 in every 6 housing units and approximately 95% of the total population was enumerated. The overall final response rate for the 2000 census was 67%. Imputation methods were used by the census to account for non-response, although it is recognized that black, Hispanic, and poor populations were undercounted.

1.5.2 Aim 2 Study Population and Data Source

Specific Aim 2: Determine the effect of fetal death registration requirements and reporting of largely non-viable births on state level differences in infant, early and late neonatal, postneonatal, and fetal mortality rates and racial disparities in mortality rates.

The source population for aim 2 included singleton live births, infant deaths, and fetal deaths from 2000-2002 among non-Hispanic, white [22] and non-Hispanic, black (black) infants (n=10,999,362 live births; 66,566 infant deaths; 154,119 fetal deaths). The study population included live births and infant deaths among white and black infants who had complete ascertainment of all variables of interest (n=10,980,512 live births; 66,569 infant deaths; 68,755 fetal deaths).

In addition to the United States linked birth/infant death dataset from 2000-2002, aim 2 also made use of U.S. Fetal Death Data. Fetal death statistics for every year are based on all reports of fetal death received by the NCHS. Reporting requirements for fetal deaths vary from state to state. Overall reporting is not as complete for fetal deaths as for births and deaths, but is believed to be relatively complete for fetal deaths at ≥28 weeks gestation or more [60]. National data on fetal deaths include fetal deaths occurring at a stated or presumed gestation of 20 weeks or more. The fetal-death reporting system encompasses the 50 States, Washington DC, and New York City. Coding is done by the NCHS and quality control for fetal death data is done by computer edit checks, code validations, and comparisons of tabulated data with data for the previous year.

1.5.3 Aim 3 Study Population and Data Source

Specific Aim 3: Examine the effect of perinatal regionalization (ie. hospital level at birth and NICU access) on racial disparities in preterm infant and neonatal mortality in Michigan.

The source population for aim 3 included singleton, preterm (gestational age < 37 weeks) live births and infant deaths from 1996-2006 among non-Hispanic, white [22] and non-Hispanic, black (black) infants (n=111,671 live births). The study population included preterm live births and infant deaths among white and black infants who had complete ascertainment of all variables of interest (n=107,046 live births; 3,950 infant deaths).

Live birth and infant death certificates were obtained from the Vital Records and Health Data Development Section of the Michigan Department of Community Heath (MDCH). The data were coded according to uniform coding specifications, passed rigid quality control standards, were edited and reviewed and are the basis for official Michigan birth and death statistics. Cohort mortality data for each of the years were used, as opposed to period data, which links deaths of all infants born in a certain year, regardless to whether the death occurred during the birth year, or the following year. Birth cohort data files were preferred for these analyses because they follow a given cohort of births for an entire year to ascertain mortality-specific information. Birth certificates included information on hospital at birth, maternal demographic and pregnancy characteristics and infant characteristics at birth.

The main exposure of perinatal regionalization was determined by two variables obtained from the birth certificate: hospital level at birth (1 vs. 3) and infant transport to a NICU (yes/no). Assignment of hospital level was based on the availability of a NICU at any point during the 11 year study period. Hospitals which had a NICU during the study period were designated level 3. Hospitals which did not have a NICU during the study period were designated level 1. In rare instances where hospital level could not be obtained from the MDCH, hospitals were contacted directly and asked if they had a NICU at any point in time from 1996-2006. Three hospitals were contacted directly; one of the three was designated level 3, white the other two were designated level 1. NICU transfer was based on the birth certificate question which asked "Was the child transferred to a neonatal intensive care unit". Response options were yes, no and unknown. Other secondary variables included maternal demographics (education, age, smoking status, alcohol use, urbanicity and the Kessner prenatal care index) [61] and infant demographics (sex and birthweight).

1.5.4 Strengths of Vital Statistics

The most obvious strength of vital statistics data is its comprehensiveness. Birth and death registration are thought to be virtually complete, with records on >99% of all live births and infant deaths in the United States [58]. Due to the completeness of vital statistics data, they are less subject to the selection biases one could encounter in more clinical study populations. Furthermore, since natality and mortality data have been collected since the early 1900s, it allows for multi-site comparisons over time. Detailed information on demographic, geographic and medical factors also allows for population stratification with relative completeness of virtually all perinatal variables [7, 58]. Finally, vital statistics data are publicly available and relatively easy to use.

1.5.5 Limitations of Vital Statistics

Studies have shown that vital statistics data may underreport or incorrectly report variables such as paternal education or cause of death. Variables with a low reliability or a high proportion of underreporting (such as cause of death) were not used in our analyses and therefore were not a source of bias for this study. With respect to this research, other studies have provided evidence that obstetric procedures, complications of labor and delivery and maternal and infant conditions have been underreported [7]. This underreporting may not be random, especially for conditions associated with adverse pregnancy outcomes. For example, maternal data may be less complete when a high-risk pregnant woman is transferred prior to birth, or an infant is transferred shortly after birth [58]. Second, gestational age is based on the date of the last menstrual period. Potential problems with this measure include recall bias and misclassification because of bleeding post-conception [62]. With the 1989 birth certificate revision, a clinical estimate of gestation improved gestational age misclassification to some extent [58]. In response to this limitation, aim 2 specifically examined state-level differences in the completeness and accuracy of perinatal reporting among specific gestational age/birthweight groups. Third, there could be clustering of maternal risk factors for twins and higher order multiple births. Analyses excluded multiple births and only examined the effect of sociodemographics, reporting, and perinatal regionalization among singleton births. Finally, there are several limitations of the U.S. census data. Urban and minority populations have been underrepresented in the census and the sampling scheme of the SF-3 long form reflects similar issues. Nevertheless, the U.S. census data is recognized as the most complete data source to enumerate population-based characteristics.

CHAPTER 2: THE EFFECT OF RACIAL INEQUALITIES IN SOCIODEMOGRAPHIC FACTORS ON RACIAL DISPARITIES IN INFANT MORTALITY, BY STATE

This chapter includes an examination of the effect of inequalities in sociodemographic factors on state level differences in racial disparities in IM and is study 1 for this three paper dissertation option.

2.1 Abstract

Objective: To determine the effect of racial inequalities in infant, maternal and state sociodemographic factors on nationwide variation in racial disparities in IM. We also sought to determine if disparity/inequality measurement influenced findings.

Methods: National Center for Health Statistics, Division of Vital Statistics (NCHS) live birth and linked infant death records among singleton, non-Hispanic white (white) and non-Hispanic black (black) infants from 2000-2002 were used to calculate absolute (black/white) and relative (black - white) disparities in infant mortality (IM). Racial disparities in IM data were correlated, using the Pearson Correlation Coefficient, with racial inequalities in infant, maternal, and state sociodemographic factors. Inequalities in infant and maternal factors were obtained from NCHS natality files, while inequalities in state sociodemographic factors were obtained from the U.S. Bureau of the Census, 2000 Census of Population and Housing.

Results: Absolute and relative U.S. disparity measures were 6.99 per 1,000 live births and 2.42, respectively. The absolute disparity measure was highly correlated with black IM ($r = 0.91$) but not white IM ($r = -0.03$), while the relative measure was correlated with both black IM ($r = 0.57$) and white IM ($r = -0.51$). After adjustment for confounding factors, relative inequalities in the proportion of very low birthweight births (VLBW)

exhibited the strongest correlation with relative disparities in IM (r=0.75), while absolute inequalities in low birthweight births (LBW) exhibited the strongest correlation with absolute disparities in IM (r=0.67).

Conclusion: Absolute measures of disparity were strongly related to black IM rates, while both black and white IM rates equally contributed to relative disparity measures. In order to reduce state differences in racial disparities in IM, efforts should be made to target women who are at high risk for a LBW or VLBW birth.

2.2 Introduction

2.2.1 Background on Infant Mortality

The infant mortality (IM) rate (number of infant deaths <1 year of age per 1,000 live births) is commonly used to assess the health and well-being of populations [63]. In the U.S., reducing the overall IM rate is consistent with the first and second overarching goals of Healthy People 2010. The first goal is to increase years and quality of life [2, 64], and by reducing a person's life by nearly 80 years, IM can be seen as the most dramatic loss of years of life. From 1950 to 1991 the U.S. IM rate declined an average of 3% per year [65]. However, despite this decline, the Healthy People 2010 target of 4.5 infant deaths per 1,000 live births has not yet been met.

2.2.2 Racial Disparities in Infant Mortality

The second goal of Healthy People 2010 is to eliminate health disparities [64]. Although IM rates have declined for all races during the 20th century, there are substantial disparities among racial groups [3]. Slower IM declines among blacks compared to whites have led to a 25% increases in disparities in the U.S. [1, 2]. For example, in 1980, the IM rate among whites in the United States was 8.7 per 1,000 live births compared to an IM rate of 16.5 per 1,000 live births among blacks [4], meaning blacks were 1.90 times as likely as white infants to die during the first year of life. On the other hand in 2005, the white IM rate was 5.7 per 1,000 live births compared to the black IM rate of 13.6 per 1,000 live births among black infants, meaning blacks were 2.39 times as likely as whites to die during the first year of life.

2.2.3 Disparity Measurement

Related to the second healthy people 2010 goal is the question of how best to measure racial disparities in health outcomes [20, 23, 25, 26]. While a number of disparity measures exist, each is based on its own assumption and therefore requires its own scientific interpretation [23-25]. A number of potential summary measures have been proposed but a clear consensus on the best type of measurement (relative or absolute) has not been achieved [5, 20, 23-27]. Disparity ratios (DR) are a commonly used relative measure for quantifying inequality between two groups [20, 24-26, 28, 29]. In this research, the DR is the ratio of black IM to white IM and its meaning can vary depending on the rates of those groups. For example, a high DR can be due to a high black IM rate, a low white IM rate, or a combination of the two. In contrast, a low DR can be due to a low black IM rate, a high white IM rate or a combination of the two. In 1980, the black/white disparity ratio in IM was 1.90 and in 2005, the black/white disparity ratio was 2.39, in order to gain meaning from these DRs it is important to know the race-specific composition of the ratios and if it varies over time.

The absolute disparity difference (DD) is the difference between the black IM rate and the white IM rate (ie. black IM – white IM). The DD reflects the actual (absolute) size of the disparity by indicating how large a proportion of the disadvantaged group is affected by the outcome. The DD can also be used to make comparisons across health indicators, regardless of unit of measurement [5, 20, 24]. In 1980 the DD in IM was 7.8 excess deaths per 1,000 live births, while the 2005 DD was 7.9 excess deaths per 1,000 live births. When comparing the relative to the absolute measure, the DR depends heavily on the baseline level of the measure of interest, while the DD depends heavily on the overall rate of disease. Larger DDs are seen while overall rates of disease are average and smaller differences DDs are seen at the extremes [24, 26]. With the 1980 and 2005 IM rates, the same absolute decrease in white and black IM rates affects the DR but not the DD. Equally, the same proportion increase in white and black IM rates would be reflected in a change in the DD, but not in the DR.

2.2.4 Nationwide Variation in Infant Mortality and Racial Disparities in Infant Mortality

State-level differences in IM and racial disparities in IM (relative and absolute disparities) have been apparent since the 1950s [28], with regional and statewide variations seen within and between racial groups [4, 6, 29, 31-36]. For example Allen (1987) found that southern states had the highest total and white IM rates (12.1 and 9.8 per 1,000 live births, respectively) but the north central states had the highest black IM rates [31]. Furthermore, Marks (1987) found that state-specific black/white DRs in IM varied from 1.9 to 2.4 [4]. More recently, in their 2008 report, the Robert Wood Johnson Foundation found that IM rates from 2000-2002 ranged from 4.6 per 1,000 live births in Massachusetts to 11.0 per 1,000 live births in Washington DC [66]. While studies have shown that southern states have the highest overall IM rates [67], little research has been done on the highest disparity states. The factor(s) underlying state-level differences in IM rates are not well-understood and even less is known of state-level differences in racial disparities. States vary in the prevalence of known risk factors for IM such as low birthweight births [68] and adequacy of prenatal care [4]; although racial inequalities in these risk factors have not been well examined in relation to nationwide variation in racial disparities in infant IM. Furthermore, comparisons of different disparity measures have not been made in relation to IM or risk factors for IM.

2.2.5 Study Objective

This study estimated the effect of racial inequalities in infant, maternal and state sociodemographic factors on state level differences in racial disparities in IM. We also determined if results were influenced by measurement techniques (relative vs. absolute) used to describe inequalities in exposures (infant, maternal and state factors) and/or disparities in outcome (IM).

2.3 Materials and Methods

We examined singleton live births and linked infant deaths to self-identified, non-Hispanic white and non-Hispanic black (hereafter referred to as white and black) mothers who resided in the U.S. at the time of their infant's birth. Birth and death records missing information on maternal race were omitted from the dataset and not used in this analysis.

2.3.1 Study Population

The study population included singleton live births and infant deaths from 2000-2002 among non-Hispanic, white [22] and non-Hispanic, black (black) infants aggregated to each of the 50 states, Washington DC, and New York City (n=52 areas;10,999,362 live births; 66,566 infant deaths). The study population included live births and infant deaths among non-Hispanic, white and non-Hispanic, black infants aggregated to each of the states who had complete ascertainment of all variables of interest and adequate race specific sample sizes within each state (n=41 areas; 10,586,415 live births; 64,502 infant deaths).

2.3.2 Data Source and Preparation

Birth and linked infant death records were obtained from the 2000-2002 Linked Birth/Infant Death Dataset, produced by the National Center for Health Statistics Division of Vital Statistics (NCHS) [59]. Three years of cohort data were used to obtain a sufficient sample of infant deaths for the numerator and live births for the denominator from which to produce stable IM rates. Cohort data links infants born in one year to subsequent deaths regardless to whether the death occurred during the birth year, or the following year [59]. Birth cohort data files were preferred over period data for this analysis because they follow a given cohort of births for an entire year to ascertain mortality.

National birth and linked infant death records make use of state natality data for the identification of birth and infant death certificates used in the NCHS computerized statistical files. When the birth and death of an infant occur in different states, copies of the records are exchanged by the state of death and the state of birth in order for a linkage to take place. In addition, if a third state is identified as the state of residence at the time of birth or death, that state is also sent a copy of the appropriate certificate by the state when the birth or death occurred. The annual NCHS natality and mortality files include statistical data from birth and death certificates that are provided by states under the Vital Statistical Cooperative Program. Data were coded according to uniform coding specifications, passed rigid quality control standards, were edited and reviewed and are the basis for official U.S. birth and death statistics [59].

2.3.3 Outcome Variables

Region- and state-specific IM rates were calculated by dividing the number of infant deaths by the total number of live births. All IM rates were expressed per 1,000 live births. Crude IM rates were calculated, in addition to rates stratified by race. Births and deaths were assigned to the birth state, regardless of if the infant death occurred in another state. Regions were defined based on the Census of Population and Housing categories and included the northeast, midwest, south and west. States were defined as each of the 50 states, the District of Columbia and New York City, which reports separately from New York State in the Vital Statistics Cooperative Program.

We employed both a relative measure, the disparity ratio (DR) and an absolute measure, the disparity difference (DD) of racial disparities in IM. In the case of no disparity, the value DR took was one and the value DD took was zero. All DDs were expressed per 1,000 live births.

To characterize relative and absolute measures of racial disparities in IM and determine which measure most reflected race-specific IM rates, racial composition scores were calculated. We defined racial composition as the race-specific IM ranking of each state, compared to the rest of the U.S. Racial composition was determined as follows: first, race-specific IM rates were calculated for each state; second, black IM rates were broken into tertiles with the highest 1/3 of black IM rates receiving the racial composition score of 'high', the middle 1/3 of black IM rates receiving the racial composition score of 'medium' and the lowest 1/3 of black IM rates receiving the racial composition score of 'low'; third, the same criterion was used for white infants. This resulted in a black racial composition score (high, medium, or low) and a white composition score (high, medium, low) based on the relative rank of each state's race-specific IM rate. For example, if a state has a white IM rate in the highest tertile, and a black IM rate in the middle tertile, their racial composition score would be as follows: white=high; black=medium. Racial composition scores were also grouped into quartiles and quintiles but tertiles were found to correspond best with our data. To prevent unstable IM rates by race, eleven states (Alaska, Hawaii, Idaho, Maine, Montana, New Hampshire, North Dakota, South Dakota, Utah, Vermont, and Wyoming) were excluded from analyses for having fewer than 20 black infant deaths [6]. Thus, all rates presented had at least 20 deaths in the numerator.

2.3.4 Exposure Variables

Racial inequalities in several sociodemographic risk factors for IM were examined in relation to racial disparities in IM. Racial differences in exposure variables were referred to as 'inequalities', while the term 'disparities' was used to describe racial differences in the outcome.

2.3.4.1 Vital Statistics Measures

Infant and maternal sociodemographic factors were collected from birth certificate records for each state. Infant factors included information on gestational age, specifically preterm birth (PTB) or infants born less than 37 completed weeks gestation and very preterm birth (VPTB) or infants born less than 32 completed weeks gestation and birthweight, including low birthweight (LBW) or infants born less than 2,500 grams, and very low birthweight (VLBW) or infants born less than 1,500 grams. Maternal characteristics included information on teen pregnancy (maternal age less than 20 years), education (less than a high school diploma), marital status (unmarried), tobacco use during pregnancy (yes), alcohol use during pregnancy (yes) and inadequate prenatal care (Kessner index) [61]. The presence of a father on the birth certificate (as reflected by the presence or absence of paternal age) was also included [69] and will hereafter be referred to as a maternal factor because of its reflection of the social circumstances surrounding the pregnancy and time shortly after birth. Inequalities in the proportion (%) of each variable were computed for the total study population and in race-specific analyses.

2.3.4.2 Census Measures

State sociodemographic factors were obtained from the long-form records of the U.S. Bureau of the Census 2000 census of population and housing (census). Census variables examined in this study included inequalities in the proportion of the following population variables: foreign born, education (less than high school diploma, ≥ high school graduate, and ≥ college graduate; education categories were not mutually exclusive), unemployment, and poverty status. Proportions (%) of each state level variable were collected from the census for white and black women (includes Hispanic ethnicity) and for the entire state (includes all races and ethnicities).

As we did for IM disparities, we expressed racial inequalities in sociodemographic risk factors using two inequality measures: relative risk (RR), ie. black proportion/white proportion; and the risk difference (RD), ie. black proportion – white proportion. The RD was expressed as a percentage.

2.3.5 Data Analysis

Pearson correlation coefficients and partial correlations (r) were used to examine the correlation between relative and absolute racial disparities in IM and relative and absolute racial inequalities in infant, maternal and state sociodemographic factors. Statistical control for potential confounding variables was undertaken in the following manner: adjustments were made for inequalities in confounding variables that were significantly associated with both the exposure inequality of interest and disparities in IM in univariate analyses, but were not on the causal pathway. Furthermore, state proportions of the exposure variable of interest (ie. total percent low birthweight) along with the proportion of the state population which was black were also held constant in partial correlation models. In the case of multicollinearity between multiple confounding variables, the least significant predictor of racial disparities in IM, was omitted from the model (appendix table 1). Statistical significance was determined by using the cutoff of $p<0.05$.

2.3.6 Mapping

Maps were used to visualize national differences in IM rates and racial disparities in IM rates. We also mapped racial disparities in selected infant, maternal and state sociodemographic factors. Maps were created using ArcMap version 9.3 within ArcGIS version 9. Continuous data were split into 4 categories based on quantile classification within ArcGIS. Darker colors indicate higher proportions/rates, while lighter colors indicate lower proportions/rates.

2.4 Results

2.4.1 Region- and state-specific number of live births and infant deaths by race

From 2000-2002, there were 10,586,415 births to women in the United States (Table 2.1). Of these births, 64,502 (0.6%) resulted in deaths before the infant's first birthday. There were 8,832,933 (83.4%) births to white women and 1,753,482 (17.6%) births to black women. Of these births, 43,596 white and 20,906 black infants died before the first year of life. In regional analyses the south had the highest number of births (total=4,158,949; 39.3%; white=3,191,515; 36.1%; black=967,434; 55.1%) and deaths (total=28,323; 43.9%; white=16,685; 38.3%; black=11,638; 55.7%).

Table 2.1. Region and state specific number of live births and infant deaths by race: United States, 2000-2002.

State†	Live Births			Infant Deaths		
	Total*	White	Black	Total*	White	Black
United States	10,586,415	8,832,933	1,753,482	64,502	43,596	20,906
Regions (n=4 regions)						
Northeast (7 states)	1,753,552	1,441,778	311,774	9,400	6,171	3,229
Midwest (10 states)	2,428,673	2,090,076	338,597	15,563	10,921	4,642
South (17 states)	4,158,949	3,191,515	967,434	28,323	16,685	11,638
West (7 states)	2,245,241	2,109,564	135,677	11,216	9,819	1,397
States (n=41 states)						
Alabama	174,511	118,652	55,859	1,429	698	731
Arizona	228,807	220,804	8,003	1,311	1,212	99
Arkansas	106,819	84,761	22,058	799	559	240
California	1,347,631	1,249,979	97,652	6,441	5,470	971
Colorado	186,117	177,472	8,645	978	872	106
Connecticut	116,622	101,543	15,079	617	424	193
Delaware	30,477	22,727	7,750	232	133	99
District of Columbia	21,435	7,269	14,166	227	33	194
Florida	578,397	442,072	136,325	3,736	2,159	1,577
Georgia	374,581	248,465	126,116	2,915	1,388	1,527
Illinois	505,409	409,642	95,767	3,340	2,018	1,322
Indiana	246,807	219,355	27,452	1,615	1,291	324
Iowa	106,377	102,723	3,654	551	513	38
Kansas	109,882	101,642	8,240	700	590	110
Kentucky	157,389	142,979	14,410	938	803	135
Louisiana	187,736	108,294	79,442	1,572	646	926
Maryland	201,139	130,408	70,731	1,408	597	811
Massachusetts	216,989	193,279	23,710	833	643	190
Michigan	372,086	304,311	67,775	2,582	1,590	992
Minnesota	181,669	168,085	13,584	822	683	139
Mississippi	121,868	66,841	55,027	1,135	413	722
Missouri	214,413	182,038	32,375	1,430	990	440
Nebraska	69,546	65,504	4,042	404	352	52
Nevada	84,187	76,963	7,224	463	373	90
New Jersey	302,632	243,245	59,387	1,631	954	677
New Mexico	68,743	67,259	1,484	390	368	22
New York	373,985	331,401	42,584	1,917	1,413	504
New York City	303,113	194,577	108,536	1,638	741	897
North Carolina	331,036	248,622	82,414	2,406	1,315	1,091
Ohio	430,981	364,032	66,949	2,978	2,043	935
Oklahoma	127,901	114,229	13,672	907	739	168

*Total denotes both black and white infants

† Inclusion criteria: Singleton, Black and White, US born, sufficient infant deaths (>19)

Table 2.1 (continued). Region- and state-specific number of live births and infant deaths† by race: United States, 2000-2002.

State	Live Births			Infant Deaths		
	Total	White	Black	Total	White	Black
Oregon	123,230	120,429	2,801	614	588	26
Pennsylvania	405,378	346,157	59,221	2,562	1,826	736
Rhode Island	34,833	31,576	3,257	202	170	32
South Carolina	158,295	103,256	55,039	1,287	531	756
Tennessee	223,831	175,669	48,162	1,811	1,078	733
Texas	1,032,807	913,226	119,581	5,380	4,223	1,157
Virginia	270,913	206,345	64,568	1,711	965	746
Washington	206,526	196,658	9,868	1,019	936	83
West Virginia	59,814	57,700	2,114	430	405	25
Wisconsin	191,503	172,744	18,759	1,141	851	290

The excluded states (due to insufficient black deaths) are shown in table 2.2.

Table 2.2. State-specific number of live births and infant deaths among excluded states, United States 2000-2002.

State†	Live Births			Infant Deaths		
	Total*	White	Black	Total*	White	Black
Alaska	*19,871*	*18,582*	*1,289*	*89*	*86*	*3*
Hawaii	*12,861*	*11,435*	*1,426*	*79*	*67*	*12*
Idaho	*58,359*	*58,105*	*254*	*358*	*357*	*1*
Maine	*38,680*	*38,260*	*420*	*175*	*173*	*2*
Montana	*27,703*	*27,579*	*124*	*165*	*164*	*1*
New Hampshire	*40,707*	*40,126*	*581*	*167*	*164*	*3*
North Dakota	*19,746*	*19,478*	*268*	*121*	*118*	*3*
South Dakota	*25,060*	*24,754*	*306*	*124*	*124*	*0*
Utah	*134,115*	*133,150*	*965*	*610*	*606*	*4*
Vermont	*18,368*	*18,263*	*105*	*76*	*76*	*0*
Wyoming	*17,477*	*17,307*	*170*	*100*	*100*	*0*

*Total denotes both black and white infants

† States were excluded due to insufficient cell specific infant deaths (<19)

2.4.2 Infant mortality rates, disparity ratios, disparity differences and racial composition scores

Table 2.3 shows IM rates, DRs, DDs and racial composition scores among live born infants in the U.S, ranked by DR from lowest to highest. In comparison to the national IM rate of 6.09 per 1,000 live births, region-specific IM rates ranged from 5.26 per 1,000 live births in the West to 7.53 per 1,000 live births in the South. State-specific IM rates ranged from 3.84 per 1,000 live births in Massachusetts to 10.59 per 1,000 live births in the District of Columbia. Among white infants, the IM rate was 4.94 per 1,000 live births, and state IM rates among whites varied from 3.33 per 1,000 live births in Massachusetts to 7.02 per 1,000 live births in West Virginia. Among black infants, the national IM rate was 11.92 per 1,000 live births and ranged from 8.01 per 1,000 live births in Massachusetts to 15.46 per 1,000 live births in Wisconsin. The national DR was 2.42 while the national DD was 6.98 per 1,000 live births. Regional differences in infant mortality rates and disparity measures were of interest, especially when examining the southern and midwest regions. While the south had the highest overall IM rates, the midwest had the highest black IM rates and subsequent disparities.

Figure 2.1 Infant Mortality Rates, United States 2000-2002

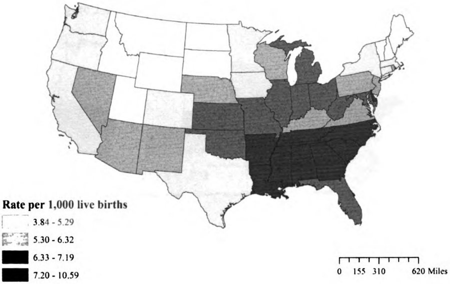


Figure 2.2 Disparity Ratios in Infant Mortality, United States 2000-2002

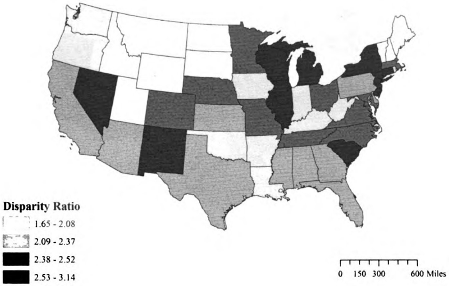
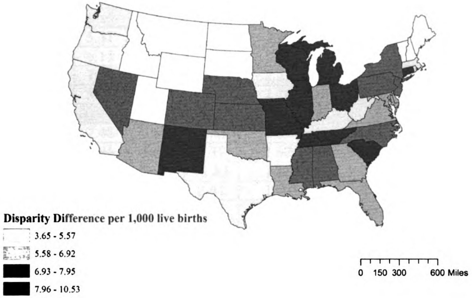


Figure 2.3 Disparity Differences in Infant Mortality, United States 2000-2002



Each state was also characterized by a racial composition score. Eight states, all but one on the east or west coasts were in the lowest tertiles for both black and white racial composition scores: Massachusetts, New York City, Washington, Texas, California, Minnesota, New Jersey and Maryland. Five states, all but one located in the south, were in the highest tertiles for both black and high white racial composition scores: Alabama, Mississippi, Kansas, Ohio and Tennessee.

Table 2.3. Infant mortality rates*, disparity ratios†, disparity differences‡ and racial composition scores§ by race: United States||, 2000-2002

State	Infant Mortality Rate			Disparity Ratio	Disparity Difference	Racial Composition	
	Total	White	Black			White	Black
United States	6.09	4.94	11.92	2.42	6.99		
Regions (n=4 regions)							
Northeast	5.31	4.31	10.65	2.50	6.34		
Midwest	6.15	5.22	13.01	2.50	7.79		
South	7.53	5.59	12.19	2.22	6.60		
West	5.26	4.96	11.36	2.28	6.40		
States (n=41 states)							
Arkansas	7.48	6.60	10.88	1.65	4.29	H	L
Kentucky	5.96	5.62	9.37	1.67	3.75	H	L
West Virginia	7.19	7.02	11.83	1.68	4.81	H	M
Washington	4.93	4.76	8.41	1.77	3.65	L	L
Rhode Island	5.80	5.38	9.82	1.82	4.44	M	L
Oklahoma	7.09	6.47	12.29	1.90	5.82	H	M
Oregon	4.98	4.88	9.28	1.90	4.40	M	L
Louisiana	8.37	5.97	11.66	1.95	5.69	H	M
Indiana	6.54	5.89	11.80	2.01	5.92	H	M
Iowa	5.18	4.99	10.40	2.08	5.41	M	L
Texas	5.21	4.62	9.68	2.09	5.05	L	L
Mississippi	9.31	6.18	13.12	2.12	6.94	H	H
Georgia	7.78	5.59	12.11	2.17	6.52	H	M
New York City	5.40	3.81	8.26	2.17	4.46	L	L
Delaware	7.61	5.85	12.77	2.18	6.92	H	M
Alabama	8.19	5.88	13.09	2.22	7.20	H	H
Arizona	5.73	5.49	12.37	2.25	6.88	H	M
California	4.78	4.38	9.94	2.27	5.57	L	L
Kansas	6.37	5.80	13.35	2.30	7.54	H	H
Pennsylvania	6.32	5.28	12.43	2.36	7.15	M	M
Florida	6.46	4.88	11.57	2.37	6.68	M	M
Nebraska	5.81	5.37	12.86	2.39	7.49	M	H
Massachusetts	3.84	3.33	8.01	2.41	4.69	L	L
Virginia	6.32	4.68	11.55	2.47	6.88	L	M
Tennessee	8.09	6.14	15.22	2.48	9.08	H	H
Ohio	6.91	5.61	13.97	2.49	8.35	H	H
Colorado	5.25	4.91	12.26	2.50	7.35	M	M
Missouri	6.67	5.44	13.59	2.50	8.15	M	H

*Infant mortality rates and disparity differences expressed per 1,000 live births
†Disparity ratios expressed are (black IM) ÷ (white IM)
‡Disparity differences expressed are (black IM) – (white IM)
§ Racial composition scores are broken into tertiles (H=High; M=Medium; L=Low)
|| Inclusion criteria: singleton, Black and White, US born, sufficient infant deaths (>19)

Table 2.3 (continued). Infant mortality rates*, disparity ratios†, disparity differences‡ and racial composition scores§ by race: United States||, 2000-2002

State	Infant Mortality Rate			Disparity Ratio	Disparity Difference	Racial Composition	
	Total	White	Black			White	Black
North Carolina	7.27	5.29	13.24	2.50	7.95	M	H
Maryland	7.00	4.58	11.47	2.50	6.89	L	L
Minnesota	4.52	4.06	10.23	2.52	6.17	L	L
Nevada	5.50	4.85	12.46	2.57	7.61	L	M
South Carolina	8.13	5.14	13.74	2.67	8.59	M	H
New Mexico	5.67	5.47	14.82	2.71	9.35	M	H
New York	5.13	4.26	11.84	2.78	7.57	L	M
Michigan	6.94	5.22	14.64	2.80	9.41	M	H
Illinois	6.61	4.93	13.80	2.80	8.88	M	H
New Jersey	5.39	3.92	11.40	2.91	7.48	L	L
District of Columbia	10.59	4.54	13.69	3.02	9.15	L	H
Connecticut	5.29	4.18	12.80	3.07	8.62	L	M
Wisconsin	5.96	4.93	15.46	3.14	10.53	M	H

2.4.3 Lowest and highest disparity ratios and disparity differences

To determine if high and low disparity states differed with respect to disparity measure used, table 2.4 includes the ten lowest and highest DR and DD states with accompanying racial composition scores. The lowest 10 DRs ranged from 1.65 to 2.08 with the lowest DR found in Arkansas. The ten highest DR states ranged from 2.57 to 3.14 with the highest DR in Wisconsin. Geographically the highest DR states were primarily located in the northeast and midwest regions. The lowest DDs ranged from 3.65 per 1,000 live births in Washington to 5.41 per 1,000 live births in Iowa. The highest DDs range from 8.15 per 1,000 live births in Missouri to 10.53 per 1,000 live births in Wisconsin. The two states with the lowest disparity ratios (Arkansas and Kentucky) were characterized by low racial composition scores among blacks and high racial composition scores among whites. Disparity, measures categorized most of the same states as high disparity states and low disparity states, but reflected differences in composition scores with more consistent black IM rates seen with the absolute disparity measure.

The combination of racial composition scores and disparity measures shed new night on highest and lowest disparity states. The evaluation of both racial disparities and racial composition scores leads to conclusion that Washington has the lowest relative disparities in IM and Massachusetts has the lowest absolute racial disparities in IM since they have low DRs and DDs in addition to low black and low white racial composition scores. On the other hand, Tennessee and Ohio would be the highest disparity states because they have high disparity measures, high black and high white racial composition scores. Furthermore, a state such as New Jersey, which has low black and low white racial composition scores, would not be listed as a high disparity state.

Table 2.4. Lowest and highest disparity ratios* and disparity differences† with accompanying racial composition scores‡; United States 2000-2002.

State	Disparity Ratio	Racial Composition		State	Disparity Difference	Racial Composition	
		White	Black			White	Black
Lowest Disparity Ratios				Lowest Disparity Differences			
Arkansas	1.65	H	L	Washington	3.65	L	L
Kentucky	1.67	H	L	Kentucky	3.75	H	L
West Virginia	1.68	H	M	Arkansas	4.29	H	L
Washington	1.77	L	L	Oregon	4.40	M	L
Rhode Island	1.82	M	L	Rhode Island	4.44	M	L
Oklahoma	1.90	H	M	New York City	4.46	L	L
Oregon	1.90	M	L	Massachusetts	4.69	L	L
Louisiana	1.95	H	M	West Virginia	4.81	H	M
Indiana	2.01	H	M	Texas	5.05	L	L
Iowa	2.08	M	L	Iowa	5.41	M	L
Highest Disparity Ratios				Highest Disparity Differences			
Nevada	2.57	L	M	Missouri	8.15	M	H
South Carolina	2.67	M	H	Ohio	8.35	H	H
New Mexico	2.71	M	H	South Carolina	8.59	M	H
New York	2.78	L	M	Connecticut	8.62	L	M
Michigan	2.80	M	H	Illinois	8.88	M	H
Illinois	2.80	M	H	Tennessee	9.08	H	H
New Jersey	2.91	L	L	District of Columbia	9.15	L	H
District of Columbia	3.02	L	H	New Mexico	9.35	M	H
Connecticut	3.07	L	M	Michigan	9.41	M	H
Wisconsin	3.14	M	H	Wisconsin	10.53	M	H

* Disparity ratios expressed are (black IM) ÷ (white IM)

† Disparity differences expressed are (black IM) – (white IM) per 1,000 live births

‡ Racial composition scores are broken into tertiles (H=High; M=Medium; L=Low)

2.4.4 Racial inequalities among selected infant characteristics

Table 2.5 shows RRs and RDs of infant characteristics which are thought to account for a large proportion of the black excess in IM. States were ordered according to DRs in IM from low to high. When examining the relative inequality measures, U.S. RRs were highest among VLBW births (RR=2.9) with the highest RR seen among VLBW births in Michigan (RR=3.5). The lowest RRs were seen among PTB with a U.S. RR of 1.6. Compared to the other states, the lowest overall RRs were seen in Oregon (PTB=1.4; VPTB=1.8; VLBW=2.4). Among absolute inequality measures in the U.S., the highest RDs were seen among preterm births, which had a national average of 6.1% and ranged from 3.3% in Oregon to 8.8% in the District of Columbia. RDs in very preterm births ranged from 1.1% in Oregon to 3.6% in Alabama.

Figure 2.4 Relative Risks of Low Birthweight, United States 2000-2002

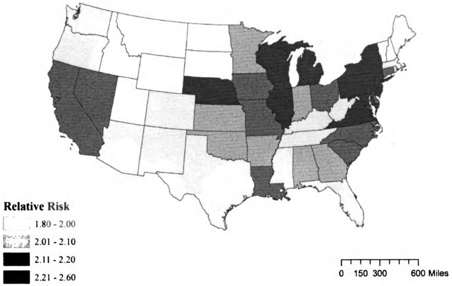


Figure 2.5 Risk Difference of Low Birthweight, United States 2000-2002

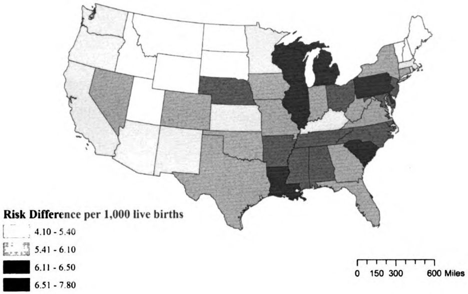


Figure 2.6 Relative Risk of Very Low Birthweight, United States 2000-2002

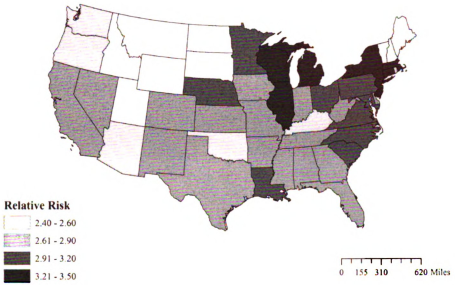


Figure 2.7 Risk Difference of Very Low Birthweight, United States 2000-2002

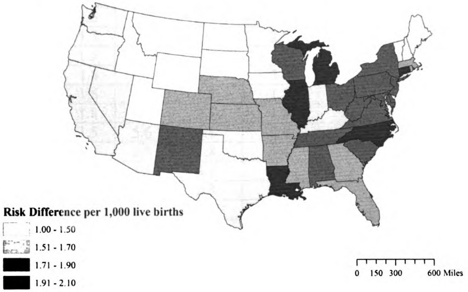


Table 2.5. State-specific relative risks* and risk differences† of selected infant birth certificate characteristics: United States‡, 2000-2002

State (n=41)	Preterm		Very Preterm		Low Birthweight		Very Low Birthweight	
	RR	RD	RR	RD	RR	RD	RR	RD
United States	**1.6**	**6.1**	**2.5**	**2.5**	**2.1**	**5.9**	**2.9**	**1.7**
Arkansas	1.7	6.9	2.6	2.8	2.1	6.2	2.7	1.7
Kentucky	1.5	6.0	2.2	2.3	1.9	5.3	2.4	1.4
West Virginia	1.6	6.6	2.4	3.0	1.8	5.7	2.7	1.9
Washington	1.5	3.6	2.2	1.5	2.0	4.3	2.6	1.1
Rhode Island	1.8	6.8	2.1	1.8	1.9	4.7	2.6	1.6
Oklahoma	1.5	5.6	2.1	2.1	2.1	6.1	2.6	1.4
Oregon	1.4	3.3	1.8	1.1	2.0	4.1	2.4	1.0
Louisiana	1.8	8.1	3.1	3.6	2.2	6.8	3.2	2.0
Indiana	1.6	6.4	2.3	2.4	2.1	5.6	2.7	1.5
Iowa	1.8	7.1	2.6	2.8	2.2	5.7	2.9	1.5
Texas	1.5	5.2	2.1	2.2	2.0	5.6	2.7	1.5
Mississippi	1.6	7.2	2.6	3.2	2.0	6.4	2.7	1.7
Georgia	1.6	5.2	2.5	2.1	2.1	5.9	2.9	1.7
New York City	1.5	4.6	2.0	1.8	1.8	4.2	2.4	1.3
Delaware	1.6	6.0	2.6	2.7	2.2	6.8	2.9	1.9
Alabama	1.7	7.7	2.9	3.6	2.1	6.2	2.9	1.9
Arizona	1.4	4.1	1.9	1.6	2.0	5.2	2.5	1.2
California	1.5	4.1	2.3	1.8	2.2	5.2	2.9	1.5
Kansas	1.6	5.0	2.2	2.1	2.1	5.4	2.8	1.6
Pennsylvania	1.8	7.2	2.8	2.9	2.3	6.7	3.1	1.9
Florida	1.7	6.5	2.5	2.6	2.0	5.5	2.8	1.6
Nebraska	1.7	6.1	2.5	2.3	2.4	6.4	3.1	1.7
Massachusetts	1.6	4.5	2.4	1.9	1.9	4.2	3.3	1.6
Virginia	1.7	6.4	2.7	2.6	2.3	6.0	3.0	1.8
Tennessee	1.6	6.4	2.6	2.9	2.0	6.2	2.8	1.8
Ohio	1.6	5.9	2.4	2.6	2.2	6.3	3.0	1.8
Colorado	1.5	5.1	2.3	2.3	1.9	5.9	2.8	1.6
Missouri	1.8	8.1	2.7	2.9	2.2	6.1	2.9	1.7
North Carolina	1.7	7.0	2.6	3.1	2.2	6.5	3.0	2.0

* Relative risks expressed are (black proportion) ÷ (white proportion)

† Risk differences expressed are (black proportion) - (white proportion), expressed as the excess proportion (%) of black infants affected by the characteristic

‡ States ordered from high IM disparity ratio to low IM disparity ratio

Table 2.5 (continued). State-specific relative risks* and risk differences† of selected infant birth certificate characteristics: United States‡, 2000-2002

State (n=41)	Preterm		Very Preterm		Low Birthweight		Very Low Birthweight	
	RR	RD	RR	RD	RR	RD	RR	RD
Maryland	1.7	6.4	2.8	2.8	2.3	6.4	3.1	1.9
Minnesota	1.4	2.8	2.4	1.8	2.1	4.5	3.1	1.5
Nevada	1.6	6.2	2.4	2.3	2.2	6.1	2.8	1.4
South Carolina	1.7	6.7	2.8	3.0	2.2	6.8	3.1	1.9
New Mexico	1.5	5.0	2.0	2.3	1.8	5.3	2.8	1.8
New York	1.8	6.4	2.7	2.6	2.3	6.1	3.4	1.9
Michigan	1.9	7.9	3.1	3.2	2.5	7.3	3.5	2.0
Illinois	1.8	7.6	2.8	3.1	2.5	7.3	3.5	2.0
New Jersey	1.8	6.8	2.7	2.9	2.3	6.2	3.4	1.9
District of Columbia	2.0	8.8	2.6	3.4	2.5	7.8	3.1	2.1
Connecticut	1.6	4.4	2.9	2.7	2.2	5.7	3.3	2.1
Wisconsin	1.9	7.8	3.1	3.3	2.6	6.9	3.4	1.9

2.4.5 Racial inequalities among selected maternal characteristics

Table 2.6 shows RR and RD of selected maternal sociodemographic factors. States were ordered according to DRs in IM from low to high. Large state variations in inequality measures were seen in each of the maternal characteristics, with the largest nationwide variation in RRs and RDs were seen within marital status (United States RR=2.5; range=1.7 in New York City and Arizona to 3.6 in Alabama; RD=40.6%; range 24.% in Arizona to 57.8% in Wisconsin).

Figure 2.8 Relative Risk of Teen Pregnancy, United States 2000-2002

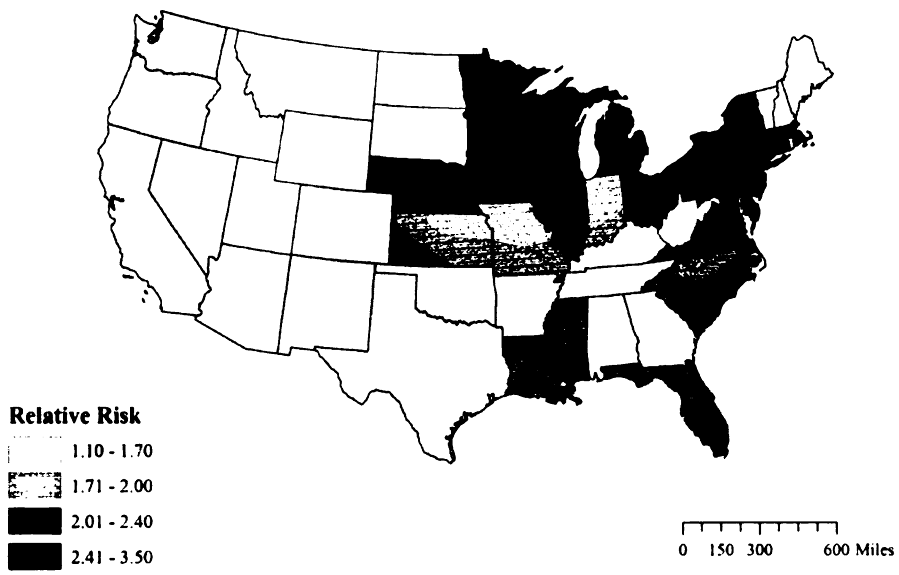


Figure 2.9 Risk Difference of Teen Pregnancy, United States 2000-2002

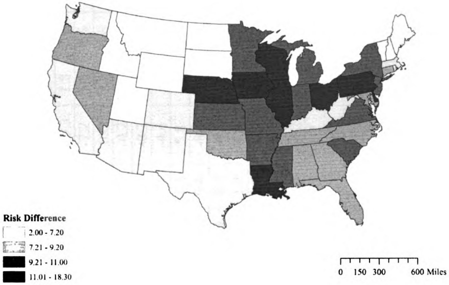


Table 2.6. State-specific relative risks* and risk differences† of selected maternal birth certificate characteristics: United States‡, 2000-2002.

State	Teen Pregnancy		Unknown Father		< High School		Unmarried		Tobacco Use		Alcohol Use		Inadequate Prenatal Care	
	RR	RD	RR	RD	RR	RD	RR	RD	RR	RD	RR	RD	RR	RD
United States	**1.9**	**9.2**	**3.5**	**27.6**	**1.3**	**5.2**	**2.5**	**40.6**	**0.9**	**-2.0**	**1.4**	**0.3**	**1.6**	**2.5**
Arkansas	1.7	10.7	3.7	34.3	1.2	4.0	2.9	49.1	0.5	-10.3	1.8	0.6	0.8	-0.6
Kentucky	1.5	7.2	3.3	37.0	1.2	4.5	2.6	44.5	0.7	-7.2	1.5	0.6	1.0	0.0
West Virginia	1.5	7.0	3.3	27.6	1.1	2.2	2.4	43.9	1.0	0.6	2.5	0.6	1.4	2.1
Washington	1.5	4.8	2.8	17.9	0.9	-1.1	1.9	25.7	1.0	-0.2	0.9	-0.2	1.8	9.7
Rhode Island	1.7	6.6	3.0	21.3	1.6	8.1	2.0	32.4	1.0	-0.3	0.7	-0.4	2.2	2.9
Oklahoma	1.6	8.0	3.0	27.2	1.0	0.9	2.4	40.6	0.7	-4.4	1.0	0.0	1.3	2.6
Oregon	1.7	7.3	2.9	18.1	1.0	0.3	2.1	33.3	1.4	5.8	1.2	0.3	1.0	0.0
Louisiana	2.0	11.5	4.8	30.3	1.9	14.8	2.8	48.1	0.4	-8.1	2.0	0.3	1.4	0.2
Indiana	1.9	10.2	3.9	28.5	1.4	7.8	2.4	45.0	0.7	-6.3	1.9	0.6	2.5	3.0
Iowa	2.4	13.4	4.3	38.8	2.3	18.4	2.7	46.6	1.3	4.8	2.2	1.3	1.5	1.2
Texas	1.4	5.2	2.8	21.6	0.7	-12.0	2.2	33.4	0.9	-0.8	0.9	-0.1	1.6	4.6
Mississippi	1.8	11.0	4.8	31.1	1.4	8.7	3.3	52.8	0.3	-11.9	2.0	0.4	1.8	0.9
Georgia	1.7	7.3	3.4	24.0	1.0	-1.2	2.7	41.9	0.4	-6.2	0.9	-0.1	1.3	1.7
New York City	1.5	3.8	2.2	15.4	1.1	1.4	1.7	28.5	1.7	1.7	4.0	0.3	0.9	-1.1
Delaware	2.4	12.6	2.8	39.3	1.4	6.6	2.3	40.9	0.9	-1.2	1.2	0.2	2.5	0.6
Alabama	1.7	9.0	4.5	35.9	1.3	5.5	3.6	49.3	0.3	-10.6	1.8	0.3	1.3	0.2
Arizona	1.4	5.7	2.2	21.4	0.8	-7.0	1.7	24.9	1.5	3.6	1.9	0.7	1.9	3.7
California	1.4	4.3	2.8	12.3	0.5	-16.7	1.9	29.2	1.0	0.0	1.0	0.0	1.3	2.6
Kansas	1.9	10.0	3.8	23.8	1.3	5.5	2.5	41.6	0.9	-0.7	2.2	0.6	0.7	-0.6

* Relative risks expressed are (black proportion) ÷ (white proportion)

† Risk differences expressed are (black proportion) - (white proportion), expressed as the excess proportion (%) of black mothers

‡ States ordered from high IM disparity ratio to low IM disparity ratio

Table 2.6 (continued). State-specific relative risks* and risk differences† of selected maternal birth certificate characteristics: United States‡, 2000-2002.

State (n=41)	Teen Pregnancy		Unknown Father		< High School		Unmarried		Tobacco Use		Alcohol Use		Inadequate Prenatal Care	
	RR	RD	RR	RD	RR	RD	RR	RD	RR	RD	RR	RD	RR	RD
Pennsylvania	2.6	12.8	3.2	8.6	1.7	9.6	2.8	49.1	0.9	-1.6	1.6	0.8	2.1	7.8
Florida	1.9	9.0	3.3	24.8	1.4	7.3	2.2	36.3	0.4	-6.8	0.8	-0.1	2.4	2.5
Nebraska	2.5	13.6	4.4	33.3	1.9	14.0	2.7	42.4	1.1	1.4	1.4	0.4	1.3	0.2
Massachusetts	2.1	6.4	4.4	18.4	2.0	10.4	2.5	35.0	0.7	-2.9	0.5	-1.2	1.0	0.0
Virginia	2.3	10.2	3.6	27.8	1.5	7.4	2.9	40.8	0.7	-2.5	1.4	0.2	0.6	-0.4
Tennessee	1.7	8.8	3.9	27.5	1.4	7.6	2.8	46.9	0.4	-11.3	1.6	0.4	1.4	0.9
Ohio	2.2	11.7	4.5	35.1	1.6	10.0	2.6	46.9	0.8	-4.5	1.7	0.5	3.1	5.3
Colorado	1.6	7.1	3.2	16.5	0.9	-3.1	2.1	27.8	1.2	2.0	0.9	-0.1	1.8	1.7
Missouri	2.0	11.0	4.2	39.5	1.6	10.4	2.7	48.5	0.7	-6.5	1.3	0.2	1.5	1.3
North Carolina	1.8	8.9	4.0	27.4	1.1	1.7	2.7	41.9	0.8	-3.7	1.5	0.3	1.2	0.2
Maryland	2.4	9.2	3.4	16.0	1.4	4.5	2.6	36.6	0.7	-3.1	0.9	-0.1	2.3	4.4
Minnesota	2.5	10.1	5.0	27.1	2.8	15.8	2.5	35.7	1.0	0.0	2.3	0.9	2.3	7.1
Nevada	1.7	8.0	2.4	26.7	0.8	-6.2	2.0	34.1	1.2	2.1	1.6	0.7	1.6	5.4
South Carolina	1.9	9.9	3.9	40.1	1.3	5.2	3.0	47.2	0.4	-8.9	0.9	-0.1	1.6	0.7
New Mexico	1.1	2.0	1.7	15.2	0.8	-6.2	1.4	15.2	1.4	4.8	1.4	0.6	1.3	2.0
New York	2.6	10.3	4.0	25.2	1.8	10.5	2.7	39.9	1.1	1.2	2.0	0.8	2.3	5.1
Michigan	2.2	10.3	5.5	36.6	1.8	12.7	2.8	47.2	0.9	-2.0	1.3	0.2	2.2	4.7
Illinois	2.5	13.5	5.5	34.0	1.3	7.2	2.9	49.9	1.3	2.7	2.5	0.6	1.3	0.9
New Jersey	2.8	9.8	5.3	20.1	1.5	7.1	2.7	41.1	1.3	2.4	1.9	1.0	1.6	3.4
District of Columbia	3.5	13.1	4.3	42.3	1.1	1.1	3.1	52.1	7.0	4.2	1.3	0.3	1.5	8.0
Connecticut	2.3	8.8	4.4	24.8	1.6	6.9	2.7	41.6	1.0	0.1	1.3	0.2	2.5	7.1
Wisconsin	3.3	18.3	3.4	58.2	3.0	26.7	3.4	57.8	1.2	3.3	1.4	0.5	1.0	0.0

2.4.6 Racial inequalities in selected state characteristics

Table 2.7 includes RRs and RDs of selected state sociodemographic factors. Relative inequality measures, demonstrate that blacks were more likely than whites to be foreign born, less than high school educated, unemployed and in poverty (RR = 1.2,1.2, 2.5, 2.7, respectively.) Absolute inequality measures demonstrate that blacks were less likely than whites to have a high school degree, college degree, or be employed (RD = -9.6%, -12.0%, -4.0%). Between states, there was little variation in inequality measures for the proportion with greater than a high school degree and employment status when measured with the RR; both categories ranged from 0.7 to 1.0. In contrast, variation in RD among proportion with greater than a high school degree ranged from -24.0% to 1.5%. Also of interest was the trend in education inequalities with inequalities increasing as educational level increased. The highest racial inequalities were in the proportion college educated (RR=0.5%; RD = -12.0%).

Figure 2.10 Relative Risk of Poverty, United States 2000-2002

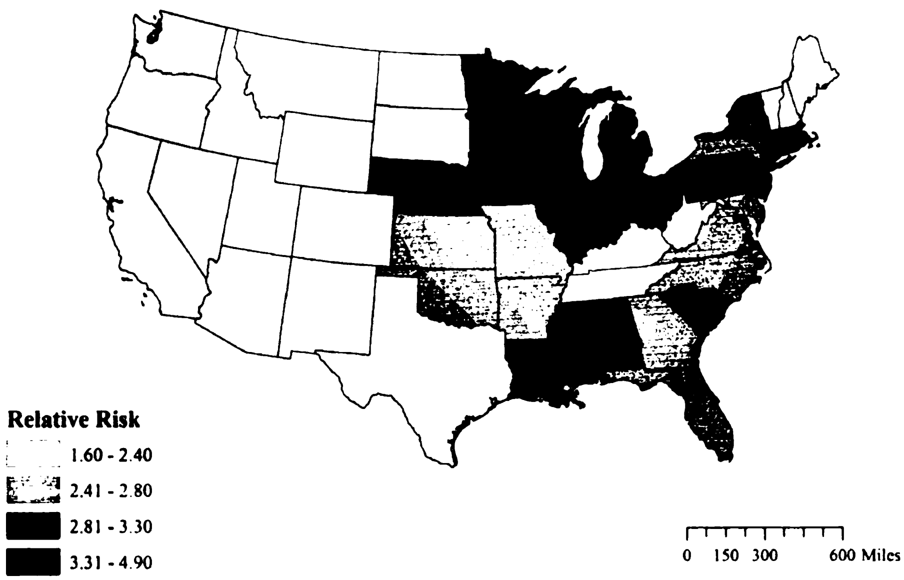


Figure 2.11 Risk Difference of Poverty, United States 2000-2002

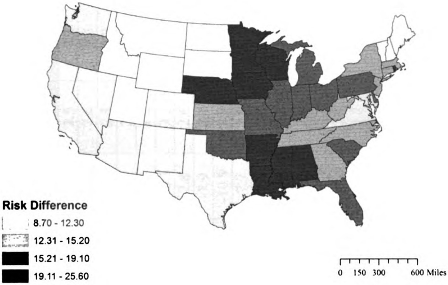


Table 2.7. State-specific relative risks* and risk differences† of selected state census characteristics: United States‡, 2000-2002.

State (n=41)	Foreign Born		≤ High School		≥ High School		≥ College		Unemployment		Poverty	
	RR	RD	RR	RD	RR	RD	RR	RD	RR	RD	RR	RD
United States	**1.2**	**0.9**	**1.2**	**1.4**	**0.9**	**-9.6**	**0.5**	**-12.0**	**2.5**	**7.1**	**2.7**	**15.9**
Arkansas	0.4	-0.9	1.5	3.8	0.8	-11.7	0.6	-7.6	2.6	7.8	2.8	21.5
Kentucky	1.5	0.5	0.6	-4.8	1.0	-1.0	0.6	-6.7	2.3	6.7	1.9	13.5
West Virginia	2.2	0.7	0.7	-2.9	1.0	1.5	0.8	-3.2	2.0	6.8	1.9	15.2
Washington	1.7	3.4	1.6	1.5	0.9	-5.3	0.7	-9.1	1.8	4.6	2.2	10.4
Rhode Island	3.5	16.1	1.4	2.5	0.9	-9.1	0.6	-10.1	2.5	7.5	3.3	20.7
Oklahoma	1.2	0.3	0.9	-0.4	1.0	-3.6	0.6	-7.8	2.6	6.9	2.5	17.6
Oregon	2.0	4.3	1.5	1.8	0.9	-7.3	0.7	-7.9	2.1	6.6	2.4	13.9
Louisiana	0.3	-1.2	1.7	5.1	0.8	-16.9	0.5	-10.9	2.9	9.0	3.3	25.6
Indiana	0.9	-0.1	1.2	0.9	0.9	-8.3	0.6	-7.7	2.9	7.9	3.0	15.4
Iowa	4.1	4.3	1.3	1.4	0.9	-9.6	0.7	-6.6	3.7	10.4	3.9	23.4
Texas	0.3	-6.3	0.7	-2.7	1.0	-3.7	0.6	-10.5	2.1	5.5	1.9	11.0
Mississippi	0.2	-0.7	2.2	8.3	0.8	-18.5	0.5	-9.9	2.9	8.7	3.1	23.8
Georgia	0.7	-1.1	1.5	2.8	0.9	-9.3	0.6	-11.9	2.7	6.2	2.8	14.9
Delaware	0.3	-10.7	2.6	4.9	0.7	-24.0	0.2	-59.8	2.1	7.7	2.7	16.2
Alabama	0.5	-0.6	1.5	3.5	0.9	-11.1	0.5	-9.7	2.8	7.9	3.0	20.8
Arizona	0.7	-2.9	1.0	0.0	1.0	-3.7	0.7	-7.4	2.0	4.5	1.9	9.6
California	0.3	-10.0	0.6	-2.5	1.0	-2.8	0.6	-12.6	2.1	6.4	2.1	11.9
Kansas	1.1	0.3	1.0	0.1	0.9	-8.1	0.6	-12.0	3.0	7.5	2.8	14.8
Pennsylvania	1.5	1.1	1.1	0.5	0.9	-11.6	0.5	-11.1	2.9	8.7	3.2	18.3

* Relative risks expressed are (black proportion) ÷ (white proportion)

† Risk differences expressed are (black proportion) – (white proportion), expressed as the excess proportion (%) of blacks affected by the characteristic in each state

‡ States ordered from high IM disparity ratio to low IM disparity ratio

Table 2.7 (continued). State-specific relative risks* and risk differences† of selected state census characteristics: United States‡, 2000-2002.

State (n=41)	Foreign Born		≤ High School		≥ High School		≥ College		Unemployed		Poverty	
	RR	RD	RR	RD	RR	RD	RR	RD	RR	RD	RR	RD
Florida	1.2	2.5	1.9	4.8	0.8	-15.5	0.5	-11.4	2.2	5.7	2.7	16.4
Nebraska	2.0	1.9	1.2	0.8	0.9	-9.6	0.6	-10.3	3.4	7.3	3.3	19.2
Massachusetts	3.4	17.1	1.5	2.4	0.9	-10.5	0.6	-14.6	2.5	5.7	3.0	14.2
Virginia	0.8	-0.7	1.6	3.6	0.8	-12.7	0.5	-17.2	2.6	5.2	2.8	12.3
Tennessee	0.6	-0.5	0.9	-0.7	0.9	-6.2	0.6	-7.6	2.4	6.2	2.3	14.5
Ohio	0.8	-0.3	1.3	1.3	0.9	-10.3	0.5	-9.9	2.7	7.0	3.2	18.3
Colorado	1.0	0.1	0.9	-0.5	0.9	-5.1	0.6	-14.5	2.1	4.2	2.1	8.7
Missouri	0.9	-0.1	1.0	0.2	0.9	-8.5	0.6	-9.1	2.8	7.9	2.7	15.9
North Carolina	0.6	-1.3	1.4	2.8	0.9	-10.5	0.5	-11.9	2.6	6.4	2.7	14.5
Maryland	1.3	1.7	1.2	0.9	0.9	-7.4	0.6	-14.4	2.6	5.2	2.7	9.4
Minnesota	9.2	15.6	1.1	0.6	0.9	-10.2	0.7	-9.2	3.3	8.2	4.4	20.9
Nevada	0.4	-5.5	0.9	-0.5	0.9	-5.0	0.6	-7.3	2.0	5.7	2.4	11.8
South Carolina	0.3	-1.5	1.9	5.9	0.8	-16.0	0.4	-14.3	2.7	6.9	3.1	17.8
New Mexico	0.7	-2.2	0.9	-0.5	1.0	-3.9	0.7	-9.2	1.9	5.1	1.6	9.0
New York	2.2	13.0	1.4	2.1	0.8	-13.4	0.5	-14.7	2.5	8.0	2.6	15.2
Michigan	0.3	-2.5	1.4	1.6	0.9	-11.2	0.6	-9.8	2.7	8.2	3.4	17.7
Illinois	0.2	-6.3	1.1	0.6	0.9	-12.0	0.5	-13.1	3.5	10.8	3.8	19.1
New Jersey	1.1	0.7	1.2	0.9	0.9	-10.2	0.5	-14.8	2.5	6.9	3.3	12.9
District of Columbia	1.2	0.7	1.4	1.8	0.9	-10.8	0.5	-12.3	2.5	5.9	3.0	12.3
Connecticut	1.9	6.8	1.4	1.9	0.9	-12.4	0.4	-19.8	2.6	6.9	3.6	13.7
Wisconsin	0.8	-0.4	1.3	1.3	0.8	-18.1	0.5	-12.5	3.9	11.7	4.9	25.3

2.4.7 Correlation between infant mortality, disparity ratios and disparity differences

To determine which measure of IM disparity was more correlated with race-specific IM rates, table 2.8 shows Pearson correlation coefficients between IM rates, DRs and DDs. DRs were significantly correlated with both white and black IM rates (white IM r=-0.51; black IM r=0.57). While DDs were positively correlated with black IM rates (r=0.91) but, were not at all correlated with white IM rates (r=0.03). Relative and absolute disparities consistently reflected black IM rates, while the relationship with white IM rates was not as consistent. As expected, DRs and RDs were significantly correlated with each other (r=0.86).

Table 2.8. Correlations* between infant mortality†, disparity ratios‡ and disparity differences§: United States, 2000-2002.

Infant Mortality	All States (n=41 states)	
	Disparity Ratio	Disparity Difference
Total	0.01	**0.33**
White	**-0.51**	-0.03
Black	**0.57**	**0.91**
Disparity Ratio	1.00	**0.86**
Risk Difference	**0.86**	1.00

* Pearson correlation coefficients (r)
† Infant mortality rates expressed per 1,000 live births
‡ Disparity ratios expressed are (black IM) ÷ (white IM)
§ Disparity difference is expressed as (black IM) – (white IM)
Bold indicates significant correlation at 0.05 level

The next three tables determined which sociodemographic inequalities were most correlated with racial disparities in IM. They also examined if Pearson correlation coefficients between inequalities in exposures and disparities in outcomes differed by disparity measure used. Model 1 shows the unadjusted Pearson correlation coefficient, model 2, shows adjustment for the total (white and black) state-specific proportion of the exposure variable of interest and model 3 shows full adjustment for all confounding variables, along with the percent of each state that is black.

2.4.8 Correlation between inequalities in infant antecedents and disparities in infant mortality

Table 2.9 shows correlations between inequalities in infant sociodemographic factors and disparities in IM. While both absolute and relative IM disparity measures were positively correlated with a number of infant sociodemographics, inequalities in VLBW were considerably more correlated with DRs and DDs in fully adjusted models than the other infant factors (RR r=0.75 and 0.60, for DR and DD, respectively; and RD r=0.63

and 0.57 for DR and DD, respectively). Surprisingly, the LBW RD was not significantly associated with either IM disparity measure in fully adjusted models. Although both the DR and DD were significantly correlated with the same infant inequalities, the DR was most correlated with inequalities in infant sociodemographic measures.

Table 2.9. Correlations* between proportion of infant antecedents†, disparity ratios‡ and disparity differences§: United States, 2000-2002.

Infant Antecedent Inequality	Relative Disparity Ratio			Absolute Disparity Difference		
	Model 1‖	Model 2¶	Model 3**	Model 1	Model 2	Model 3
Preterm Ratio	0.43	0.24	0.10	0.46	0.32	0.05
Preterm Difference	0.22	0.17	0.06	0.42	0.30	0.02
Very Preterm Ratio	0.49	0.38	**0.53**	0.53	0.43	**0.36**
Very Preterm Difference	0.37	0.40	**0.51**	0.55	0.49	**0.41**
Low Birthweight Ratio	0.61	0.53	**0.58**	0.60	0.61	**0.54**
Low Birthweight Difference	0.46	0.52	**0.65**	0.67	0.67	**0.67**
Very Low Birthweight Ratio	0.75	0.70	**0.75**	0.62	0.63	**0.60**
Very Low Birthweight Difference	0.56	0.57	**0.63**	0.65	0.62	**0.57**

* Pearson correlation coefficients (r)

† Infant antecedents are from all black and white infants, singleton infants born during the study period and are aggregated to the state

‡ Disparity ratios expressed are (black IM) ÷ (white IM)

§ Risk difference is expressed as (black IM) – (white IM)

Bold indicates significant correlation at 0.05 level in fully adjusted models

‖ Model 1: Unadjusted Model

¶ Model 2: Adjusted for the proportion of each variable in the total (white and black) population

** Model 3: Additionally adjusted for proportion black and confounding inequalities in maternal and state sociodemographic risk factors

2.4.9 Correlation between inequalities in maternal characteristics and disparities in infant mortality

Table 2.10 shows correlations between inequalities in maternal sociodemographic factors and disparities in IM. Despite significant correlation in unadjusted models, inequalities in maternal factors were not significantly correlated with disparities in IM (as measured by the DR or DD). While inequalities in teen pregnancy and the proportion with unknown fathers were correlated with IM disparity measures in unadjusted models 1 and 2, they failed to reach statistical significance in adjusted model 3.

Table 2.10. Correlations* between proportion of maternal birth certificate characteristics†, disparity ratios‡ and risk differences§: United States, 2000-2002.

Maternal Inequality	Relative Disparity Ratio			Absolute Disparity Difference		
	Model 1‖	Model 2¶	Model 3**	Model 2	Model 1	Model 2
Teen Pregnancy Ratio	0.62	0.55	0.27	0.48	0.56	0.31
Teen Pregnancy Difference	0.36	0.34	0.18	0.47	0.47	0.27
Unknown Father Ratio	0.33	0.36	0.32	0.31	0.36	0.20
Unknown Father Difference	0.21	0.13	-0.15	0.40	0.24	-0.08
< High School Ratio	0.31	0.21	0.06	0.23	0.27	0.00
< High School Difference	0.23	0.09	-0.21	0.26	0.31	-0.04
Unmarried Ratio	0.27	0.32	0.10	0.38	0.40	0.05
Unmarried Difference	0.16	0.20	-0.14	0.33	0.35	-0.08
Tobacco Ratio	0.33	0.35	-0.13	0.21	0.19	0.00
Tobacco Difference	0.31	0.23	0.01	0.08	0.06	0.00
Alcohol Ratio	0.05	0.12	-0.02	-0.04	0.21	0.06
Alcohol Difference	0.11	-0.01	-0.14	0.21	-0.06	-0.05
Inadequate Prenatal Care Ratio	0.18	0.17	0.19	0.17	0.17	0.14
Inadequate Prenatal Care Difference	0.24	0.17	0.21	0.09	0.10	0.08

* Pearson correlation coefficients (r)
† Maternal characteristics are from all black and white women who gave birth to a singleton infant during the study period and are aggregated to the state
‡ Disparity ratios expressed are (black IM) ÷ (white IM)
§ Risk difference is expressed as (black IM) – (white IM)
Bold indicates significant correlation at 0.05 level in fully adjusted models
‖ Model 1: Unadjusted Model
¶ Model 2: Adjusted for the proportion of each variable in the total (white and black) population
** Model 3: Additionally adjusted for proportion black and confounding inequalities in maternal and state sociodemographic risk factors

2.4.10 Correlation between inequalities in state characteristics and disparities in infant mortality

Table 2.11 demonstrates correlations between inequalities in state sociodemographic factors and disparities in IM. Inequalities in foreign born status were negatively correlated with both relative and absolute disparity measures in IM, with the largest correlation seen between RR in foreign born status and DD in IM ($r = -0.48$). This negative correlation indicates that as racial differences in the proportion foreign born increases, racial disparities in IM decrease. Inequalities in education, unemployment status, and percent poverty were not significantly correlated with racial disparities in IM after adjustment for confounding variables.

Table 2.11. Correlations* between proportion of state census characteristics†, disparity ratios‡ and disparity differences§: United States, 2000-2002.

State Inequality	Relative Disparity Ratio			Absolute Disparity Difference		
	Model 1‖	Model 2¶	Model 3**	Model 1	Model 2	Model 3
Foreign Born Ratio	-0.06	-0.05	**-0.36**	-0.29	-0.30	**-0.48**
Foreign Born Difference	-0.00	0.01	-0.26	-0.26	-0.26	**-0.41**
< High School Ratio	0.02	-0.04	-0.29	0.05	0.01	-0.31
< High School Difference	0.08	0.03	-0.19	0.13	0.10	-0.13
≥ High School Ratio	-0.18	-0.20	0.11	-0.20	-0.21	0.11
≥ High School Difference	-0.33	-0.36	-0.11	-0.34	-0.35	-0.10
≥ College Ratio	-0.39	-0.31	-0.32	-0.40	-0.40	-0.29
≥ College Difference	-0.18	0.10	0.14	-0.15	-0.13	-0.03
Unemployed Ratio	0.28	0.20	-0.26	0.32	0.31	-0.05
Unemployed Difference	0.12	0.13	-0.39	0.21	0.22	-0.17
Poverty Ratio	0.42	0.26	0.09	0.33	0.27	0.15
Poverty Difference	-0.11	-0.04	-0.31	0.03	0.07	-0.10

* Pearson correlation coefficients (r)
† State characteristics are state-level census characteristics which represent all races, ages and both sexes in a state
‡ Disparity ratios expressed are (black IM) ÷ (white IM)
§ Risk difference is expressed as (black IM) – (white IM)
Bold indicates significant correlation at 0.05 level in fully adjusted models
‖ Model 1: Unadjusted Model
¶ Model 2: Adjusted for the proportion of each variable in the total (white and black) population
** Model 3: Additionally adjusted for proportion black and confounding inequalities in maternal and state sociodemographic risk factors

2.5 Discussion

2.5.1 Nationwide variation in infant mortality rates

Considerable nationwide variation in IM was seen during the study period. The highest IM rates were found in the southeastern part of the U.S. with the District of Columbia and Mississippi having rates twice the national average. Our finding of regional patterns in IM was similar to those of other studies which examined state level differences in infant mortality [4, 32, 35, 36]. High southern IM rates such as those seen in our results led the Southern Governor's Association to identify IM as a focus area for increased effort [4].

2.5.2 Racial disparities in infant mortality

State level differences in IM were even more pronounced when examining race-specific rates. Among white infants, southern states again had the highest IM rates, while black IM rates were highest in the north and midwest. The highest disparities were primarily found in the northern states with black infants in Wisconsin, Connecticut and the District of Columbia three times as likely to die as their white counterparts. This amounted to an excess of 10 deaths per 1,000 live births among black infants in the highest disparity states. The DR as a measure of relative disparity and the DD as a measure of absolute disparity had similar, but not identical, results when identifying the highest and lowest disparity states. Among those identified as low disparity states, DDs included more states with low IM rates (ie. New York City, Massachusetts and Texas). On the other hand, categorizing disparity based on the DR allowed states with high IM rates to be counted as low disparity states (ie. Louisiana and Oklahoma).

Racial composition scores were most predictive of absolute disparities and more closely followed black IM rates than white IM rates. According to racial composition scores for the lowest and highest disparity states, low disparities primarily reflected low black IM rates (as opposed to high IM white rates), while high disparities primarily reflected high black IM rates (as opposed to low white IM rates). To our knowledge, this use of racial composition scores to characterize nationwide variation in disparity across had not previously been examined.

2.5.3 Racial inequalities in sociodemographic factors

Similar to other studies of racial disparities in socioeconomic factors [26, 28, 37, 70-72], our study found striking racial inequalities in socioeconomic factors at the infant, maternal and state level. Similar to other studies, inequalities in gestational age and birthweight categories were found to vary by state [29, 31, 68] with the highest rates found in the south but the highest racial disparities found in the midwest. Racial differences in infant factors also varied by inequality measure used [10]. Furthermore, we also found that the prevalence of each infant factor influenced the magnitude of relative and absolute inequalities in different ways. Relative inequalities were more pronounced for small proportions (ie. VPTB and VLBW) while absolute inequalities were larger when overall rates were larger (ie. PTB).

Among maternal risk factors, the largest inequalities were seen in the proportion of teen pregnancies [73] and the proportion unmarried [10]. Although variation in maternal inequalities were seen by state, comparable inequality patterns emerged between relative and absolute measures. Other studies which examined maternal risk factors have found racial inequalities in maternal age, education, income and prenatal care among other factors [10, 28, 37] although these have not been well examined on a national level.

Similar to other studies, our study found racial inequalities in state level census factors [28, 70-72]. Nationwide variation in inequalities were seen for each of the state factors, with the largest fluctuations seen among relative inequalities in the proportion with greater than a college degree and the percent poverty. As with maternal sociodemographic factors, studies have examined racial differences in these state-level census variables, but state-specific racial differences have not been well examined on a national level.

2.5.4 Correlation between disparity measures and infant mortality

Racial composition score findings were reinforced when examining correlations between IM rates and disparity measures. While relative and absolute disparity measures were significantly correlated with each other, they exhibited different relationships with IM rates. Absolute measures of disparity were strongly correlated with black IM rates, while both black and white IM rates equally contributed to relative disparity measures. Results indicated that the absolute disparity measure more closely reflected black IM rates than did the relative disparity measure.

2.5.5 Correlation between inequalities in exposures and disparities in outcome

Racial inequalities in infant characteristics were strongly correlated to both relative and absolute disparity measures in IM. Numerous studies have shown robust associations between preterm/low birthweight birth and risk of infant death and between preterm/low birthweight birth [11] and racial disparities in infant mortality [46, 52]. In addition, the proportion of VLBW births has long been correlated with national differences in IM rates [74]. While inequalities in both VPT and VLBW births were significantly correlated with disparities in IM, of interest were differences in the magnitude of prediction for each of the infant factors. Inequalities in the proportion of VLBW births were the strongest predictor of nationwide variation in racial disparities in IM. Although other studies have found strong relationships between the proportion of VLBW births and IM rates [74], it is unclear why inequalities in VLBW births would be a stronger predictor than inequalities in VPTB. A possible reason is misreporting of gestational age reporting versus the reporting birthweight in vital statistics data [62].

The ~200 gram difference in birthweight [75] between blacks and whites could have something to do with the higher correlation between inequalities in VLBW and disparities in IM but there is also a ~6 day difference in gestational age [76] between the races as well. Or, the effect of inequalities in the proportion of very low birthweight births could just be the strongest predictor of racial disparities in IM. Despite reasons for differences in the magnitude of the effect, VLBW births and VPTB are still the largest risk factors for IM and should still be prevented.

Other than its association with preterm birth, the relationship between race, low birthweight and risk of IM is not a straight forward one. Populations with a higher percent of LBW births often have higher rates of IM. But, LBW infants from these same populations often have lower mortality than LBW infants from populations with a more favorable birthweight distribution (ie. black vs. white infants) [77]. Examined another way, among LBW infants, risk of IM is relatively independent of the social and demographic factors that affect the overall IM rate. It appears that those social factors influence IM by altering the birthweight distribution (ie. increasing the proportion of low birthweight births), whereas for a given birthweight, the influence of those factors is relatively small, specifically among black infants [52]. This concept is referred to as the LBW paradox. Despite this complex relationship between birthweight, race and IM, the fact remains that the smallest infants are at the greatest risk of mortality [6]. Furthermore, as this research shows, inequalities in the very low birthweight proportion are consistently correlated with disparities in IM.

After adjustment, relative and absolute inequalities in maternal factors were not significantly correlated with racial disparities in IM. The strong positive correlation seen between inequalities in teen pregnancy and disparities in IM were no longer significantly correlated after accounting for confounding variables such as education and marital status. Another study examining 1995-1996 linked birth infant death data found that racial disparities in IM risk varied by teen category, with infants born to 18-19 year old blacks more likely than their white counterparts to die, while the risk of infant death was lower for blacks whose mothers were less than 18 [78]. Overall, black women are more likely to have a teen pregnancy, which increases IM risk. This excess in teen pregnancy among black mothers could account for the significant correlation between inequality in teen pregnancy and disparities in IM. While there was a lack of correlation between inequalities in maternal sociodemographic factors and disparities in IM in state level analyses, these factors have still been found to influence the risk of individual infant death.

With respect to correlations between inequalities in state level factors and disparities in IM, inequalities in the proportion foreign born and in the percent poverty were significantly correlated with racial disparities in IM, even after accounting for other confounding variables. Although numerous studies have evaluated the effect of foreign born status on racial differences in infant outcomes [79, 80], to our knowledge a state-level examination of inequalities in foreign born status has not yet been done. Historically, the effect of poverty on racial disparities in IM has been examined by numerous studies [81-83]. More recently, Sims (2007) examined the effect of urban area poverty on racial disparities in IM and found that high poverty was significantly associated with black/white racial disparities in IM. But, unlike our results, the black poverty coefficient shrunk by 78% when other maternal factors were added to the model.

Other studies have found associations between in income inequality, education, medical care, proportion black, and unemployment [33, 34, 84, 85], and population level IM although many of these were modest associations. The most consistent state-level predictor of IM in these studies was the proportion of the population which was black. We also found that the proportion black was significantly correlated with racial disparities in IM (results not shown). There are several theories as to why social inequalities could be related to health [41]. Social capital theories assert that individual and group level relationships influence population health either directly or indirectly through proximal factors. Psychosocial theories hold that inequalities in social standing create stress that can eventually damage a person's health. Others have suggested that areas with greater social inequalities may systematically under invest in health care and housing which may lead to poor health status among disadvantaged groups [84]. Schoendorf (1992) found that racial disparities in IM persist even after classification on socioeconomic position. In contrast to black infants in the general population, black infants born to college educated parents have higher IM rates than similar white infants [37]. Cultural differences and institutionalized racism [5, 37, 86, 87], are also thought to be contributors to racial disparities in infant outcomes directly or through access to medical care but further studies are needed to examine their true contributions. Although inequalities in state factors were not as strongly correlated with IM disparities as were inequalities in infant factors, this research is in line with suggestions that racial disparities in IM reflect inequalities among socioeconomic groups in state level characteristics [88].

2.5.6 Other reasons for national variation in disparities in infant mortality

This study examined the effect of inequalities in sociodemographic risk factors for IM on racial disparities in IM. Another factor which could have accounted for nationwide variation in IM disparities are state discrepancies in the reporting of live births and infant or fetal deaths, especially at non-viable birthweights or gestations and state differences in access to medical care. While it is unlikely that state to state variations in the quality of vital records contributes to differences noted in our results, since approximately 99 percent of all births are reported in the U.S., state level variation in the reporting of fetal and infant deaths could influence state IM rates and disparities differently [36, 43, 45]. In addition, since black infants are more likely to be born at extremely preterm gestations [1, 2, 10], race may differentially affect the reporting of these non-viable births, therefore leading to disparities in IM.

2.6 Conclusion

Our study found that relative and absolute measures of disparity provided similar, but not identical results when examining inequality in infant, maternal and state sociodemographic factors. They provided different results, however, when examining state-level racial disparities in IM. The combination of racial composition scores and disparity measures shed new night on highest and lowest disparity states. The evaluation of both racial disparities and racial composition scores leads to conclusion that Washington has the lowest relative disparities in IM and Massachusetts has the lowest absolute racial disparities in IM since they have low DRs and DDs in addition to low black and low white racial composition scores. On the other hand, Tennessee and Ohio would be the highest disparity states because they have high disparity measures, high black and high white racial composition scores. Furthermore, a state such as New Jersey, which has low black and low white racial composition scores, would not be listed as a high disparity state.

State differences in the proportion of VLBW births were the strongest predictor of racial disparities in IM and efforts should be made to target women who are at high risk for a VLBW birth. Furthermore inequalities in foreign born status and percent poverty were also significantly correlated with national variation in IM disparities. Inequalities in maternal factors did not play a strong role in nationwide variation in IM disparities, but are still important predictors of individual IM risk. Due to differences in IM disparity results depending on the measure used, future studies examining reasons for state-level differences in racial disparities in IM, should use both relative and absolute disparity measures. Care should also be taken when examining nationwide variation in racial disparities in IM and interpretation of results should include discussion of how results differ, with the disparity measure used.

CHAPTER 3: THE IMPACT OF FETAL DEATH REPORTING PRACTICES ON RACIAL DISPARITIES IN INFANT, EARLY AND LATE NEONATAL, POSTNEONATAL, AND FETAL MORTALITY

This chapter includes an examination of the impact of state reporting practices on racial disparities in infant, early and late neonatal, postneonatal and fetal mortality rates and is study 2 for this three paper dissertation option.

3.1 Abstract

Objective: To determine the impact of state fetal death reporting requirements and reporting of non-viable births on racial disparities in infant, early and late neonatal, postneonatal and fetal mortality rates.

Methods: Birth and death certificate data from non-Hispanic white (white) and non-Hispanic black (black) infants were obtained from the 2000-2002 Vital Statistics Division of the National Center for Health Statistics linked birth/infant death and fetal death dataset. Mortality rates were grouped by state fetal death reporting requirements and by the proportion of non-viable births. Relative and absolute measures of racial disparity were examined in relation to mortality. Logistic regression was used to examine the effect of fetal death registration area and proportion of non-viable births on the risk of race-specific mortality.

Results: Mortality rates and racial disparities were the highest among states with birthweight only fetal death reporting criteria and among states with the highest proportion of non-viable births recorded in birth certificates. The largest proportion of this difference was accounted for by births ≤ 22 weeks gestation. Racial disparities in fetal deaths were highest among states which report all products of conception and

among states with the highest proportion of non-viable births. The absolute measure of disparity was most sensitive to registration area differences in disparity.

Conclusions: Fetal death registration area and proportion non-viable differences in mortality were most pronounced among black, extremely preterm infants. A uniform definition of fetal death should be adopted to reduce systematic differences in the reporting of live births and fetal deaths.

3.2 Introduction

3.2.1 Nationwide variation in racial disparities in infant mortality

Racial disparities in infant mortality (IM) rates (death prior to 1 year of age per 1,000 live births) have been a problem in the U.S. for decades with some states experiencing higher disparities than others [1, 2, 4, 6, 29, 31-36, 63]. Little is understood of the cause for state-level differences in IM rates and racial disparities in IM rates but states have been found to vary in population risk characteristics, prevalence of low birthweight, and geographic obstacles to delivery in care [4]. The reporting of fetal deaths and births at the border of viability has received little attention in relation to state-level variation in IM rates[36, 45] and even less in relation to racial disparities[43].

3.2.2 Fetal death reporting

Variation in the completeness and accuracy of reporting fetal and infant deaths can influence both fetal and infant mortality rates [43]. Although all states require the reporting of a live birth regardless of the length of gestation or weight, there is considerable variation in fetal death reporting criteria. The 1992 revision of the Model State Vital Statistics Act and Regulations *recommend* the following definition of fetal death: "...death prior to the complete expulsion or extraction from its mother of a product of human conception...after such expulsion or extraction the fetus does not breathe or show any evidence of life such as beating of the heart, pulsation of the umbilical cord or definite movement of voluntary muscles...each fetal death of 350 grams or more, or if weight is unknown, of 20 completed weeks of gestation or more...shall be reported within 5 days after delivery" [44]. Thirty eight of the U.S. registration areas use a definition similar to this definition while twelve areas use a shortened or different definition of fetal death.

Because there is only a recommended definition of fetal death, systematic variation does appear in state reported rates of low birthweight fetal deaths. In addition, imprecision in recognizing or acknowledging very brief and faint signs of life may lead to systematic variations in reporting a delivery as a live birth or a fetal death [43]. Previous studies have examined the effect of reporting differences on the proportion of low birthweight births [45, 46], racial differences in perinatal mortality [43], and neonatal mortality [36]. Although there is conflicting evidence on the effect of reporting differences on state-level differences in perinatal outcomes, Wingate [43] found that there may be underreporting of low birthweight fetal deaths and recommended further analyses to establish if black fetal death rates are underreported. Systematic misclassification of very low birthweight infants as fetal deaths could lead either to an underestimation or an overestimation of the overall IM rate and racial disparities in IM rates, depending on the racial composition of the under- or over-reported deaths.

3.2.3 Study Objective

The objective of this study was to determine the impact of state differences in a) fetal death registration requirements and b) the reporting of births at the border of viability on absolute and relative racial disparities in reported infant, early and late neonatal, postneonatal and fetal mortality rates. We hypothesized that reported infant and fetal mortality rates and racial disparities in reported mortality rates would vary depending on the a) restrictiveness of fetal death reporting requirements and b) proportion of live births reported at the border of viability. We further hypothesized that racial disparities would vary depending on the disparity measure (relative vs. absolute) used. The effects of reporting requirements and the proportion of non-viable births were expected to vary by gestational age at birth, with the strongest hypothesized effect on mortality rates and disparities among extremely preterm infants.

3.3 Materials and Methods

3.3.1 Study Population

The source population included singleton, live births, infant deaths and fetal deaths to non-Hispanic white and non-Hispanic black (hereafter referred to as white and black) maternal residents of the U.S. (n=10,999,362 live births; 66,566 infant deaths; 154,712 fetal deaths). Due to documented, systematic variation in the reporting of infant and fetal deaths less than 20 weeks gestation, these records were excluded (n=2,902 live births; 2,331infant deaths; 80,783 fetal deaths). Usually, records missing gestational age are excluded from analyses such as these, but due to the thought that missing gestational age information could lead to state-level discrepancies in infant and fetal mortality, records missing information on gestational age were examined as well (n=108,784 live births; 2,174 infant deaths; 7,563 fetal deaths). The study population therefore included 10,996,460 live births, 64,235 infant deaths and 73,929 fetal deaths.

3.3.2 Data source and Preparation

Birth and linked infant death records and fetal death records were obtained from the 2000-2002 Linked Birth/Infant Death Dataset, and the 2000-2002 U.S. Fetal Death Dataset produced by the National Center for Health Statistics (NCHS) Division of Vital Statistics [59]. Three years of cohort, as opposed to period, data were used in order to obtain a sufficient number of infant cases in the numerator and live births in the denominator from which to produce stable mortality rates. Cohort data links infants born in one year to subsequent deaths regardless to whether the death occurred during the birth year, or the following year. Birth cohort data files were preferred for this analysis because they followed a given cohort of births for an entire year to ascertain mortality-specific information. Since fetal deaths do not have a corresponding birth certificate, this cohort argument only applies to infant deaths.

National birth and linked infant death records make use of state linked files for the identification of linked birth and infant death certificates and NCHS natality and mortality computerized statistical files. When the birth and death of an infant occur in different states, copies of the records are exchanged by the state of death and the state of birth in order for the record to be linked. In addition, if a third state is identified as the state of residence at the time of birth or death, that state is also sent a copy of the appropriate certificate by the state when the birth or death occurred. Fetal death statistics for every year are based on all reports of fetal death received by the NCHS and include fetal deaths occurring at a stated or presumed gestation of 20 weeks or more. Reporting requirements for fetal deaths vary from state to state, therefore, reporting is not as complete for fetal deaths as it is for live births and subsequent infant deaths. Fetal death reporting is believed to be relatively complete for fetal deaths at ≥ 28 weeks gestation [60].

The NCHS natality and mortality files, produced annually, include data from birth and death certificates that are provided to NCHS by states under the Vital Statistical Cooperative Program. Data were coded according to uniform coding specifications, passed rigid quality control standards, were edited and reviewed and are the basis for official U.S. birth and death statistics [59].

3.3.3 Outcome Variables

Reported mortality rates included IM (infant death between 1 and 364 days / live births), early neonatal mortality (infant death during the first 6 days of life / live births), late neonatal mortality (infant death between 7 and 27 days of life / live births - early neonatal deaths), postneonatal mortality (infant death between 28 days and 364 days of life / live births – neonatal deaths) and fetal mortality (fetal death ≥20 weeks gestation / live births + fetal deaths) and were expressed per 1,000 live births (table 2). Crude mortality rates in addition to rates stratified by race were calculated.

Both relative, via the disparity ratio (DR), and absolute, via the disparity difference (DD) measures of racial disparity in mortality were employed to test which was most sensitive when assessing nationwide variation in racial disparity. The DR, one of the most commonly used measures of health disparity, was calculated by dividing the reported mortality rate of the most disadvantaged group (black infants) by the reported mortality rate of the most advantaged group (white infants). In the case of no disparity, the value the DR took was one. The DD, a measure of the absolute disparity between two groups, was calculated by subtracting the reported mortality rate among the most advantaged group (white infants) from the reported mortality rate among the most disadvantaged group (black infants). In the case of no disparity, the value the DD took was zero. All DDs were expressed per 1,000 live births.

3.3.4 Exposure Variables

State level fetal death reporting requirements and the proportion of live births at the border of viability were the main exposures of interest. For the purpose of this study, state referred to birth state, as opposed to maternal state of residence. Although infant 'exposure' to state reporting requirements do not increase risk of IM or racial disparities in IM per se, state reporting practices could influence whether a death is classified as a live birth and subsequent infant death, or classified as a fetal death. The exposure-outcome relationship was therefore the effect of reporting practices on the risk of being classified as a infant death versus the risk of being classified as a fetal death.

Fetal death registration areas were classified by two sets of criteria. The first was the state adopted fetal death reporting requirements classification system (table 1) and the second set of criteria included four consolidated categories thought to capture most of the reporting differences which may occur through birthweight or gestational age criteria (table 2). Registration areas were consolidated to account for small sample sizes in a number of the fetal death registration areas (ie. birthweight ≥ 350 grams: Kansas, birthweight ≥ 400 grams or gestation of ≥ 20 weeks: Michigan, birthweight ≥ 500 grams or gestation of ≥ 20 weeks: District of Columbia and gestation of ≥ 16 weeks: Pennsylvania). The newly created registration areas included states which reported: 1. all products of conception; 2. birthweight criteria or gestational age criteria; 3. birthweight criteria, only; 4. gestational age criteria, only. Newly created fetal death registration areas were then ranked from 'most liberal' which included states which report all products of conception, regardless of the birthweight or gestational age to the 'most strict' which included states which report based on report gestational age criteria, only.

Table 3.1. Fetal death registration requirements, 1997 revision.

All products of human conception		
Arkansas	Hawaii	Rhode Island
Colorado	New York State	Virginia
Georgia	New York City	
Gestation of ≥20 weeks		
Alabama	Maine	Oklahoma
Alaska	Maryland	Oregon
California	Minnesota	Texas
Connecticut	Nebraska	Utah
Florida	Nevada	Vermont
Illinois	New Jersey	Washington
Indiana	North Carolina	West Virginia
Iowa	North Dakota	Wyoming
	Ohio	
Birthweight of ≥350 grams		
Kansas		
Birthweight of ≥350 grams or Gestation of ≥20 weeks		
Arizona	Louisiana	Montana
Delaware	Massachusetts	New Hampshire
Idaho	Mississippi	South Carolina
Kentucky	Missouri	Wisconsin
Birthweight of ≥400 grams or Gestation of ≥20 weeks		
Michigan		
Birthweight of ≥500 grams or Gestation of ≥20 weeks		
District of Columbia		
Birthweight of ≥500 grams		
New Mexico	South Dakota	Tennessee
Gestation of ≥16 weeks		
Pennsylvania		

Figure 3.1. Fetal Death Registration Areas, United States 1997 Revision

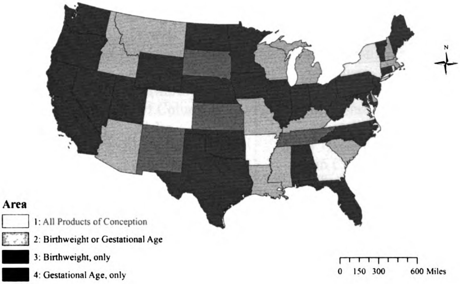


Table 3.2. Consolidated fetal death reporting requirements, United States 2000-2002.

Registration Area 1: All products of human conception	
Arkansas	New York State
Colorado	New York City
Georgia	Rhode Island
Hawaii	Virginia
Registration Area 2: Birthweight or Gestational Age	
Arizona	Michigan
Delaware	Mississippi
District of Columbia	Missouri
Idaho	Montana
Kentucky	New Hampshire
Louisiana	South Carolina
Massachusetts	Wisconsin
Registration Area 3: Birthweight, Only	
Kansas	South Dakota
New Mexico	Tennessee
Registration Area 4: Gestational Age, Only	
Alabama	New Jersey
Alaska	North Carolina
California	North Dakota
Connecticut	Ohio
Florida	Oklahoma
Illinois	Oregon
Indiana	Pennsylvania
Iowa	Texas
Maine	Utah
Maryland	Vermont
Minnesota	Washington
Nebraska	West Virginia
Nevada	Wyoming

The second reporting exposure of interest was the proportion of non-viable live births. This exposure was classified by the proportion of live births <500 grams and <23 weeks gestation within each state. The proportions for each state were ranked from smallest to largest by the proportion <500 grams then by the proportion <23 weeks and were subsequently were split into four categories (table 3).

Figure 3.2. Proportion of Non-Viable Births, United States 2000-2002

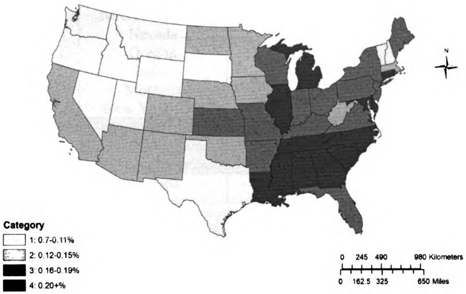


Table 3.3. Borderline live births based on the proportion non-viable, United States 2000-2002.

Category 1 <500 grams: 0.03-0.09% <23 weeks: 0.04-0.10%	
Alaska New Hampshire Nevada Oregon Idaho Montana New York City	South Dakota Texas Utah Vermont Washington Wyoming
Category 2 <500 grams: 0.10-0.12% <23 weeks: 0.10-0.12%	
Arizona California Colorado Iowa Massachusetts Minnesota	Nebraska New Mexico North Dakota Oklahoma West Virginia
Category 3 <500 grams: 0.12-0.16% <23 weeks: 0.13-0.16%	
Arkansas Florida Hawaii Indiana Kansas Kentucky Maine	Missouri New Jersey New York State Virginia Ohio Pennsylvania Wisconsin
Category 4 <500 grams: 0.16-0.33% <23 weeks: 0.17-0.37%	
Alabama Connecticut Delaware District of Columbia Georgia Illinois Louisiana	Maryland Michigan Mississippi North Carolina South Carolina Tennessee Rhode Island

3.3.5 Gestational age stratification

Each state is required to report all fetal and infant deaths ≥20 weeks gestation so reporting differences in mortality and disparity were stratified with this cut-point in mind. The first gestational stratification included all live births, infant deaths and fetal deaths ≥20 weeks gestation and was selected as the 'baseline' estimator of reporting area differences. Next, reporting differences among those missing information on gestational age were examined. Since information on gestational age and/or birthweight was required by most states for reporting purposes (table 3.1), mortality rates, relative and absolute disparities among those missing information on birthweight or gestation age were hypothesized to vary by fetal death registration area and proportion non-viable category. Reporting differences were also hypothesized to fluctuate around 23 weeks gestation, since lungs are thought to be too immature to survive before this point. For this reason, mortality rates and disparities among infants ≤22 weeks gestation were also examined. Additionally, mortality rates and disparities between 23-28 weeks were examined to see if any reporting differences among infants ≤ 22 weeks were still apparent.

3.3.6 Data Analysis

Logistic regression was used to model the effect of fetal death classification area and the proportion of non-viable births on the race-specific risk of mortality. Gestational week adjustments were made when appropriate to account for national variation in gestational age at birth. Relative differences in gestational age specific mortality risk between fetal death classification areas and proportion non-viable categories were quantified using the relative risk and statistical significance was determined with a 95% confidence interval. All statistical analyses were conducted using SAS version 9.1.3.

3.3.7 Mapping

Maps were used to visualize national differences in IM rates and racial disparities in IM rates. Continuous data were split into 4 categories based on quantile classification within ArcGIS. Darker colors indicate higher rates, while lighter colors indicate lower proportions/rates. We also mapped state differences in reporting practices. Maps were created using ArcMap version 9.3 within ArcGIS version 9.

3.4 Results

3.4.1 Mortality rates, disparity ratios and disparity differences by race

From 2000-2002, there were 10,996,460 (white = 9,238,461; black = 1,757,999) reported live births and 64,235 (white = 44,397 and black =19,838) reported infant deaths in our study population. This resulted in a reported IM rate of 5.8 per 1,000 live births (white IM=4.8 per 1,000 live births; black IM =11.3 per 1,000 live births). The DR was 2.4 and DD was 6.5 excess deaths per 1,000 live births. There were 73,929 (white=52,181 and black=21,748) reported fetal deaths in our study population. This resulted in a fetal mortality rate of 6.7 (white=5.6 per 1,000 live births; black=12.2 per 1,000 live births), a DR of 2.2 and a DD of 6.6 excess fetal deaths per 1,000 live births (table 3.4).

Table 3.4. Mortality rates, disparity ratios and disparity differences, United States 2000-2002

Mortality Rate*	Total	White	Black	Disparity Ratio	Disparity Difference*
Infant	5.8	4.8	11.3	2.4	6.5
Early Neonatal	3.1	2.5	6.3	2.5	3.8
Late Neonatal	0.8	0.7	1.5	2.1	0.8
Postneonatal	2.2	1.8	4.0	2.2	2.2
Fetal	6.7	5.6	12.2	2.2	6.6

*expressed per 1,000 live births

Figure 3.3. Total Infant Mortality Rates, United States 2000-2002

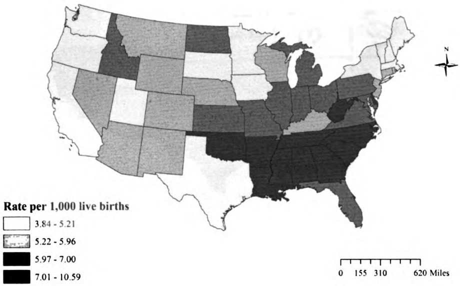


Figure 3.4. Disparity Ratios in Infant Mortality, United States 2000-2002

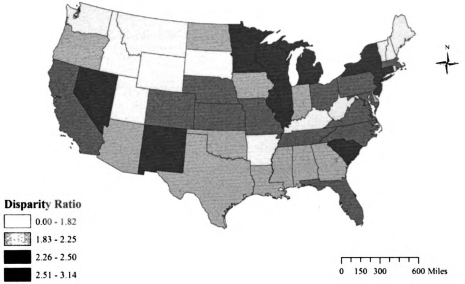
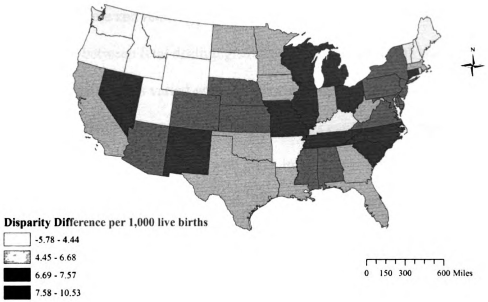


Figure 3.5. Disparity Differences in Infant Mortality, United States 2000-2002



3.4.2 Mortality rates and racial disparities among infants ≥ 20 weeks and with unknown gestational ages by fetal death registration area

Table 3.5 shows mortality rates, relative disparities and absolute disparities among infants with a reported gestational age of ≥ 20 weeks and infants with unknown gestational ages by fetal death registration area. Among infants with a reported gestational age of ≥ 20 weeks, the highest infant mortality rates were generally seen in fetal death classification area 3, with birthweight, only criteria. The lowest mortality rates were generally seen in fetal death classification area 1 which reported all products of conception. In contrast to the mortality rates seen among infant deaths, area 1 had the highest fetal mortality rates, while area 3 had the lowest fetal mortality rates.

Both absolute and relative disparity measures showed similar results, but the largest variation between fetal death registration areas was seen with the absolute measure. Nationally, DDs varied with differences ranging from 2.3 excess postneonatal deaths per 1,000 live births to 6.8 excess infant deaths per 1,000 live births. DRs demonstrated less national variation with black infants approximately 2.5 times as likely as white infants to die during each period. The highest DRs and DDs for infant, early neonatal, neonatal, and postneonatal mortality were found in registration area 3, while registration area 1 had the highest fetal death DDs.

Infant, early neonatal and neonatal disparity measures among infants missing information on gestational age were higher than disparity measures among infants with complete gestational age information. DRs and DDs demonstrated similar disparity findings, although the DD was more sensitive to large registration area differences in disparity.

Table 3.5. Mortality among infants ≥20 weeks gestation and with unknown gestational age by fetal death registration area, United States 2000-2002.

Fetal Death Classification Area	Gestational Age ≥20 weeks n=10,887,676 births					Unknown Gestational Age n=108,784 births				
	Total	White	Black	DR	DD*	Total	White	Black	DR	DD*
Infant Mortality										
United States	5.7	4.7	11.0	2.4	6.3	20.8	16.2	55.1	3.4	38.9
Area 1	5.8	4.6	10.0	2.2	5.4	65.1	41.9	151.5	3.6	109.6
Area 2	6.2	4.9	11.9	2.4	7.0	61.1	45.7	132.0	2.9	86.3
Area 3	6.7	5.6	13.3	2.4	7.6	74.6	51.5	135.7	2.6	84.3
Area 4	5.5	4.6	10.9	2.4	6.3	16.8	13.6	41.5	3.1	27.9
Early Neonatal Mortality										
United States	2.7	2.2	5.4	2.5	2.5	15.8	11.8	45.0	3.8	33.2
Area 1	2.9	2.2	5.2	2.3	2.9	57.0	36.4	133.3	3.7	96.9
Area 2	3.0	2.3	5.9	2.5	3.6	55.1	40.0	125.3	3.1	85.4
Area 3	3.1	2.5	6.7	2.7	4.2	56.0	36.0	108.6	3.0	72.6
Area 4	2.6	2.2	5.2	2.4	3.1	12.2	9.6	32.4	3.4	22.8
Late Neonatal Mortality										
United States	0.8	0.7	1.5	2.2	0.8	1.6	1.4	3.0	2.2	1.7
Area 1	0.8	0.7	1.4	2.1	0.7	--	--	--	--	--
Area 2	0.9	0.7	1.6	2.2	0.9	--	--	--	--	--
Area 3	0.9	0.8	1.7	2.2	0.9	--	--	--	--	--
Area 4	0.8	0.7	1.5	2.2	0.8	1.5	1.3	2.8	2.2	1.5
Postneonatal Mortality										
United States	2.2	1.8	4.1	2.3	2.3	3.5	3.0	7.4	2.5	4.4
Area 1	2.1	1.7	3.4	2.0	1.7	--	--	--	--	--
Area 2	2.3	1.9	4.4	2.3	2.5	--	--	--	--	--
Area 3	2.7	2.3	4.9	2.1	2.6	--	--	--	--	--
Area 4	2.1	1.8	4.2	2.3	2.4	3.1	2.7	6.6	2.4	3.9
Fetal Mortality										
United States	6.2	5.2	11.7	2.3	6.5	459.9	418.3	646.0	1.5	227.7
Area 1	7.6	5.9	13.4	2.2	7.4	971.8	970.1	976.9	1.0	6.8
Area 2	6.0	4.8	10.8	2.2	6.0	199.8	178.9	284.4	1.6	105.5
Area 3	4.1	3.5	7.7	2.1	4.1	88.4	96.1	67.5	0.7	-28.6
Area 4	5.8	4.9	11.0	2.2	6.1	65.5	58.3	116.9	2.0	58.6

*expressed per 1,000 live births
-- indicates inadequate cell specific count
Area 1= All products of conception
Area 2=Birthweight and gestational age criteria
Area 3= Birthweight criteria
Area 4= Gestational age criteria

3.4.3 Mortality rates and racial disparities among infants ≤22 weeks and 23-28 weeks gestation by fetal death registration area

Table 3.6 shows mortality rates and disparity measures among infants born at reported gestations of ≤22 weeks and 23-28 weeks, by fetal death registration area. Despite high mortality rates among infants ≤22 weeks reported gestation, black infants were less likely than their white counterparts to die in most registration areas. DRs were approximately 0.9 and DDs ranged from -77.0 to -16.0 for infant, early neonatal and neonatal mortality. Any black survival advantage was not seen among infants in registration area 3, as this was the only registration area which reported similar black and white mortality rates (DR≈1.0). Despite this finding, relative and absolute disparity measures demonstrated the largest black advantage among fetal death in registration area 3 (DR=0.4; DD=-159.9).

A black survival advantage was seen for most mortality periods among infants between 23 and 28 weeks reported gestation, with DRs and DDs ranging from 0.8-1.0 and -48.0 to -13.0, respectively. Relative and absolute disparities were similar between registration areas. Of note were large registration area differences in late neonatal mortality rates and disparity measures. While black infants were less likely than their white counterparts to die in areas 1 and 2, they were nearly three times as likely as their white counterparts to die in registration area 4.

Table 3.6. Mortality rates among infants ≤22 weeks and 23-28 weeks gestation by fetal death registration area, United States 2000-2002.

Fetal Death Area	Gestational Age ≤22 Weeks n=14,415 births					Gestational Age 23-28 Weeks n=50,909 births				
	Total	White	Black	DR	DD*	Total	White	Black	DR	DD*
Infant Mortality										
U.S.	787.3	801.1	770.2	1.0	-30.9	232.2	288.9	274.4	1.0	-14.5
Area 1	837.2	877.8	801.2	0.9	-76.6	303.0	309.5	296.2	1.0	-13.3
Area 2	784.2	820.9	748.9	0.9	-72.0	286.6	299.1	271.8	0.9	-27.3
Area 3	855.5	841.3	873.1	1.0	-31.8	289.0	296.3	275.1	0.9	-21.2
Area 4	770.3	776.6	761.1	1.0	-15.5	276.1	281.1	267.2	1.0	-13.9
Early Neonatal Mortality										
U.S.	753.0	773.8	727.4	0.9	-46.4	187.8	199.9	167.2	0.8	-32.7
Area 1	808.9	855.3	767.8	0.9	-87.5	202.8	219.7	184.9	0.8	-34.8
Area 2	750.6	794.1	709.0	0.9	-85.1	190.0	207.5	169.2	0.8	-38.3
Area 3	822.2	802.4	847.0	1.1	44.6	193.0	207.1	166.2	0.8	-40.9
Area 4	734.1	748.8	712.5	1.0	-36.3	182.6	192.9	163.9	0.9	-29.0
Late Neonatal Mortality										
U.S.	77.3	69.4	85.3	1.2	15.9	60.9	40.4	58.2	1.4	17.8
Area 1	97.2	--	--	--	--	64.9	82.7	65.0	0.8	-17.7
Area 2	77.7	74.9	79.6	1.1	4.7	63.6	90.1	55.9	0.6	-34.2
Area 3	--	--	--	--	--	53.1	52.0	55.0	1.1	2.9
Area 4	69.8	58.1	85.0	1.5	26.9	59.4	21.2	56.9	2.7	35.7
Postneonatal Mortality										
U.S.	66.7	55.5	78.3	1.4	22.8	60.2	49.4	76.0	1.5	26.6
Area 1	56.4	--	--	--	--	65.0	53.6	76.6	1.4	23.0
Area 2	61.4	--	62.5	--	--	59.4	48.6	71.5	1.5	22.9
Area 3	--	--	--	--	--	69.6	63.9	80.0	1.3	16.1
Area 4	71.3	55.8	91.8	1.6	36.0	58.6	51.7	70.7	1.4	19.0
Fetal Mortality										
U.S.	550.0	586.1	495.7	0.9	-90.4	226.8	245.9	195.6	0.8	-50.2
Area 1	653.9	689.3	614.9	0.9	-74.4	259.2	280.6	235.0	0.8	-45.6
Area 2	505.9	562.6	435.7	0.8	-127.0	210.4	235.4	178.3	0.8	-57.1
Area 3	190.9	254.5	94.6	0.4	-159.9	145.6	153.1	130.8	0.9	-22.4
Area 4	542.5	575.7	482.7	0.8	-93.0	227.5	246.3	191.0	0.8	-55.3

*expressed per 1,000 live births
-- indicates inadequate cell specific count
Area 1= All products of conception
Area 2=Birthweight and gestational age criteria
Area 3= Birthweight criteria
Area 4= Gestational age criteria

Next, we examined mortality rates, relative disparities and absolute disparity measures by the proportion of non-viable births.

3.4.4 Mortality rates and racial disparities among infants ≥ 20 weeks and with unknown gestational ages by non-viable category

Table 3.7 shows mortality rates and relative and absolute disparities among infants with a reported gestational age ≥ 20 weeks and among infants missing gestational age by the proportion of largely non-viable births. Among infants ≥ 20 weeks gestation, the highest infant *and* fetal mortality rates and disparities were generally found in category 4, which also had the highest proportion of non-viable births. Category 1, which had the lowest proportion of non-viable births, had the lowest mortality rates and disparities. The corresponding high infant and high fetal mortality rates seen when examining proportion non-viable categories were contrary to the pattern of high infant and low and low fetal mortality rates seen when examining fetal death registration areas.

Among births with unknown gestational ages, mortality rates and disparity measures fluctuated by proportion non-viable category with the highest rates in category 3.

Table 3.7. Mortality among infants ≥20 weeks gestation and with unknown gestational age by Proportion Unviable, United States 2000-2002.

Non-viable Category	Gestational Age ≥20 weeks n=10,887,676 births					Unknown Gestational Age n=108,784 births				
	Total	White	Black	DR	DD*	Total	White	Black	DR	DD*
Infant Mortality										
United States	5.7	4.7	11.0	2.4	6.3	20.8	16.2	55.1	3.4	38.9
Category 1	4.9	4.4	8.5	1.9	4.1	32.6	29.8	45.8	1.5	16.1
Category 2	4.7	4.4	9.1	2.1	4.7	11.2	10.0	22.9	2.3	12.9
Category 3	5.9	4.9	11.1	2.3	6.3	95.6	68.5	177.6	2.6	109.0
Category 4	7.0	5.1	12.1	2.4	7.0	88.3	65.5	124.0	1.9	58.5
Early Neonatal Mortality										
United States	2.7	2.2	5.4	2.5	2.5	15.8	11.8	45.0	3.8	33.2
Category 1	2.2	2.0	3.7	1.9	1.8	24.7	22.2	36.8	1.7	14.6
Category 2	2.3	2.1	4.3	2.1	2.2	7.3	6.6	13.9	2.1	7.3
Category 3	2.8	2.3	5.5	2.4	3.2	86.5	60.1	166.5	2.8	106.5
Category 4	2.3	2.4	6.1	2.5	3.7	78.7	57.6	111.8	1.9	54.1
Late Neonatal Mortality										
United States	0.8	0.7	1.5	2.2	0.8	1.6	1.4	3.0	2.2	1.7
Category 1	0.7	0.7	1.2	1.9	0.6	3.1	2.9	--	--	--
Category 2	0.7	0.6	1.3	2.1	0.7	1.2	1.1	2.6	2.3	1.4
Category 3	0.8	0.7	1.5	2.1	0.8	--	--	--	--	--
Category 4	1.0	0.8	1.7	2.2	0.9	--	--	--	--	--
Postneonatal Mortality										
United States	2.2	1.8	4.1	2.3	2.3	3.5	3.0	7.4	2.5	4.4
Category 1	2.0	1.8	3.5	1.9	1.7	5.0	4.8	--	--	--
Category 2	1.8	1.6	3.4	2.1	1.8	2.8	2.4	6.6	2.8	4.2
Category 3	2.2	1.8	4.2	2.3	2.3	7.0	6.5	--	--	--
Category 4	2.6	1.9	4.4	2.3	2.5	7.7	--	--	--	--
Fetal Mortality										
United States	6.2	5.2	11.7	2.3	6.5	459.9	418.3	646.0	1.5	227.7
Category 1	6.0	5.1	12.4	2.4	7.3	168.7	149.4	249.4	1.7	100.1
Category 2	4.9	4.6	9.5	2.1	4.9	19.6	17.9	35.8	2.0	18.0
Category 3	6.3	5.3	11.3	2.1	6.0	431.6	418.6	467.7	1.1	49.1
Category 4	6.8	4.9	11.6	2.3	6.6	236.4	218.1	263.3	1.2	45.2

*expressed per 1,000 live births
-- indicates inadequate cell specific count
Category 1 = <500 grams: 0.03-0.09%; <23 weeks: 0.04-0.10%
Category 2 = <500 grams: 0.10-0.12%; <23 weeks: 0.10-0.12%
Category 3 = <500 grams: 0.12-0.16%; <23 weeks: 0.13-0.16%
Category 4 = <500 grams: 0.16-0.33%;<23 weeks: 0.17-0.37%

3.4.5 Mortality rates and racial disparities among infants ≤22 weeks and 23-28 weeks gestation by non-viable category

Table 3.8 shows mortality rates and disparities among infants with a reported gestation of ≤ 22 weeks and 23-28 weeks, by the proportion of largely non-viable births. For both gestational age groups, the lowest mortality rates and disparities were generally seen among category 1 births, while the highest mortality rates and disparities were seen among category 4 births. Although the relative measure of disparity was similar between each of the non-viable categories, the absolute measure showed more variation with DDs ranging from -118.0 to -29.0.

Table 3.8. Mortality Rates Among Infants ≤22 Weeks and 23-28 Weeks Gestation by Proportion Non-Viable, United States 2000-2002.

Non-Viable Category	Gestational Age ≤22 Weeks n=14,415 births					Gestational Age 23-28 Weeks n=50,909 births				
	Total	White	Black	DR	DD*	Total	White	Black	DR	DD*
Infant Mortality										
U.S.	787.3	801.1	770.2	1.0	-30.9	232.2	288.9	274.4	1.0	-14.5
Category 1	697.8	725.1	637.0	0.9	-88.1	260.8	263.8	253.7	1.0	-10.1
Category 2	773.1	783.7	731.9	0.9	-51.9	279.3	284.4	256.6	0.9	-27.8
Category 3	802.5	821.0	779.1	1.0	-41.9	281.3	288.0	270.7	0.9	-17.3
Category 4	813.5	843.1	795.4	0.9	-47.7	298.4	315.6	285.4	0.9	-30.3
Early Neonatal Mortality										
U.S.	753.0	773.8	727.4	0.9	-46.4	187.8	199.9	167.2	0.8	-32.7
Category 1	659.5	695.5	579.2	0.8	-116.3	170.0	179.5	147.0	0.8	-32.4
Category 2	744.5	757.2	695.6	0.9	-61.6	196.1	202.1	169.6	0.8	-32.4
Category 3	774.7	798.7	744.3	0.9	-54.4	187.6	198.2	171.0	0.9	-27.2
Category 4	772.0	809.4	749.1	0.9	-60.3	192.7	216.8	174.4	0.8	-42.4
Late Neonatal Mortality										
U.S.	77.3	69.4	85.3	1.2	15.9	60.9	40.4	58.2	1.4	17.8
Category 1	48.0	--	--	--	--	54.2	54.5	53.4	1.0	-1.1
Category 2	64.8	64.4	--	--	--	58.2	60.3	49.0	0.8	-11.3
Category 3	64.5	58.2	70.8	1.2	12.6	61.8	66.0	55.5	0.8	-10.6
Category 4	112.3	118.0	109.7	0.9	-8.2	64.8	67.3	62.9	0.9	-4.4
Postneonatal Mortality										
U.S.	66.7	55.5	78.3	1.4	22.8	60.2	49.4	76.0	1.5	26.6
Category 1	67.7	53.4	37.1	0.7	-16.3	58.5	51.0	64.0	1.3	13.0
Category 2	50.3	48.2	--	--	--	48.1	45.6	58.6	1.3	13.0
Category 3	63.1	56.0	70.3	1.3	14.3	57.0	49.2	68.6	1.4	19.4
Category 4	78.6	59.0	74.8	1.3	15.8	70.8	58.9	71.5	1.2	12.7
Fetal Mortality										
U.S.	550.0	586.1	495.7	0.9	-90.4	226.8	245.9	195.6	0.8	-50.2
Category 1	649.1	642.4	663.0	1.0	20.5	248.7	258.1	225.1	0.9	-33.1
Category 2	531.3	546.7	460.3	0.8	-86.4	237.2	245.4	197.5	0.8	-47.8
Category 3	549.9	592.8	480.5	0.8	-112.3	228.0	247.9	194.6	0.8	-53.3
Category 4	506.4	565.9	461.1	0.8	-104.7	208.0	232.9	187.9	0.8	-45.0

*expressed per 1,000 live births
-- indicates inadequate cell specific count
Category 1 = <500 grams: 0.03-0.09%; <23 weeks: 0.04-0.10%
Category 2 = <500 grams: 0.10-0.12%; <23 weeks: 0.10-0.12%
Category 3 = <500 grams: 0.12-0.16%; <23 weeks: 0.13-0.16%
Category 4 = <500 grams: 0.16-0.33%;<23 weeks: 0.17-0.37%

3.4.6 Relative risk of mortality

In order to determine if noted reporting differences in mortality were statistically significant, tables 3.9 and 3.10 show fetal registration area and proportion non-viable differences in the race-specific risk of early neonatal mortality among infants ≥ 20 weeks gestation, ≤ 22 weeks gestation, and 23-28 weeks gestation. Early neonatal mortality was chosen because it offers specificity in time of death. Furthermore, sample sizes for late neonatal and postneonatal mortality were too small to calculate stable registration area relative risks. Fetal death registration area 1, had the lowest mortality rates and was used as the referent category.

Among infants ≥ 20 weeks gestation, significant fetal death registration area differences in early neonatal mortality risk were seen among black, but not white infants. Black infants in fetal death registration areas 2 and 3 had significantly higher mortality rates than infants in registration area 1 (RR=1.15; 1.09-1.22, RR=1.33; 1.20-1.48, respectively). This relationship became more apparent after sub-setting to black infants ≤ 22 weeks gestation in registration area 3 (RR=1.71; 1.14-2.57). In contrast, white infants ≤ 22 weeks gestation, had a significantly lower risk of death in registration areas 2 and 4 (RR=0.65; 0.52-0.82 and RR=0.55; 0.45-0.67, respectively). White infants within area 4 remained at decreased risk of mortality between 23 and 28 weeks gestation. Adjustment for gestational week did not alter the findings.

Table 3.9. Fetal Death Registration Area Differences in Risk of Race-Specific Early Neonatal Mortality, United States 2000-2002.

Neonatal Mortality	Gestational Age $\geq$ 20 weeks		Gestational Age $\leq$ 22 weeks		Gestational Age 23-28 weeks	
	White	Black	White	Black	White	Black
Area 1	1.00	1.00	1.00	1.00	1.00	1.00
Area 2	1.06 (1.01-1.12)	**1.15 (1.09-1.22)**	**0.65 (0.52-0.82)**	0.80 (0.67-1.00)	0.93 (0.84-1.02)	0.90 (0.81-1.00)
Area 3	1.12 (1.04-1.21)	**1.33 (1.20-1.48)**	0.73 (0.51-1.03)	**1.71 (1.14-2.57)**	0.93 (0.80-1.08)	0.88 (0.71-1.09)
Area 4	0.99 (0.95-1.03)	1.04 (0.99-1.10)	**0.55 (0.45-0.67)**	0.83 (0.70-1.00)	**0.85 (0.78-0.92)**	0.86 (0.79-0.95)

Bold indicates a statistically significant result

Among infants $\geq$ 20 weeks gestation, a significant proportion non-viable category differences were seen for both blacks and whites, with mortality risk increasing with the proportion of non-viable births. Category differences in early neonatal mortality became more apparent when examining infants $\leq$ 22 weeks gestation. White infants born in category 3 and 4 states were 70% more likely than white infants born in category 1 states to die and black infants in categories 3 and 4 were twice as likely as their counterparts born in category 1 states. Category differences were no longer significant among infants 23-28 weeks gestation, with the exception of whites in category 4 states (RR=1.27; 1.16-1.38). Adjustment for gestational week did not alter the findings.

Table 3.10. Proportion Non-Viable Differences in Risk of Race-Specific Early Neonatal Mortality, United States 2000-2002.

Mortality Risk	Gestational Age ≥ 20 weeks		Gestational Age ≤ 22 weeks		Gestational Age 23-28 weeks	
	White	Black	White	Black	White	Black
Category 1	1.00	1.00	1.00	1.00	1.00	1.00
Category 2	1.10 (1.05-1.14)	**1.20 (1.10-1.32)**	**1.40 (1.18-1.66)**	**1.56 (1.18-2.06)**	1.16 (1.06-1.26)	1.18 (1.00-1.40)
Category 3	**1.16 (1.11-1.20)**	**1.47 (1.37-1.58)**	**1.65 (1.40-1.95)**	**2.01 (1.64-2.48)**	1.13 (1.04-1.23)	1.20 (1.05-1.36)
Category 4	**1.22 (1.17-1.27)**	**1.59 (1.49-1.70)**	**1.71 (1.43-2.04)**	**2.05 (1.68-2.50)**	**1.27 (1.16-1.38)**	1.23 (1.08-1.39)

Bold indicates a statistically significant result
Category 1 = <500 grams: 0.03-0.09%; <23 weeks: 0.04-0.10%
Category 2 = <500 grams: 0.10-0.12%; <23 weeks: 0.10-0.12%
Category 3 = <500 grams: 0.12-0.16%; <23 weeks: 0.13-0.16%
Category 4 = <500 grams: 0.16-0.33%;<23 weeks: 0.17-0.37%

3.5 Discussion

This study was designed to determine the extent to which differences in fetal death reporting requirements and the proportion of non-viable births influence absolute and relative disparities in infant, early and late neonatal, postneonatal, and fetal mortality rates. Fetal death registration area differences in the restrictiveness of reporting were hypothesized to especially influence mortality rates among extremely preterm infants with low survival rates [89]. In addition, since black infants are more likely to be born at extremely preterm gestations, we explored the possibility that higher infant mortality rates among black infants were due in part to systematic differences in the reporting of extremely preterm live births and fetal deaths by registration area.

3.5.1 Fetal death registration area

Similar to other studies, our results demonstrated persistent racial disparities in overall infant, early and late neonatal, postneonatal and fetal mortality rates [29, 36, 90-92]. Fetal death registration area 3, with birthweight only criteria, had the highest mortality rates, while fetal death registration area 1, which reported all products of conception, had the lowest mortality rates and disparities. In contrast, the highest fetal mortality rates were found among infants in registration area 1, while the lowest fetal mortality rates seen in fetal death classification area 3. The complementary high infant mortality rates and low fetal mortality rates in area 3 suggest that fetal death registration area differences in mortality rates were largely due to differences in reporting infants as a live birth and subsequent infant death (ie. area 3) versus reporting as a fetal death (ie. area 1).

Both absolute and relative disparity measures demonstrated similar patterns with the highest infant disparities seen in fetal death registration area 3 and highest fetal disparities seen in fetal death registration area 1. While both absolute and relative disparity measures demonstrated similar findings by time at death (ie. early neonatal), the absolute disparity difference was more sensitive to variation in registration area disparities. Variation in disparity measure sensitivity was largely due to the size of mortality rates, with the DD more sensitive to high overall mortality rates and the DR more sensitive to lower overall mortality rates.

Although there were only a small number of live births with missing information on gestational age, sizable registration area differences in mortality rates and disparity measures were noted. The highest disparities were seen among infants born in registration area 4 which required gestational age specific information. Wen et al also found increases in racial disparities among infants missing birthweight and/or gestational age information [93], although authors did not examine fetal death registration area differences. These results suggest that either a) black infants missing information on gestational age were more likely than their white counterparts to be reported as an infant death than a fetal death in certain classification areas or, more likely, b) black infants who died were less likely than white infants to have gestational age or birthweight recorded.

Black infants, who have higher rates of extremely preterm birth, [91, 92, 94, 95], also had a slight survival advantage at extremely preterm gestations. This survival advantage, however, was not present in all fetal death registration areas. Black infants ≤22 weeks gestation who were born in fetal death registration area 3 had early neonatal mortality rates which were slightly higher than their white counterparts. This lack of a black survival advantage among infants ≤22 weeks gestation in registration area 3 could partially account for the higher absolute and relative disparities seen in this fetal death registration area. Corresponding to this was the finding of much lower relative and absolute fetal death disparities in fetal death registration area 3. In fact, both black and white fetal mortality rates were lower in registration area 3 than in the other registration areas. Seemingly, states within fetal death registration area 3 were more likely to report births ≤22 weeks gestation as infant births and subsequent infant deaths than as fetal deaths (as did the other fetal death registration areas). In order to determine if lower fetal mortality rates in area 3 states which strictly required birthweight information could be accounted for by a higher proportion of extremely low birthweight births [60, 67, 92], we examined the percentage of extremely low birthweight births by fetal death registration area (results not shown). No fetal death registration area differences were seen in the percentage of births <500 grams or between 500 and 1000 grams.

In early neonatal predictive models, the effect of fetal death registration area on mortality risk differed by gestational age at birth and race, with the largest differences seen among infants ≤ 22 weeks gestation. Black infants ≤ 22 weeks gestation who were born in fetal death registration area 3 were at significantly increased risk of mortality, while white infants in this same area were at decreased risk of mortality. In comparison to blacks in other fetal death registration areas, mortality rates among black infants in fetal death registration 3 were unusually high and accounted for much of the disparity among states in fetal death registration area 3.

3.5.2 Proportion of non-viable births

With respect to the proportion of non-viable births, the highest mortality rates and disparities were among infants born in category 4 states, which had the highest proportion of non-viable births. Unlike the results seen by fetal death registration area, similar results were seen among fetal deaths, with the highest fetal mortality rates also seen in category 4 states. The parallel of high infant mortality rates and high fetal mortality rates within category 4 leads to the conclusion that proportion non-viable category differences in mortality rates are not caused solely by differences in reporting.

Relative and absolute disparity measures demonstrated similar results with the highest disparities found among infant and fetal deaths in category 4. Other studies have found similar results with the proportion of extremely low birthweight infants predicting both IM rates [74], and racial disparities in IM [95]. When examining the race specific risk of mortality by the proportion non-viable births, category differences among both races were found to primarily reflect differences in mortality risk among infants ≤ 22 weeks gestation. Causes for race-specific proportion non-viable category differences in mortality risk are unknown, especially after adjustment for gestational age (which did not alter the findings). These category differences were most prominent among black infants, which likely led to higher disparities in category 4.

3.5.3 Racial differences in fetal deaths

The question of whether lower black fetal mortality rates are real or a result of racial differences in reporting has been the cause of some debate [36, 43, 60, 96]. Wingate et al found some evidence of underreporting among blacks with black infants in their national study 20% less likely than white infants to be classified as a fetal death versus an early neonatal or neonatal death. But, they conclude there is little evidence that black-white differences in mortality are a function of racial differences in classification of fetal deaths and live births [43]. Cai et al found that fetal mortality rates among blacks <

28 weeks gestation and those < 1,000 grams were significantly lower than their white counterparts, but they attribute this to the formula used to calculate fetal mortality rates [60]. Specifically, the denominator to calculate fetal mortality rates consists of the total number of births at a specific gestational age + the number of fetal deaths. Since black infants are more likely to be born at extremely preterm gestations, they have a larger denominator, and a subsequently lower fetal mortality rate. This is the main argument for the fetuses at risk approach, first introduced by Yudkin [97]. On the other hand, Allen et al found that black fetal mortality rates were 2.5 times the fetal mortality rate of whites (95% CI = 2.2-2.9). This relationship did not remain after adjustment for gestational age (RR = 1.2;0.9-1.4) [96]. We were unable to find any studies which examined fetal death reporting requirements in relation to mortality or racial disparities in mortality.

Findings of lower black fetal mortality rates < 28 weeks suggest that there are two sets of factors which lead to racial disparities in infant mortality which act at different times (ie. before 28 weeks gestation and after 28 weeks gestation). For example, the first set puts black infants at greater risk for being born extremely preterm. Extreme prematurity accounts for largest proportion of the black/white disparity in infant mortality [91, 92, 94, 95]. However, for those fetuses who remain in utero 23-28 weeks gestation, there did not appear to be an excess fetal mortality risk among blacks (tables 6 and 8). This leads to the second factor which acts sometime after 28 weeks and puts blacks at twice the mortality risk as whites both in utero and after birth (results not shown). This is reinforced by the finding that among fetal deaths >28 weeks, there doesn't appear to be registration area differences in relative disparity.

3.5.4 Limitations of Study

The findings of this study were subject to several limitations. First, by definition, fetal deaths were truncated at ≥20 weeks gestation; with any deaths before 20 weeks gestation classified as a miscarriage. Due to this left censoring, any disparities which occurred before 20 weeks gestation were not measured in this study. Although some miscarriages (<20 weeks gestation) were available for analysis, their inclusion could have introduced bias because of possible confusion with late abortion, along with the limited sample of mothers who present to hospitals after a miscarriage. Second, due to small sample sizes, the original eight fetal death classification areas were consolidated into four which were though to reflect differences in restrictiveness between areas. The consolidation of registration areas may have attenuated any differences which could have been more visible between the original eight fetal death classification areas. Third, due to black/white differences in rates of preterm birth and subsequent denominators, racial differences in fetal mortality rates should be interpreted with caution. This is especially the case at extremely preterm gestations. Finally, excluding cases which were missing information on race could have biased our results in light of the registration area differences in mortality rates and disparity ratios by unknown gestational age and/or birthweight categories. The basic hypothesis of this study was that fetal death registration and proportion non-viable category differences would influence racial differences in mortality. Since there were not official race requirements for each registration area, excluding records with missing information on race was unlikely to differentially influence mortality rates.

3.5.5 Strengths of Study

Despite these limitations, this study had several strengths. First, it made use of national vital statistics data to determine if differences in fetal death reporting requirements and the proportion of non-viable births influenced area differences in mortality rates and disparity ratios. Second, it is the only study of its kind to examine the effect of fetal death registration requirements on racial disparities in infant, early and late neonatal, postneonatal and/or fetal mortality. Third, it made use of both absolute and relative disparity measures, which were found to vary in their sensitivity to registration area differences. Finally, biologically relevant gestational age stratification was used to determine if any area or category differences were due to actual reporting or due to differences in extremely preterm birth rates.

3.6 Conclusion

Overall, registration area differences and proportion non-viable differences in mortality rates, absolute disparities and relative disparities were most pronounced among infants ≤ 22 weeks gestation. Although significant area and classification differences were seen among both races, differences were most prominent among black infants. Findings of proportion non-viable category similarities among infant and fetal deaths indicated real category differences in not only the proportion of at-risk infants born (ie. extremely preterm/low birthweight) but also in racial disparities between proportion non-viable categories. Absolute disparities as measured by the DD were most sensitive to area differences in disparities, especially when mortality rates were high.

State differences in fetal death reporting requirements lead to differences in the reported number of live births, infant deaths and fetal deaths. These differences persist even after limiting data to gestations which should be reported by all states. In order for national vital statistics data to be meaningful, a uniform definition of fetal death must be adopted. This would reduce systematic differences in the reporting of live births and fetal deaths and give an accurate record of state mortality rates and disparities.

Future studies should examine proportion non-viable differences in relative and absolute disparities. Studies should also examine registration area differences in the continuum of miscarriages, fetal deaths and early neonatal deaths. Racial disparities in infant mortality have persisted throughout the last century; determining what proportion of the disparity is due to statistical artifact and versus an actual excess in deaths is critical to solving the problem.

CHAPTER 4: RACIAL DIFFERENCES IN THE EFFECT OF PERINATAL REGIONALIZATION ON RACIAL DISPARITIES IN INFANT AND NEONATAL MORTALITY, MICHIGAN 1996-2006

This chapter includes an examination of racial patterns of birth hospital level and neonatal intensive care unit (NICU) transfer among preterm infants in Michigan. It also explores the subsequent effect on racial disparities in infant and neonatal mortality and is study 3 for this three paper dissertation option.

4.1 Abstract

Objective: We examined patterns of perinatal regionalization (birth hospital level and neonatal intensive care unit (NICU) transfer) among preterm infants in Michigan and the subsequent effect on racial disparities in infant and neonatal mortality.

Methods: Michigan Department of Community Health Vital Records on singleton, preterm (<37 weeks) live births and infant deaths between 1996 and 2006 (n=107,046 preterm births and 3,950 infant deaths) were used to examine patterns of perinatal regionalization and mortality (infant and neonatal). Perinatal regionalization measures and mortality rates were examined by race (non-Hispanic white and non-Hispanic black) and preterm gestational week. The adjusted relative risk of black infant death (with whites as the reference category) was examined using logistic regression.

Results: The majority of infants were born at a level 3 hospital (preterm white 62.8% vs. black 85.3%; very preterm white 83.1 vs. black 91.3% extremely preterm white 83.0% vs. black 89.9%). The highest infant mortality rates were seen among extremely preterm infants born at level 1 hospitals (465.3 per 1,000 live births) compared to their level 3 counterparts (336.9 per 1,000 live births) and among extremely preterm level 1 white births (506.1 per 1,000 live births) compared to their black counterparts (383.3 per

1,000 live births). Gestational week specific analyses revealed different race-specific effects of hospital level at birth on mortality, with the largest racial differences seen between 23-28 weeks gestation. After adjustment for demographic and hospital characteristics, extremely preterm, level 3, black infants who were transferred to the NICU had an increased risk of infant death compared to their white counterparts (RR=1.25 95% CI=1.07-1.45), while extremely preterm, level 1, black infants who were transferred to the NICU had a significantly decreased risk of infant death, compared to their white counterparts (RR=0.41 95% CI=0.26-0.66).

Conclusion: Racial disparities in preterm mortality differ by gestational week and hospital level at birth. Efforts should be made to reduce rates of extremely preterm birth where mortality rates and racial disparities in risk of adjusted mortality were the highest.

4.2 Introduction

4.2.1 Background on infant and neonatal mortality

The infant mortality rate (number of infant deaths <1 year of age per 1,000 live births) is commonly used to assess the health and well-being of populations between and within countries [63]. Depending on the time at which infant mortality occurs, it can be categorized as neonatal mortality or postneonatal mortality. Neonatal mortality (infant death between 1 and <28 days) accounts for two thirds of all infant mortality and is primarily related to exposures and conditions related to pregnancy and soon after birth, such as medical care. As a result, very preterm (<32 weeks gestation) and extremely preterm births (<28 weeks gestation) account for the majority of deaths during this time period [98]. Due to improvements in medical technology and neonatal care (ie. mechanical ventilation) [99], and more recently the introduction and use of surfactant therapy and antenatal steroids for extremely preterm infants [11]) the U.S. has seen significant declines in birthweight-specific infant and neonatal mortality rates over the years. For example, from 1980 to 2004, the U.S. infant mortality rate declined 46% from 12.6 to 6.8 infant deaths per 1,000 live births [1, 2].

4.2.2 Racial disparities in infant and neonatal mortality

Despite this decline and improved care for extremely preterm infants, the infant mortality gap between black and white infants in the U.S. has increased [1]. For example, in 1980, the IM rate among whites in the United States was 8.7 per 1,000 live births compared to an IM rate of 16.5 per 1,000 live births among blacks [4], meaning blacks were 1.90 times as likely as white infants to die during the first year of life. On the other hand in 2005, the white IM rate was 5.7 per 1,000 live births compared to the black IM rate of 13.6 per 1,000 live births among black infants, meaning blacks were 2.39 times as likely as whites to die during the first year of life. Studies have shown that a large portion of the excess mortality among black infants is due to higher rates of extremely preterm birth and the subsequent neonatal mortality of black infants [46, 74].

4.2.3 Perinatal regionalization

Extremely preterm infants born in hospitals with neonatal intensive care units (NICU) or transferred to such centers immediately after birth have lower mortality and morbidity rates than comparable infants born in other settings [47]. The process of perinatal regionalization involves a “regionally coordinated system focusing on levels of hospital-based perinatal care” and has been shown to improve outcomes for both mothers and newborns [48]. Perinatal regionalization incorporates the use of maternal and/or infant transport services to ensure that low birthweight or at-risk infants are inborn or promptly transferred to appropriate facilities (preferably with NICUs), regardless of where their mother initially sought obstetrical care [49]. This system evolved to increase the number of mothers and infants who had access to neonatologists, obstetricians and pediatricians. Furthermore perinatal regionalization offered improved health care for mothers and infants and has been adopted by many states and hospital systems [50].

In 1976, the March of Dimes Committee on Perinatal Health designated three levels of perinatal care. The three basic levels as described in the latest American Academy of Pediatrics (AAP)/American College of Obstetricians and Gynecologists (ACOG) guidelines are as follows: level 1 hospitals are able to treat newborns without obstetric complications and do not have a NICU; level 2 hospitals are able to treat moderately ill newborns and they may or may not have a NICU; level 3 hospitals always have a NICU and are able to treat the highest risk infants [48]. Recently, level 2 and level 3 hospitals have been further categorized by factors such as the volume of extremely preterm infants and/or the number of NICU beds [51]. Alternatively some states, such as Michigan, recognize only two levels of care, bypassing the intermediate (level 2) category [52].

The effectiveness of perinatal regionalization can be determined by examining the proportion of extremely preterm, low birthweight infants which are born at a level 3 hospital or by examining the proportion of extremely preterm, low birthweight infants which are transferred to a NICU after birth [53-56].

Throughout the 1990s, increases in the number of smaller, community NICUs with 1 or 2 neonatologists has led to breakdowns in the cooperative relationships between the less specialized level 1and level 2 hospitals and the most specialized level 3 facilities [57]. Furthermore, decreases in state funding of the regionalized transport of mothers and infants as well as decreases in insurance funding of level 3 care (when less expensive level 2 care is available) has led to de-regionalization in many states (ie. Michigan). This de-regionalization is thought to have the largest effect on lower socioeconomic groups with limited access to level 3 hospitals [39]. With the disproportionate representation of racial/ethnic minorities in lower socioeconomic groups, perinatal de-regionalization could impact racial disparities in infant and neonatal mortality rates. In addition, state-level differences in regionalization funding could account for state differences in preterm or low birthweight infant and neonatal mortality rates. While some studies have examined the effect of perinatal regionalization on infant and neonatal mortality rates, it is not clear whether racial differences in mortality can be partially explained by differences in access to medical care for high risk neonates.

4.2.4 Study Objective

We examined patterns of race-specific perinatal regionalization among preterm births in Michigan and the effect of perinatal regionalization on subsequent risk of infant and neonatal mortality. Specifically, racial differences were estimated in the following:

1) preterm infant and neonatal mortality rates;
2) hospital level at birth and access to NICU treatment;
3) the hospital level distribution of access to NICU treatment; and
4) the effect of hospital level at birth and access to NICU treatment on infant and neonatal mortality.

Michigan was chosen due to its high infant mortality rate (Michigan = 6.9 per 1,000 live births vs. United States = 6.1 per 1,000 live births), high racial disparities in IM (Michigan disparity ratio = 2.8 and risk differences = 9.4 per 1,000 live births vs. United

States disparity ratio = 2.4 and risk differences = 6.9 1,000 live births) and because of the historical existence of a well-defined perinatal regionalization system in the 1980s and 1990s [56].

4.3 Materials and Methods

We examined Michigan live birth and linked infant death data from 1996-2006. All preterm (gestational age <37 weeks) live births and infant deaths to non-Hispanic white and non-Hispanic black (herein referred to as white and black), maternal residents of Michigan were included.

4.3.1 Data Source

Live birth and infant death certificates were obtained from the Vital Records and Health Data Development Section of the Michigan Department of Community Heath (MDCH). Data were coded according to uniform coding specifications, passed rigid quality control standards, were edited and reviewed and are the basis for official Michigan birth and death statistics. Cohort mortality data for each of the years were used, as opposed to period data, which links deaths of all infants born in a certain year, regardless to whether the death occurred during the birth year, or the following year. Birth cohort data files were preferred because they follow a given cohort of births for an entire year to ascertain mortality-specific information. Birth certificates included information on hospital at birth, maternal demographic and pregnancy characteristics and infant characteristics at birth.

4.3.2 Outcome Variables

Crude infant mortality (death within the first year) and neonatal mortality (death within the first month) rates were calculated, in addition to those stratified by race and gestational week. Gestational age data were based on the clinical estimate of gestation and were classified as preterm, defined as <37 completed weeks gestation, very preterm, defined as <32 completed weeks gestation, and extremely preterm, defined as <28 weeks gestation.

4.3.3 Exposure Variables

Perinatal regionalization was determined by two variables obtained from the birth certificate: hospital level at birth (level 1 vs. level 3) and infant transport to a NICU (yes vs. no). We assigned of hospital level at birth based on the availability of a NICU, at any point during the 11 year study period. Hospitals which had a NICU during the study period were designated level 3, while hospitals which did not have a NICU during the study period were designated level 1. In rare instances where hospital level could not be obtained from the MDCH, hospital obstetrics departments were contacted by telephone and asked if they had a NICU at any point in time from 1996-2006. Three hospitals were contacted directly; one was designated level 3, white the other two were designated level 1. NICU transfer was based on the birth certificate question: "Was the child transferred to a neonatal intensive care unit?". Response options were yes, no and unknown. Demographic third variables examined in addition the main exposures were obtained from birth certificate records and included maternal factors: education (less than high school, high school diploma, some college, college degree, graduate school or unknown), age (less than 20 years, 20-29 years, 30-39 years, 40-49 years, 50+ years, or unknown), smoking during pregnancy (yes, no or unknown), alcohol use during pregnancy (yes, no or unknown), adequacy of prenatal care (adequate, intermediate, inadequate or unknown), and urbanicity (rural, micropolitan or metropolitan); and infant factors: sex (male, female or unknown) and infant birthweight (500-999, 1000-1499, 1500-1999, 2000-2499, and 2500+).

4.3.4 Exclusion Criteria

To prevent possible bias in the registration of live births or fetal deaths by hospital, the following exclusions were made in a sequential manner: birthweight < 500 grams (n=2,582) and gestational age < 20 completed weeks (n=314). Furthermore, records missing information on main exposures of interest: NICU transfer (n=703) and hospital of birth (n=1,026) were also excluded. Before exclusions there were 111,671 singleton, preterm births to black and white women in Michigan, the final dataset contained 107,046 preterm births to black and white women.

4.3.5 Statistical Analysis

All statistical analyses were carried out using SAS version 9.1.3. We first examined the distribution of maternal and infant demographic characteristics, preterm birth rates, and perinatal regionalization measures. Second, the proportion of NICU transfers by birth hospital level were calculated to establish if variation in access to NICU treatment existed by hospital level at birth. Third, in order to determine if mortality differed by hospital level at birth or by access to NICU treatment, mortality rates were calculated by hospital level at birth and by NICU transfer. Crude and race-specific analyses were carried out to establish if regionalization patterns in Michigan differed by race. Statistically significant racial differences in exposures and outcomes of interest were quantified by the Mantel Hanzel chi-square test. Differences were considered statistically significant at the p-value <0.05 level. Finally, logistic regression was used to determine the effect of hospital level at birth and NICU transfer on mortality risk, after adjustment for demographic factors.

Relative differences in gestational age specific mortality risk between white and black infants were quantified using the relative risk and statistical significance was determined with a 95% confidence interval. White infants were used as the referent category. All statistical analyses were conducted using SAS version 9.1.3.

4.4 Results

4.4.1 Maternal and infant demographic characteristics among preterm infants

During the study period, there were 107,046 preterm births with 76,044 (71.0%) to white women and 31,022 (29.0%) to black women. The majority of mothers had a high school degree (33.9%), were between the ages of 20 and 29 (50.7%) and had adequate prenatal care (66.7%). Smoking during pregnancy was prevalent in 20.0% of all preterm births, while alcohol use during pregnancy was prevalent in 1.4% of all preterm births. The majority of preterm infants were male (53.6%) and had a normal birthweight of >2500 grams (50%).

Racial differences in the prevalence of numerous maternal characteristics were apparent. Mothers of black preterm infants more likely than their white counterparts to have less than a high school degree (31.4% vs. 17.5%), a teen pregnancy (19.2% vs. 10.5%), consume alcohol during the pregnancy (2.4% vs. 1.0%) and have inadequate prenatal care (25% vs. 10.1%). Black infants were significantly more likely than their white counterparts to be born in a metropolitan county (99.7% vs. 87.7%), with only 12 black preterm births in rural counties over the 11 year period. With respect to sex, the proportion of black preterm births were evenly split between males and females, while among whites, 55% of all preterm births were male. More than half of white preterm births were normal birthweight (54.8%) vs. 38% of black preterm births. Furthermore, black infants were more than twice as likely as their white counterparts to weigh 500-999 grams (10.1% vs. 4.4%, respectively) (table 4.1).

Table 4.1. Maternal and infant demographic characteristics by race among preterm infants, Michigan 1996-2006

Maternal Characteristics	Total n=107,046		White n=76,044 (71.0)		Black n=31,022 (29.0)		p-value
Maternal Characteristics							
Education							<0.0001
< High School	23,018	21.5	13,283	17.5	9,735	31.4	
High School Degree	36,307	33.9	25,070	33.0	11,237	36.3	
Some College	24,306	22.7	17,762	23.4	6,544	21.1	
College Degree	13,238	12.4	11,683	15.4	1,555	5.0	
> College	8,026	7.5	7,118	9.4	908	2.9	
Unknown	2,151	2.0	1,128	1.5	1,023	3.3	
Maternal Age							<0.0001
<20	13,912	13.0	7,972	10.5	5,940	19.2	
20-29	54,308	50.7	38,429	50.5	15,879	51.2	
30-39	35,934	33.6	27,545	36.2	8,389	27.1	
40+	2,889	2.7	2096	2.8	793	2.6	
Unknown	3	0.0	2	0.0	1	0.0	
Smoking During Pregnancy							0.4956
Yes	21,391	20.0	15,319	20.1	6,072	19.6	
No	83,972	78.4	59,526	78.3	24,446	78.9	
Unknown	1,683	1.6	1,199	1.6	484	1.6	
Alcohol Use During Pregnancy							0.0030
Yes	1,468	1.4	731	1.0	737	2.4	
No	103,777	97.0	74,021	97.3	29,756	96.0	
Unknown	1,801	1.7	1,292	1.7	509	1.6	
Kessner Prenatal Care Index							<0.0001
Adequate	71,350	66.7	55,220	72.6	16,130	52.0	
Intermediate	19,629	18.3	12,731	16.7	6,898	22.3	
Inadequate	15,437	14.4	7,688	10.1	7,749	25.0	
Unknown	630	0.6	405	0.5	225	35.7	
Urbanicity (County of birth)							<0.0001
Rural	2812	2.6	2797	4.7	12	0.1	
Micropolitan	6624	6.2	6530	8.6	94	0.3	
Metropolitan	97587	91.2	66694	87.7	30893	99.7	

Table 4.1 (continued). Maternal and infant demographic characteristics by race among preterm infants, Michigan 1996-2006

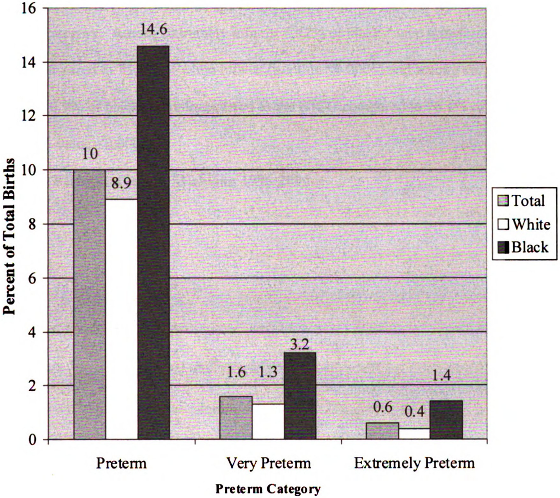
Infant Characteristics							
Sex							<0.0001
Male	57,411	53.6	41,663	54.8	15,748	50.8	
Female	49,631	46.4	34,378	45.2	15,253	49.2	
Unknown	4	0.0	3	0.0	1	0.0	
Birthweight							<0.0001
500-999	6,155	5.8	3,332	4.4	2,823	10.1	
1000-1499	7,101	6.6	4,255	5.6	2,846	9.2	
1500-1999	12,965	12.1	8,166	10.7	4,799	15.5	
2000-2499	27,357	25.6	18,616	24.5	8,741	28.2	
2500 +	53,466	50.0	41,673	54.8	11,793	38.0	

4.4.2 Rates of preterm birth

Figure 1 shows racial differences in rates of preterm birth during the study period. Significant racial differences were seen in each preterm category with black infants 1.6 times as likely as whites to experience preterm birth (p-value <0.0001), 2.5 times as likely as whites to experience very preterm birth (p-value <0.0001), and 3.5 times as likely as white infants to experience extremely birth (p-value

<0.0001).

Figure 4.1. Rates of preterm birth by race, Michigan 1996-2006



4.4.3 Perinatal regionalization

Rates of hospital level at birth and NICU transfer are shown in table 4.2. The majority of preterm, very preterm and extremely infants were born at a level 3 hospital (69.3%, 86.5%, and 86.2%, respectively). In race-specific analyses, black infants were significantly more likely than their white counterparts to be born at a level 3 hospital. This relationship was seen across gestational categories.

The majority of extremely and very preterm infants were transferred to a NICU after birth (79.2% and 78.1%, respectively). Despite this trend, significant racial differences in the proportion of infants transferred to the NICU were seen within each preterm category. Among extremely infants, 83.2% of blacks were transferred to the NICU compared to 75.8% of white infants (p-value <0.0001) and among very preterm infants, 80.9% of blacks were transferred to the NICU compared to 76.1% of white infants (p-value <0.0001).

Figure 4.2 Hospital levels, Michigan 1996-2006.

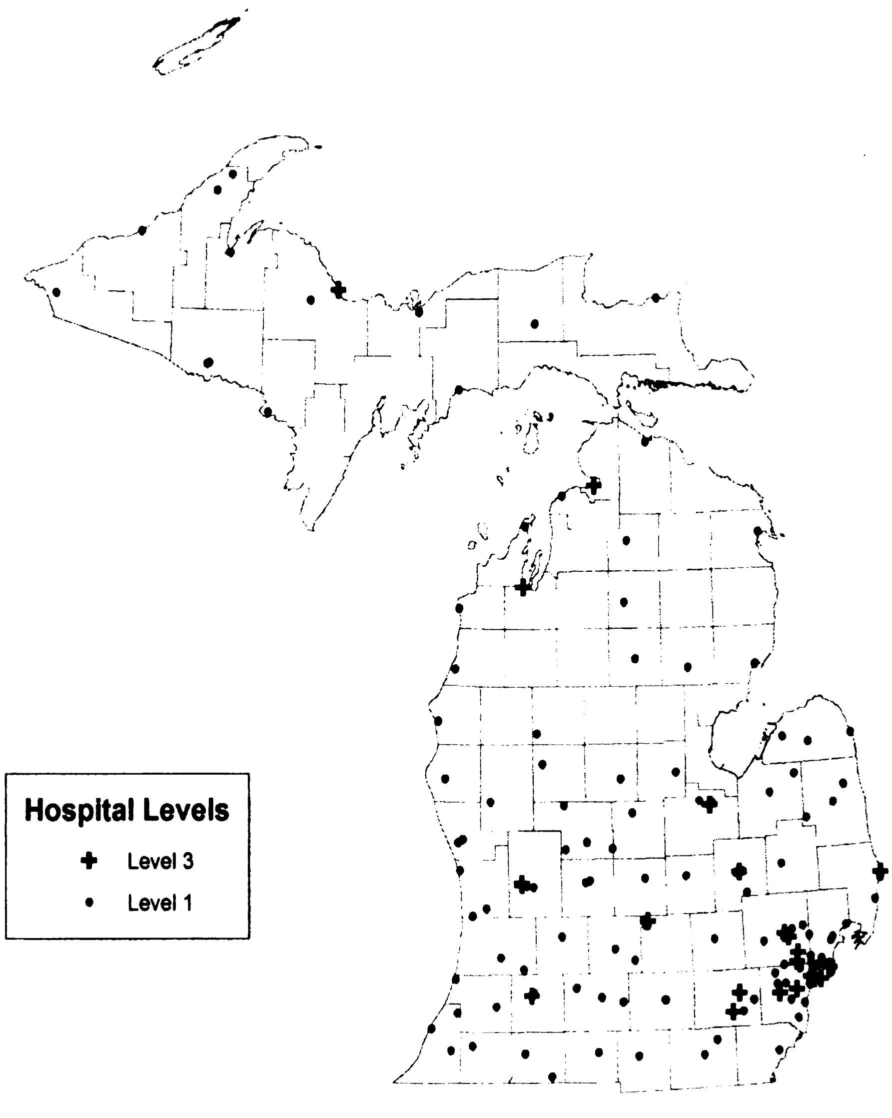


Table 4.2. Hospital level at birth and NICU transfer by race among preterm infants, Michigan 1996-2006

Regionalization Measures	Total n=137,702 (100%)		White n=100,680 (73.1%)		Black n=37,022 (26.9%)		p value
	N	%	N	%	N	%	
Hospital Level at Birth							
Extremely Preterm Birth: <28 weeks							<0.0001
1	864	13.8	577	17.0	287	10.1	
3	5,382	86.2	2,820	83.0	2,562	89.9	
Total	6,246	100.0	3,397	54.4	2,849	45.6	
Very Preterm Birth: <32 weeks							<0.0001
1	2,148	13.5	1,575	16.9	573	8.7	
3	13,728	86.5	7,732	83.1	5,996	91.3	
Total	15,876	100.0	9,307	58.6	6,569	41.4	
Preterm Birth: <37 weeks							<0.0001
1	32,873	30.7	28,318	37.2	4,555	14.7	
3	74,173	69.3	47,726	62.8	26,447	85.3	
Total	107,046	100.0	76,044	71.0	31,002	23.0	
NICU Transfer							
Extremely Preterm Birth: <28 weeks							<0.0001
Yes	4,946	79.2	2,576	75.8	2,370	83.2	
No	1,300	20.8	821	24.2	479	16.8	
Total	6,246	100.0	3,397	54.4	2,849	45.6	
Very Preterm Birth: <32 weeks							<0.0001
Yes	12,397	78.1	7,083	76.1	5,314	80.9	
No	3,479	21.9	2,224	23.9	1,255	19.1	
Total	15,876	100.0	9,307	58.6	6,569	41.4	
Preterm Birth: <37 weeks							<0.0001
Yes	33,792	31.6	21,981	28.9	11,811	38.1	
No	73,254	68.4	54,063	71.1	19,191	61.9	
Total	107,046	100.0	76,044	71.0	31,002	23.0	

4.4.4 NICU transfer by birth hospital level

In order to determine if racial differences in the proportion preterm infants transferred to a NICU were due to differences in hospital level at birth, table 4.3 includes rates of NICU transfer by birth hospital level and race. The majority of very and extremely preterm infants were transferred to the NICU, regardless of hospital level at birth. Rates of NICU transfer were the highest among very and extremely preterm infants born at a level 3 hospital (80.4% and 82.1%, respectively). In race-specific analyses, black infants were significantly more likely than their white counterparts to be transferred to a NICU. This relationship was seen across preterm category and hospital level at birth, with the largest racial differences seen among extremely preterm births in level 1 hospitals (55.6% vs. 71.8% p-value <0.0001).

Table 4.3. Rates of NICU transfer by hospital level at birth and race among preterm infants, Michigan 1996-2006.

NICU Transfer	Total		White		Black		p value	Total		White		Black		p value
	N	%	N	%	N	%		N	%	N	%	N	%	
Birth Hospital Level 1								Birth Hospital Level 3						
Extremely Preterm Birth: <28 weeks							<0.0001	Extremely Preterm Birth: <28 weeks						<0.0001
Yes	527	61.0	321	55.6	206	71.8		4,419	82.1	2,255	80.0	2,164	84.5	
No	337	39.0	256	44.4	81	28.2		963	17.9	565	20.0	398	15.5	
Total	864	100.0	577	44.4	287	33.2		5,382	100.0	2,820	52.4	2,562	47.6	
Very Preterm Birth: <32 weeks							<0.0001	Very Preterm Birth: <32 weeks						0.0009
Yes	1,360	63.3	943	59.9	417	72.8		11,037	80.4	6,140	79.4	4,897	81.7	
No	788	36.7	632	40.1	156	27.2		2,691	19.6	1,592	20.6	1,099	18.3	
Total	2,148	100.0	1,575	73.3	573	26.7		13,728	100.0	7,732	56.3	5,996	43.7	
Preterm Birth: < 37 weeks							<0.0001	Preterm Birth: < 37 weeks						<0.0001
Yes	5,107	15.5	4,172	14.7	935	20.5		28,685	38.7	17,809	37.3	10,876	41.1	
No	27,766	84.5	24,146	85.3	3,620	79.5		45,488	61.3	29,917	62.7	15,571	58.9	
Total	32,873	100.0	28,318	86.1	4,555	12.9		74,173	100.0	47,726	64.3	26,447	35.7	

4.4.5 Infant and neonatal mortality rates

Table 4.4 includes infant and neonatal mortality rates by gestational category and race. Infant and neonatal mortality rates decreased as gestational ages moved closer to term. Black infants were significantly more likely than white infants to die during the first year of life at very preterm (white=169.5 per 1,000 live births; black=193.5 per 1,000 live births; p-value=0.0001) and preterm (white=30.8 per 1,000 live births; black=51.9 per 1,000 live births; p-value=<0.0001) gestations. Although racial differences in infant mortality were not statistically significant among extremely preterm infants, black infants had lower neonatal mortality rates (268.5 vs. 273.8 per 1,000 live births), and higher infant mortality rates (364.7 per 1,000 live births vs. 346.2 per 1,000 live births) than white infants.

Table 4.4. Infant and neonatal mortality rates (per 1,000 live births) by race among preterm infants, Michigan 1996-2006

Mortality Rates	Total		White		Black		p value
	N	Rate*	N	Rate	N	Rate	
Extremely Preterm Birth: <28 weeks							
Infant Mortality	2,215	354.6	1,176	346.2	1,039	364.7	0.1280
Neonatal Mortality	1,695	271.4	930	273.8	765	268.5	
Live Births	6,246		3,397		2,849		
Very Preterm Birth: <32 weeks							
Infant Mortality	2,849	179.5	1,578	169.5	1,271	193.5	0.0001
Neonatal Mortality	2,055	129.4	1,183	127.1	872	132.7	
Live Births	15,876		9,307		6,569		
Preterm Birth: <37 weeks							
Infant Mortality	3,950	36.9	2,342	30.8	1,608	51.9	<0.0001
Neonatal Mortality	2,646	24.7	1,627	21.4	1,019	32.9	
Live Births	107,046		76,044		31,002		

*Rate per 1,000 live births

In order to determine if race specific differences in infant and neonatal mortality rates were due to an excess of births (and deaths) at earlier gestations, tables 4.5 and 4.6 include gestational week specific infant and neonatal mortality rates by race. In gestational week specific analyses, blacks were at increased risk of infant mortality between 20 and 21 weeks, 27-28 weeks and 34-36 weeks gestation (table 4.5).

Table 4.5. Gestational week specific infant mortality rates (per 1,000 live births) by race among preterm infants, Michigan 1996-2006

Gestational Week	Total			White			Black			Ratio
	Live Births	Infant Deaths	Rate*	Live Births	Infant Deaths	Rate	Live Births	Infant Deaths	Rate	
Extremely Preterm: < 28 weeks										
20	66	40	606.1	34	19	558.8	32	21	656.3	1.2
21	103	92	893.2	60	52	866.7	43	40	930.2	1.1
22	344	308	895.4	180	164	911.1	164	144	878.1	1.0
23	715	496	693.7	364	255	700.6	351	241	686.6	1.0
24	1,055	480	455.0	538	241	448.0	517	239	462.3	1.0
25	1,165	322	276.4	622	174	279.7	543	148	272.6	1.0
26	1,325	272	205.3	742	153	206.2	583	119	204.1	1.0
27	1,402	205	146.2	825	118	143.0	577	87	150.7	1.1
Very Preterm: <32 weeks										
28	1,805	179	99.2	1,055	102	96.7	750	77	102.7	1.1
29	1,849	144	77.9	1,142	97	84.9	707	47	66.5	0.8
30	2,635	163	61.9	1,579	99	62.7	1,056	64	60.6	1.0
31	3,266	148	45.3	2,101	104	49.5	1,165	44	37.8	0.8
Preterm: <37 weeks										
32	4,991	143	28.7	3,247	100	30.8	1,744	43	24.7	0.8
33	6,847	153	22.4	4,602	107	23.3	2,245	46	20.5	0.9
34	12,407	207	16.7	8,697	132	15.2	3,710	75	20.2	1.3
35	21,079	240	11.4	15,454	174	11.3	5,625	66	11.7	1.0
36	45,368	358	7.9	34,467	251	7.3	10,901	107	9.8	1.4

*Rate per 1,000 live births

Black infants were at lower risk of neonatal mortality at each gestational week except among infants born at 20 weeks gestation and infants born at 36 weeks gestation (table 4.6).

Table 4.6. Gestational week specific neonatal mortality rates (per 1,000 live births) by race among preterm infants, Michigan 1996-2006

Gestation Week	Total			White			Black			Ratio
	Live Births	Neonatal Deaths	Rate*	Live Births	Neonatal Deaths	Rate	Live Births	Neonatal Deaths	Rate	
Extremely Preterm: < 28 weeks										
20	66	36	545.5	34	18	529.4	32	18	562.5	1.1
21	103	82	796.1	60	48	800.0	43	34	790.7	1.0
22	344	275	799.4	180	146	811.1	164	129	786.6	1.0
23	715	406	567.8	364	214	587.9	351	192	547.0	0.9
24	1055	340	322.2	538	180	334.6	517	160	309.5	0.9
25	1165	216	185.4	622	123	197.8	543	93	171.3	0.9
26	1325	180	135.9	742	102	137.5	583	78	133.8	1.0
27	1402	129	92.0	825	83	100.6	577	46	79.7	0.8
Very Preterm: <32 weeks										
28	1805	94	52.1	1055	60	56.9	750	34	45.3	0.8
29	1849	91	49.2	1142	68	59.5	707	23	32.5	0.6
30	2635	89	33.8	1579	62	39.3	1056	27	25.6	0.7
31	3266	82	25.1	2101	62	29.5	1165	20	17.2	0.6
Preterm: <37 weeks										
32	4991	87	17.4	3247	64	19.7	1744	23	13.2	0.7
33	6847	93	13.6	4602	70	15.2	2245	23	10.2	0.7
34	12407	122	9.8	8697	87	10.0	3710	35	9.4	0.9
35	21079	115	5.5	15454	96	6.2	5625	19	3.4	0.5
36	45368	167	3.7	34467	124	3.6	10901	43	3.9	1.1

*Rate per 1,000 live births

4.4.6 Infant mortality by birth hospital level

In order to determine if racial disparities in infant and neonatal mortality rates were due to differences in perinatal regionalization, table 4.7 examines infant and neonatal mortality rates by hospital level at birth. Hospital level differences in mortality rates were seen across gestational categories, with extremely and very preterm level 1 infants experiencing the highest rates. For example, the very preterm infant mortality rate was 234.4 per 1,000 live births among infants born in a level 1 hospital, compared to the infant mortality rate of 170.8 per 1,000 live births among infants born in a level 3 hospital. The most striking infant mortality rates were seen among extremely preterm, white infants, who experienced a 50% infant mortality rate if they were born at a level 1 hospital, compared to a 31% infant mortality rate if they were born in a level 3 hospital. Within race-specific analyses, black infants had significantly higher infant mortality rates than white infants of similar gestational ages. This relationship was seen across hospital level at birth.

Table 4.7. Infant and neonatal mortality rates (per 1,000 live births) by hospital level at birth and race among preterm infants, Michigan 1996-2006.

Mortality Rates	Total		White		Black		p value	Total		White		Black		p value
	N	Rate*	N	Rate	N	Rate		N	Rate	N	Rate	N	Rate	
	Birth Hospital Level 1							Birth Hospital Level 3						
Extremely Preterm Birth: <28 weeks								Extremely Preterm Birth: <28 weeks						
Infant	402	465.3	292	506.1	110	383.3	0.0007	1,813	336.9	884	313.5	929	362.6	0.0001
Neonatal	336	388.9	249	431.5	87	303.1		1359	252.5	681	241.4	678	264.6	
Live Births	864		577		287			5,382		2,820		2,562		
Very Preterm Birth: <32 weeks								Very Preterm Birth: <32 weeks						
Infant	504	234.6	368	233.7	136	237.3	0.8581	2,345	170.8	1,210	156.5	1,135	189.3	<0.0001
Neonatal	399	185.8	298	189.2	101	176.3		1695	123.4	894	115.6	801	133.6	
Live Births	2,148		1,575		573			13,728		7,732		5,996		
Preterm Birth: <37 weeks								Preterm Birth: <37 weeks						
Infant	788	24.0	603	21.3	185	40.6	<0.0001	3,162	42.6	1,739	36.4	1,423	53.8	<0.0001
Neonatal	544	16.5	420	14.8	124	27.2		2,102	28.3	1,207	25.3	895	33.8	
Live Births	32,873		28,318		4,555			74,173		47,726		26,447		

*Rate per 1,000 live births

Gestational week specific mortality analyses by hospital level at birth were undertaken to determine if hospital level infant and neonatal mortality rates differed by gestational week. Tables 4.8 and 4.9 show race-specific infant mortality rates among level 1 and level 3 births. Overall, race-specific mortality rates were comparable among level 3 births, as opposed to the race-specific mortality rates among level 1 births. The higher rates of extremely preterm mortality among white, level 1 infants in table 7 were due to decreased white survival among births between 23-27 weeks gestation. On the other hand, the higher rates of extremely preterm mortality among level 3 black births were due decreased black survival during the same gestations. In fact, compared to black level 1 births, birth at a level 3 hospital increased the risk of black infant mortality between 23-27 weeks. On the other hand, white level 3 infants between 23-27 weeks had lower mortality rates than their level 1 counterparts. Similar patterns were seen among level 1 and level 3 neonatal mortality rates (tables 4.10 and 4.11, respectively).

Table 4.8. Gestational week specific infant mortality rates among level 1 births by race, Michigan 1996-2006.

Gestational Week	Total			White			Black			Ratio
	Live Births	Infant Deaths	Rate*	Live Births	Infant Deaths	Rate	Live Births	Infant Deaths	Rate	
Extremely Preterm: < 28 weeks										
20	21	13	619.1	15	8	533.3	6	5	833.3	1.6
21	15	13	866.7	12	10	833.3	3	3	1000.0	1.2
22	68	63	926.5	53	48	905.7	15	15	1000.0	1.1
23	85	59	694.1	55	44	800.0	30	15	500.0	0.6
24	134	75	559.7	85	55	647.1	49	20	408.2	0.6
25	137	56	408.8	90	39	433.3	47	17	361.7	0.8
26	160	45	281.3	116	39	336.2	44	6	136.4	0.4
27	173	38	219.7	119	30	252.1	54	8	148.2	0.6
Very Preterm: <32 weeks										
28	206	23	111.7	152	14	92.1	54	9	166.7	1.8
29	233	20	85.8	190	16	84.2	43	4	93.0	1.1
30	329	25	76.0	261	21	80.5	68	4	58.8	0.7
31	441	27	61.2	362	23	63.5	79	4	50.6	0.8
Preterm: <37 weeks										
32	824	30	36.4	657	21	32.0	167	9	53.9	1.7
33	1,196	30	25.1	998	26	26.1	198	4	20.2	0.8
34	3,040	45	14.8	2,586	37	14.3	454	8	17.6	1.2
35	7,173	60	8.4	6,247	52	8.3	926	8	8.6	1.0
36	18,014	105	5.8	15,985	92	5.8	2,029	13	6.4	1.1

*Rate per 1,000 live births

Table 4.9. Gestational week specific infant mortality rates among level 3 births by race, Michigan 1996-2006.

Gestational Week	Total			White			Black			Ratio
	Live Births	Infant Deaths	Rate*	Live Births	Infant Deaths	Rate	Live Births	Infant Deaths	Rate	
Extremely Preterm: < 28 weeks										
20	45	27	600.0	19	11	579.0	26	16	615.4	1.1
21	88	77	875.0	48	41	854.2	40	36	900.0	1.1
22	276	239	866.0	127	111	874.0	149	128	859.1	1.0
23	360	353	980.6	309	209	676.4	321	222	691.6	1.0
24	921	393	426.7	453	179	395.1	468	214	457.3	1.2
25	1,028	260	252.9	532	134	251.9	496	126	254.0	1.0
26	1,165	221	189.7	626	112	178.9	539	109	202.2	1.1
27	1,229	165	134.3	706	87	123.2	523	78	149.1	1.2
Very Preterm: <32 weeks										
28	1,599	154	96.3	903	88	97.5	696	66	94.8	1.0
29	1,616	122	75.5	952	80	84.0	664	42	63.3	0.8
30	2,306	136	59.0	1,318	77	58.4	988	59	59.7	1.0
31	2,825	120	42.5	1,739	81	46.6	1,086	39	35.9	0.8
Preterm: <37 weeks										
32	4,167	112	26.9	2,590	79	30.5	1,577	33	20.9	0.7
33	5,651	122	21.6	3,604	81	22.5	2,047	41	20.0	0.9
34	9,367	160	17.1	6,111	94	15.4	3,256	66	20.3	1.3
35	13,906	175	12.6	9,207	118	12.8	4,699	57	12.1	1.0
36	27,354	248	9.1	18,482	157	8.5	8,872	91	10.3	1.2

*Rate per 1,000 live births

Table 4.10. Gestational week specific neonatal mortality rates among level 1 births by race, Michigan 1996-2006.

Gestational Week	Total			White			Black			Ratio
	Live Births	Neonatal Deaths	Rate*	Live Births	Neonatal Deaths	Rate	Live Births	Neonatal Deaths	Rate	
Extremely Preterm: < 28 weeks										
20	21	13	619.1	15	8	533.3	6	5	833.3	1.6
21	15	11	733.3	12	9	750.0	3	2	666.7	0.9
22	68	61	897.1	53	46	867.9	15	15	1000.0	1.2
23	85	53	623.5	55	39	709.1	30	14	466.7	0.7
24	134	64	477.6	85	48	564.7	49	16	326.5	0.6
25	137	39	284.7	90	29	322.2	47	10	212.8	0.7
26	160	37	231.3	116	32	275.9	44	5	113.6	0.4
27	173	27	156.1	119	22	184.9	54	5	92.6	0.5
Very Preterm: <32 weeks										
28	206	14	68.0	152	8	52.63	54	6	111.1	2.1
29	233	12	51.5	190	10	52.63	43	2	46.5	0.9
30	329	16	48.6	261	15	57.47	68	1	14.7	0.3
31	441	17	38.6	362	15	41.44	79	2	25.3	0.6
Preterm: <37 weeks										
32	824	16	19.4	657	12	18.26	167	4	24.0	1.3
33	1,196	16	13.4	998	13	13.03	198	3	15.2	1.2
34	3,040	29	9.5	2,586	26	10.05	454	3	6.6	0.7
35	7,173	35	4.9	6,247	32	5.12	926	3	3.2	0.6
36	18,014	42	2.3	15,985	36	2.25	2,029	6	3.0	1.3

*Rate per 1,000 live births

Table 4.11. Gestational week specific neonatal mortality rates among level 3 births by race, Michigan 1996-2006.

Gestational Week	Total			White			Black			Ratio
	Live Births	Neonatal Deaths	Rate*	Live Births	Neonatal Deaths	Rate	Live Births	Neonatal Deaths	Rate	
Extremely Preterm: < 28 weeks										
20	45	23	511.1	19	10	526.3	26	13	500.0	1.0
21	88	71	806.8	48	39	812.5	40	32	800.0	1.0
22	276	214	775.4	127	100	787.4	149	114	765.1	1.0
23	360	353	980.6	309	175	566.3	321	178	554.5	1.0
24	921	276	299.7	453	132	291.4	468	144	307.7	1.1
25	1,028	177	172.2	532	94	176.7	496	83	167.3	1.0
26	1,165	143	122.8	626	70	111.8	539	73	135.4	1.2
27	1,229	102	83.0	706	61	86.4	523	41	78.4	0.9
Very Preterm: <32 weeks										
28	1,599	80	50.0	903	52	57.6	696	28	40.2	0.7
29	1,616	79	48.9	952	58	60.9	664	21	31.6	0.5
30	2,306	73	31.7	1,318	47	35.7	988	26	26.3	0.7
31	2,825	65	23.0	1,739	47	27.0	1,086	18	16.6	0.6
Preterm: <37 weeks										
32	4,167	71	17.0	2,590	52	20.1	1,577	19	12.1	0.6
33	5,651	77	13.6	3,604	57	15.8	2,047	20	9.8	0.6
34	9,367	93	9.9	6,111	61	10.0	3,256	32	9.8	1.0
35	13,906	80	5.8	9,207	64	7.0	4,699	16	3.4	0.5
36	27,354	125	4.6	18,482	88	4.8	8,872	37	4.2	0.9

*Rate per 1,000 live births

4.4.7 Racial differences in the adjusted risk of infant mortality

Table 4.12 examines racial disparities in the risk of infant death, using white infants as the referent category. Due to effect modification by hospital level and NICU transfer, relative risks presented were stratified by the two exposures of interest (hospital level and NICU transfer). Fully adjusted, statistically significant results were bolded. After adjustment for confounding demographic and medical variables, the risk of infant mortality among extremely preterm black infants who were delivered at a level 3 hospital and subsequently transferred to a NICU was significantly higher than the mortality risk among their white counterparts (RR=1.25 95% CI=1.07-1.45). On the other hand, extremely preterm black infants who were born in a level 1 hospital and transferred to a NICU were significantly less likely than their white counterparts to die during their first year of life (RR=0.41 95% CI=0.26-0.66). The risk of infant mortality among black, very preterm infants was significantly less than the risk for their white counterparts among level 1 NICU transferred infants (RR=0.58 95% CI=0.40-0.85) and among level 3 infants who were not transferred to a NICU (RR=0.73 95% CI=0.57-0.94).

Table 4.12. Multivariate analyses predicting the risk of infant death (white infants as referent) by hospital level at birth and NICU transfer, Michigan 1996-2006

Infant Mortality	Level 1		Level 3	
	No NICU Transfer	NICU Transfer	No NICU Transfer	NICU Transfer
Extremely Preterm Birth: <28 weeks				
Unadjusted	0.94† (0.56-1.59)‡	0.48 (0.32-0.73)	0.84 (0.65-1.09)	1.48 (1.30-1.68)
Demographics*	0.94 (0.54-1.64)	0.45 (0.29-0.70)	0.77 (0.59-1.02)	1.44 (1.26-1.65)
+ BW	0.75 (0.41-1.37)	0.39 (0.25-0.62)	0.81 (0.61-1.09)	1.30 (1.13-1.50)
+ GA	0.91 (0.49-1.70)	**0.41 (0.26-0.66)**	0.84 (0.60-1.17)	1.25 (1.08-1.45)
+ NICU Beds	N/A	N/A	0.85 (0.61-1.18)	**1.25 (1.07-1.45)**
Very Preterm Birth: <32 weeks				
Unadjusted	1.31 (0.90-1.93)	0.90 (0.65-1.25)	0.83 (0.69-1.00)	1.47 (1.32-1.63)
Demographics*	1.12 (0.75-1.69)	0.84 (0.60-1.18)	0.78 (0.64-0.95)	1.38 (1.24-1.53)
+ BW	0.75 (0.47-1.19)	0.55 (0.38-0.80)	0.74 (0.59-0.92)	1.16 (1.04-1.30)
+ GA	0.83 (0.50-1.38)	**0.58 (0.40-0.85)**	0.71 (0.55-0.91)	1.14 (1.01-1.28)
+ NICU Beds	N/A	N/A	**0.73 (0.57-0.94)**	1.14 (1.01-1.29)
Preterm Birth: <37 weeks				
Unadjusted	1.65 (1.28-2.12)	1.58 (1.21-2.70)	1.12 (0.98-1.27)	1.61 (1.47-1.75)
Demographics*	1.30 (1.00-1.68)	1.30 (1.00-1.73)	0.99 (0.86-1.14)	1.47 (1.34-1.61)
+ BW	0.75 (0.55-1.02)	0.69 (0.51-0.93)	0.78 (0.66-0.91)	1.10 (1.00-1.21)
+ GA	0.92 (0.66-1.29)	0.72 (0.53-0.98)	0.81 (0.68-0.96)	1.10 (1.00-1.22)
+ NICU Beds	N/A	N/A	0.82 (0.69-0.97)	1.14 (1.04-1.26)

*Adjusted model includes the following variables: gestational age, age, education, smoking during pregnancy, alcohol use during pregnancy, urbanicity and adequacy of prenatal care

† Relative Risk

‡ 95% Confidence Interval

4.5 Discussion

Access to highly specialized care is critical among extremely preterm infants. Nearly two thirds of the decrease in neonatal mortality over the past 20 years has been attributable to the neonatal management and care of extremely preterm infants [100], as well as improved capability of specialized centers [101].

This study investigated racial differences in rates of preterm birth and the effect of hospital level at birth and access to NICU treatment on racial disparities in infant and neonatal mortality rates. Significant racial differences were found in rates of preterm birth, which have been demonstrated in other studies [38, 55]. The largest racial differences were seen among extremely preterm infants, who subsequently had the highest risk of mortality.

4.5.1 Perinatal regionalization

The vast majority of very preterm infants in Michigan were delivered at level 3 hospitals, with only 14% delivered at a level 1 hospital. Other studies have found wide variation in the proportion of very preterm/low birthweight infants born in a level 3 hospital: 82% of very low birthweight births [102], 60% very low birthweight births [103], 82.2% of very low birthweight births [54], 81% of very low birthweight [53], 88% less than 2000 grams [104], 81% of very low birthweight births [105], 68% of very preterm births [106], 67% of very low birthweight births [107], 75% of very preterm births [108], 78% of very low birthweight births [57], 79% of very preterm births [109], and 73.3% of extremely preterm births [55]. While it is positive that the majority of very preterm infants in each of these studies were born in a level 3 hospital, a problem with interpreting the results is that many of them were based on research collaboratives in large teaching hospitals. Differences in study population or hospital characteristics can influence results with large area (ie. state) analyses more prone to find lower rates of level 3 births, while analyses from research collaboratives based around large teaching hospitals (ie. Vermont Oxford Network) were more likely to find higher rates of level 3 births.

Similar to other studies, black mothers in our study were more likely than their white counterparts to deliver at a level 3 hospital, regardless of preterm gestational age category [39, 110]. Contrary to our finding of higher rates of NICU transfer among black infants, regardless of gestational age or birth hospital level, Bronstein et al found that race did not affect the likelihood that infants born in level 1 hospitals would be transferred to a NICU after delivery [39].

4.5.2 Mortality and perinatal regionalization

Mortality rates were highest among infants who were born at a level 1 hospital, regardless of gestational age or NICU transfer status. These results support the 1976 Committee on Perinatal Health statement that survival improves for high risk infants that are delivered at hospitals with a NICU, and supports other studies that found similar results [53, 55, 57, 102, 104, 105, 109, 111, 112]. For example, Paneth et al found that preterm and low birth weight infants were at a 24% higher risk of mortality if birth occurred outside of a level 3 center, regardless of whether birth occurred at a level 1 or level 2 hospital [113]. Historically prompt transfer from a level 1 to a level 3 hospital has been found to greatly reduce mortality risk [114], but more recently, for infants who are born in a level 1 hospital, subsequent transfer to a level 3 hospital has been found to only marginally decrease the risk of mortality [104], further supporting the need for high risk infants to be inborn at a level 3 hospital.

4.5.3 Racial disparities in mortality

Despite the finding that black infants were more likely than their white counterparts to deliver at a level 3 hospital, mortality rates were elevated among black infants, especially among level 3 births. The only exception was a significantly decreased mortality risk among black infants who were born at a level 3 hospital but not subsequently transferred to a NICU. Since it is puzzling that any infant <32 weeks gestation who was born at a level 3 hospital would not be transferred to a NICU, we further examined the time of death for this small group of infants (565 white and 398 black) and found that 88% of white deaths and 85% of black deaths occurred before the infants could be transferred (<1 hour). A perplexing elevation in risk among black infants was seen among extremely preterm infants who were born at a level 3 hospital and subsequently transferred to a NICU. This finding contradicts findings from four previous perinatal regionalization studies which found lower mortality rates among very preterm/low birthweight black infants compared to their white counterparts after adjusting for hospital-specific characteristics [51, 102, 104, 112], but agree with those of Bronstein et al who found that black low birthweight infants had a 35% elevated risk of mortality after adjustment for socio-demographic characteristics [39]. In our analyses, adjustment for elevated proportions of demographic risk factors such as inadequate prenatal care, alcohol use and gestational week did little to reduce the black/white disparity. Further analyses showed discrepancies in the birth hospital level and death hospital level among extremely preterm black neonatal deaths (not shown). Specifically, despite the finding that overall, black infants were more likely to be born at a level 3 hospital than white infants, among births that subsequently resulted in a death, extremely preterm black infants were less likely than their white counterparts to be born at a level 3 hospital (black = 80% vs. white = 82%). Likewise, among all deaths, extremely preterm black infants were less likely than their white counterparts to die at a level 3 hospital (black = 77% vs. white = 78%). But, race-specific concordance analyses between hospital level at birth and hospital level at death did not substantiate racial differences with 99% of both white and black neonatal deaths among level 3 births occurring at a level 3 hospital as well (not shown).

Previous studies [111, 112, 115] have identified several hospital characteristics associated with health outcomes among infants. Lower staff-to-infant ratios have been associated with higher morality rates among very low birthweight infants [111], although racial differences in mortality risk were not examined. Howell et al (2008) found that black infants were more likely to be born at hospitals with higher risk-adjusted mortality and this explained more than one third of the black/white disparity in extremely low birthweight neonatal mortality [112]. Morales et al found that minority serving hospitals had significantly higher risk adjusted mortality rates for both white and black infants than hospitals where less than 15% of infants were black (White OR=1.30, 95% CI=1.09-1.56; Black OR= 1.29, 95% CI = 1.01-1.64) which were not explained by either hospital characteristics or treatment variables [115]. It is possible that black infants in our sample were more likely than white infants to be born at minority serving hospitals with higher risk adjusted mortality rates, and this led to the excess risk among black infants across preterm categories. An examination of hospital specific mortality rates demonstrated a slight indication of higher mortality rates among minority serving institutions (>15% black), but 79% of the level 3 hospitals in our study fell into this category, so it is difficult to make strong inferences based on this information.

A growing body of evidence suggests that outcomes for surgical procedures and medical diagnoses are better for patients treated in hospitals with higher volumes of patients receiving similar procedures [57, 78, 116]. Upon examining 11 year volume within our study, we found a trend in mortality rates with the highest rates seen in level 3 hospitals with >2000 preterm births (108.4 per 1,000 live births) and the lowest mortality in hospitals with <1000 preterm births (49.4 per 1,000 live births). In contrast, Phibbs et al found that compared with a high level of care and a high volume of very low birthweight infants, lower levels of care and lower volumes were associated with significantly higher odds of death [57]. This is not always the case with high risk neonatal and infant mortality. Some studies have not found a relation between hospital volume and mortality. Horbar reported no effect of NICU patient volume on mortality outcomes of very low birthweight infants [102]. The referral of very low birthweight infants based on patient volume was minimally effective, accounting for only 1% of hospital variation in mortality outcomes in a 2004 study [51]. Authors from the same study found that the largest indicator of hospital quality was the mortality rate from the previous year, which accounted for 34% of hospital level variation in mortality rates [51]. Reasons for delivery at certain hospitals and NCU transfer involve a number of factors whose evaluation was not in the scope of this project such as place of residence [117], distance to hospitals [118], managed care and HMOs [107], which could all vary by race.

4.6 Conclusions

Our study found significant racial disparities in rates of preterm birth, hospital level at birth and NICU transfer among various gestational categories. Despite higher rates of level 3 births, racial disparities in preterm infant and neonatal mortality persist. Reasons for this elevation in black mortality rates are unclear, and limitations in available vital statistics data prevented the full exploration of hospital-specific characteristics. Furthermore, national data on hospital level at birth and the prevalence of NICU transfers are not available in the National Center for Health Statistics Linked Birth/Infant Death Records, so it was not possible to see if this relationship differed by state. Future studies should supplement state and national vital records with hospital specific characteristics which influence infant mortality rates and racial disparities in infant mortality rates (ie. infant to staff ratios). Although large teaching collaboratives, such as the Vermont Oxford Network offer detailed hospital specific information, all infants are not born in medical facilities with a NICU and therefore may be included in related studies. The addition of data on all hospitals, especially level 1 hospitals with the highest mortality rates, is essential for reducing overall infant mortality rates and racial disparities in infant mortality.

CHAPTER 5: CONCLUSION

The primary focus of this research was to determine reasons for nationwide variation in racial disparities in IM. Issues related to disparity measurement (relative vs. absolute measures) and three key exposures (inequalities in sociodemographic factors, infant and fetal reporting practices and perinatal regionalization) were examined in order to gain a better understanding of the composition of racial disparities in IM. Study aims were centered on state level factors which are amenable to intervention, with hopes of influencing future research agendas along with state and national policy. These aims allowed the untangling of a complex issue by simultaneously examining multiple factors which could influence racial disparities in IM. Furthermore, this study evaluated two policy-relevant disparity measures in relation to IM. Noteworthy results from this study include the findings that racial inequalities in the proportion of very low birthweight and very preterm infant births along with state differences in reporting very low birthweight and very preterm births were consistently associated with national variation in IM disparities. Racial inequalities in perinatal regionalization, however did not account for higher infant or neonatal mortality rates among black infants in Michigan.

Our study found that relative and absolute measures of disparity provided similar, but not identical results when examining inequality in infant, maternal and state sociodemographic factors. They provided different results, however, when examining state-level racial disparities in IM. State differences in the proportion of VLBW births were the strongest predictor of racial disparities in IM. Furthermore, inequalities in foreign born status and percent poverty were also significantly correlated with national variation in IM disparities. Inequalities in maternal factors did not play a strong role in nationwide variation in IM disparities in fully adjusted analyses, but relative and absolute measures of inequality in teen pregnancy were significantly correlated in partially adjusted models. Due to different IM disparity results depending on the measure used, future studies examining reasons for state-level differences in racial disparities in IM, should use both relative and absolute disparity measures. Care should also be taken when examining nationwide variation in racial disparities in IM interpretation of results should include discussion of how results differ, depending on the disparity measure used. While relative and absolute disparity measures were significantly correlated with each other, they exhibited different relationships with IM rates. Total IM was only correlated with the absolute disparity measure, while white IM was only correlated with the relative measure. Although both disparity measures were significantly correlated with black IM, this relationship was stronger when using the absolute measure of disparity as opposed to the relative measure. This discovery reinforced the finding that the absolute disparity measure more closely reflected black IM rates than did the relative disparity measure. Due to differences in disparity measure associations with IM rates, future research on racial disparities in IM should examine both relative and absolute disparity measures. Furthermore, high correlation between inequalities in the proportion of very low birthweight births and disparities in IM indicates that future research should work on extracting more meaning from infant birthweight. Lower birthweight for gestational age among black infants has yet to be fully explained.

Overall, registration area differences and viability differences in mortality rates, absolute disparities and relative disparities were most pronounced among infants ≤ 22 weeks gestation. Simply excluding infants less than 20 weeks gestation and/or less than

500 grams did not erase registration area differences in IM rates or disparities. Although significant area and classification differences were seen for both races, differences were most prominent among black infants. That proportion non-viable categories were similar among infant and fetal deaths indicates real category differences in not only the proportion of at-risk infants born (ie. extremely preterm/low birthweight) but also indicates real differences in racial disparities between these categories. Absolute disparities as measured by the disparity differences were most sensitive to area differences in disparities, especially when overall mortality rates were high.

State differences in fetal death reporting requirements lead to differences in the reported number of live births, infant deaths and fetal deaths. These differences persist even after limiting data to gestations which should be reported by all states. In order for national vital statistics data to be meaningful, a uniform definition of fetal death must be adopted. Based on the lowest IM rates and disparities seen in fetal death registration areas which report all products of conception, we recommend reporting all products of conception as fetal deaths. The reporting of all products of conception by each registration area would allow the examination of racial differences in the continuum of miscarriages, fetal deaths, early neonatal deaths and neonatal deaths with vital statistics data. This would reduce systematic differences in the reporting of live births and fetal deaths to give an accurate record of actual mortality rates and disparities. Future studies should examine proportion non-viable differences in relative and absolute disparities. Studies should also examine registration area differences in the continuum of miscarriages, fetal deaths and early neonatal deaths.

Finally, with respect to perinatal regionalization, our study found significant racial disparities in rates of preterm birth, hospital level at birth and NICU transfer among specific gestational categories in Michigan. Despite higher rates level 3 births among black infants, racial disparities in preterm infant and neonatal mortality persist with black infants twice as likely as their white counterparts to die during the first year of life. Reasons for this elevation in black mortality rates are unclear, and limitations in available vital statistics data prevented the full exploration of hospital-specific characteristics. Furthermore, national data on hospital level at birth and the prevalence of NICU transfers are not available in the National Center for Health Statistics Linked Birth/Infant Death Records, so it is not possible to determine if this relationship differs by state. Future studies should supplement state and national vital records with hospital specific characteristics found to influence infant mortality rates and racial disparities in infant mortality rates (ie. infant to staff ratios). Although large teaching collaboratives, such as the Vermont Oxford Network offer detailed hospital specific information, all infants are not born in medical facilities with a NICU and therefore may be included in related studies. The addition of data on all hospitals, especially level 1 hospitals with the highest mortality rates, is essential for reducing overall infant mortality rates and racial disparities in infant mortality.

A nationwide analysis of racial differences in hospital level at birth and NICU transfers needs to be done. State differences in these factors could contribute substantially to nationwide variation in IM rates and to variation in racial disparities in IM. The addition of hospital level at birth and NICU transfer to the national, publicly available linked birth, infant death dataset would provide an unbiased study population publicly available for analysis.

APPENDICIES

APPENDIX

Appendix A. Exposure variable specific adjustment for fully adjusted partial correlation model 3.

Exposure Variable Inequalities	Model 3 Partial Correlation Adjustments	
	Maternal	State
Infant		
Low Birthweight Very Low Birthweight	Low Birthweight Very Low Birthweight Unknown Father RR Teen Pregnancy RD Tobacco Use RR	Proportion Black ≥ High School RD Poverty RR
Preterm Very Preterm	Preterm Very Preterm Unknown Father RD Teen Pregnancy RD Tobacco Use RR	Proportion Black ≥ High School RD Poverty RR
Maternal		
Teen Pregnancy	Teen Pregnancy Unknown Father RD Tobacco Use RR	Proportion Black ≥ High School RD Poverty RR
Unknown Father	Unknown Father Unmarried RD	Proportion Black ≥ High School RD Poverty RR
< High School	< High School Teen Pregnancy RD	Proportion Black Unemployed RR
Unmarried	Unmarried Teen Pregnancy RD	Proportion Black ≥ High School RD
Tobacco Use	Tobacco Use Teen Pregnancy RR	Proportion Black
Alcohol Use	Alcohol Use Teen Pregnancy RD < High School RR	Proportion Black
Inadequate Prenatal Care	Inadequate Prenatal Care Tobacco Use RR	Proportion Black
State		
Foreign Born	< High School RR	Proportion Black Foreign Born
< High School	Teen Pregnancy RD Unmarried DR	Proportion Black < High School Poverty RR
≥ High School	Teen Pregnancy RD Unmarried DR	Proportion Black ≥ High School Poverty RR

Appendix A (continued). Exposure variable specific adjustment for fully adjusted partial correlation model 3.

Exposure Variable Inequalities	Model 3 Partial Correlation Adjustments	
	Maternal	State
≥ College	Teen Pregnancy RD Unmarried DR	Proportion Black ≥ College
Unemployed	Unknown Father RR Teen Pregnancy RD	Proportion Black Unemployment ≥ High School Poverty RR
Poverty	< High School RR	Proportion Black Poverty

*Each of the exposure variables of interest are inequalities (ie. relative risk or risk difference)

Appendix B. Percentage of Borderline Birthweight Births and Deaths by Fetal Death Classification Area: United States, 2000-2002.

Area	Birthweight <500 grams						Birthweight 500-1000 grams					
	Births			Deaths			Births			Deaths		
	Total	White	Black	Total	White	Black	Total	White	Black	Total	White	Black
Total	0.1	0.1	0.4	17.8	14.6	24.7	0.5	0.3	1.1	23.5	21.2	28.5
Area 1	0.1	0.1	0.3	19.1	15.6	24.7	0.5	0.3	1.1	26.2	22.9	31.2
Area 2	0.1	0.1	0.4	18.2	14.6	25.1	0.5	0.3	1.2	23.2	20.7	27.6
Area 3	0.1	0.1	0.5	18.3	14.0	28.9	0.5	0.4	1.1	20.4	19.3	23.0
Area 4	0.1	0.1	0.4	17.3	14.6	24.3	0.4	0.3	1.1	23.1	21.1	28.3

Area 1= All products of conception
Area 2= Birthweight and gestational age criteria
Area 3= Birthweight criteria
Area 4= Gestational age criteria

Appendix C. Percent of Borderline Infants Who Survive to Age 1 by Fetal Death Classification Area; United States, 2000-2002

Area, %	Birthweight <500 grams			Birthweight 500-999 grams		
	Total	White	Black	Total	White	Black
Total	16.7	16.3	17.2	69.2	68.7	70.0
Area 1	10.5	8.9	12.0	68.1	66.9	69.3
Area 2	16.6	14.6	18.4	68.5	67.8	69.4
Area 3	10.4	11.4	9.1	68.4	67.8	69.6
Area 4	18.8	18.6	19.1	69.8	69.4	70.5

Area 1= All products of conception
Area 2=Birthweight and gestational age criteria
Area 3= Birthweight criteria
Area 4= Gestational age criteria

Appendix D. Percentage of Infant and Fetal Deaths with Unknown Birthweight and/or Gestational Age by Fetal Death Classification Area; United States, 2000-2002

Area	Unknown Birthweight and Gestational Age						Unknown Gestational Age						Unknown Birthweight		
	Infant Deaths			Fetal Deaths			Infant Deaths			Fetal Deaths			Fetal Deaths		
	T	W	B	T	W	B	T	W	B	T	W	B	T	W	B
Total	1.3	1.6	1.7	3.8	2.8	4.3	2.0	1.7	2.1	1.1	0.9	1.1	52.5	49.0	53.9
Area 1	1.0	1.1	0.8	5.4	3.6	6.1	0.6	0.7	0.4	0.2	0.3	0.2	80.7	76.0	82.6
Area 2	1.5	1.5	1.5	0.5	0.9	0.3	0.4	0.6	0.3	0.6	0.8	0.5	6.8	4.9	7.7
Area 3	1.3	2.3	0.9	0.4	0.4	0.4	0.7	1.2	0.5	1.5	1.7	1.4	2.4	1.3	2.8
Area 4	0.8	1.8	1.2	1.9	1.9	1.9	3.0	2.6	3.1	2.9	2.3	3.1	10.8	8.8	11.5

**There were not any infants with known gestational age and unknown birthweight.

Area 1= All products of conception
Area 2=Birthweight and gestational age criteria
Area 3= Birthweight criteria
Area 4= Gestational age criteria

Appendix E. Presence of Level 3 hospitals by year, Michigan 1996-2006.

Hospital	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
24003											
25005											
28002											
33001											
39002											
41003											
41010											
52007											
63007											
63009											
63015											
63019											
73004				x	x	x	x	x	x	x	x
73008											
74004											
81005											
81006											
82010	x		x	x		x	x	x	x	x	x
82024											
82028											
82053											
82058											
82086											
82514											
82535											

x indicates that hospital had 0 births for that year

Appendix F. Age at death by hospital of birth level and hospital of death level among all deaths, Michigan 1996-2006.

Age at Death	Birth Level		Death Level	
	1	3	1	3
Neonatal	601 (18.1)	2719 (81.9)	390 (11.8)	2930 (88.3)
Postneonatal	216 (17.9)	989 (82.1)	353 (29.3)	852 (70.7)

Appendix G. Concordance between hospital level at birth and hospital level at death among extremely preterm (<28 weeks) neonatal deaths, Michigan 1996-2006.

Birth Level	Death Level	
	1	3
1	228 (60.5)	149 (38.5)
3	17 (0.9)	1821 (99.1)

*199 deaths <1 hour (87.3%)

Appendix H. Concordance between hospital level at birth and hospital level at death among extremely preterm (<28 weeks) white neonatal deaths, Michigan 1996-2006.

Birth Level	Death Level	
	1	3
1	182 (61.5)	114 (38.5)
3	12 (1.2)	998 (98.8)

Appendix I. Concordance between hospital level at birth and hospital level at death among extremely preterm (<28 weeks) black neonatal deaths, Michigan 1996-2006.

Birth Level	Death Level	
	1	3
1	46 (56.8)	35 (43.2)
3	5 (0.6)	823 (99.4)

BIBLIOGRAPHY

BIBLIOGRAPHY

1. Iyasu, S., K. Tomashek, and W. Barfield, *Infant mortality and low birth weight among black and white infants--United States, 1980-2000.* MMWR CDC Surveill Summ, 2002. 51(27): p. 589-592.

2. Mathews, T.J. and K.G. Keppel, *Racial/Ethnic disparities in infant mortality--United States, 1995-2002.* MMWR CDC Surveill Summ, 2005. 54(22): p. 553-556.

3. Alexander, G.R., M.S. Wingate, D. Bader, and M.D. Kogan, *The increasing racial disparity in infant mortality rates: composition and contributors to recent US trends.* Am J Obstet Gynecol, 2008. 198(1): p. 51 e51-59.

4. Marks, J.S., J.W. Buehler, L.T. Strauss, C.J. Hogue, and J.C. Smith, *Variation in state-specific infant mortality risks.* Public Health Rep, 1987. 102(2): p. 146-151.

5. Wise, P.H., *The anatomy of a disparity in infant mortality.* Annu Rev Public Health, 2003. 24: p. 341-362.

6. Mathews, T.J. and M.F. MacDorman, *Infant mortality statistics from the 2004 period linked birth/infant death data set.* Natl Vital Stat Rep, 2007. 55(14): p. 1-32.

7. DiGiuseppe, D.L., D.C. Aron, L. Ranbom, D.L. Harper, and G.E. Rosenthal, *Reliability of birth certificate data: a multi-hospital comparison to medical records information.* Matern Child Health J, 2002. 6(3): p. 169-179.

8. Anderson, R.N., A.M. Minino, D.L. Hoyert, and H.M. Rosenberg, *Comparability of cause of death between ICD-9 and ICD-10: preliminary estimates.* Natl Vital Stat Rep, 2001. 49(2): p. 1-32.

9. Krous, H.F., J.B. Beckwith, R.W. Byard, T.O. Rognum, T. Bajanowski, T. Corey, E. Cutz, R. Hanzlick, T.G. Keens, and E.A. Mitchell, *Sudden infant death syndrome and unclassified sudden infant deaths: a definitional and diagnostic approach.* Pediatrics, 2004. 114(1): p. 234-238.

10. Ananth, C.V., K.S. Joseph, K. Demissie, and A.M. Vintzileos, *Trends in twin preterm birth subtypes in the United States, 1989 through 2000: impact on perinatal mortality.* Am J Obstet Gynecol, 2005. 193(3 Pt 2): p. 1076-1082.

11. Lee, K.S., N. Paneth, L.M. Gartner, M.A. Pearlman, and L. Gruss, *Neonatal mortality: an analysis of the recent improvement in the United States.* Am J Public Health, 1980. 70(1): p. 15-21.

12. Scott, C.L., S. Iyasu, D. Rowley, and H.K. Atrash, *Postneonatal mortality surveillance--United States, 1980-1994.* MMWR CDC Surveill Summ, 1998. 47(2): p. 15-30.

13. Beck, L.F., B. Morrow, L.E. Lipscomb, C.H. Johnson, M.E. Gaffield, M. Rogers, and B.C. Gilbert, *Prevalence of selected maternal behaviors and experiences, Pregnancy Risk Assessment Monitoring System (PRAMS), 1999.* MMWR Surveill Summ, 2002. 51(2): p. 1-27.

14. Gortmaker, S.L., *The effects of prenatal care upon the health of the newborn.* Am J Public Health, 1979. 69(7): p. 653-660.

15. Poma, P.A., *Effect of prenatal care on infant mortality rates according to birth-death certificate files.* J Natl Med Assoc, 1999. 91(9): p. 515-520.

16. Salihu, H.M., M.H. Aliyu, B.J. Pierre-Louis, and G.R. Alexander, *Levels of excess infant deaths attributable to maternal smoking during pregnancy in the United States.* Matern Child Health J, 2003. 7(4): p. 219-227.

17. Mathews, T.J., F. Menacker, and M.F. MacDorman, *Infant mortality statistics from the 2002 period: linked birth/infant death data set.* Natl Vital Stat Rep, 2004. 53(10): p. 1-29.

18. Lundsberg, L.S., M.B. Bracken, and A.F. Saftlas, *Low-to-moderate gestational alcohol use and intrauterine growth retardation, low birthweight, and preterm delivery.* Ann Epidemiol, 1997. 7(7): p. 498-508.

19. Martin, J.A., B.E. Hamilton, P.D. Sutton, S.J. Ventura, F. Menacker, and M.L. Munson, *Births: final data for 2002.* Natl Vital Stat Rep, 2003. 52(10): p. 1-113.

20. Keppel, K.G., *Ten largest racial and ethnic health disparities in the United States based on Healthy People 2010 Objectives.* Am J Epidemiol, 2007. 166(1): p. 97-103.

21. Carter-Pokras, O. and C. Baquet, *What is a "health disparity"?* Public Health Rep, 2002. 117(5): p. 426-434.

22. Whitehead, M., *The concepts and principles of equity and health.* Int J Health Serv, 1992. 22(3): p. 429-445.

23. Harper, S., J. Lynch, S.C. Meersman, N. Breen, W.W. Davis, and M.E. Reichman, *An overview of methods for monitoring social disparities in cancer with an example using trends in lung cancer incidence by area-socioeconomic position and race-ethnicity, 1992-2004.* Am J Epidemiol, 2008. 167(8): p. 889-899.

24. Harper, S., J. Lynch, S.C. Meersman, N. Breen, W.W. Davis, and M.E. Reichman, *Harper et al respond to "Measuring social disparities in health".* Am J Epidemiol, 2008. 167: p. 905-907.

25. Messer, L.C., *Invited commentary: measuring social disparities in health--what was the question again?* Am J Epidemiol, 2008. 167(8): p. 900-904; author reply 908-916.

26. Houweling, T.A., A.E. Kunst, M. Huisman, and J.P. Mackenbach, *Using relative and absolute measures for monitoring health inequalities: experiences from cross-national analyses on maternal and child health.* Int J Equity Health, 2007. 6: p. 15.

27. Pearcy, J.N. and K.G. Keppel, *A summary measure of health disparity.* Public Health Rep, 2002. 117(3): p. 273-280.

28. Braveman, P., C. Cubbin, K. Marchi, S. Egerter, and G. Chavez, *Measuring socioeconomic status/position in studies of racial/ethnic disparities: maternal and infant health.* Public Health Rep, 2001. 116(5): p. 449-463.

29. Goldhagen, J., R. Remo, T. Bryant, 3rd, P. Wludyka, A. Dailey, D. Wood, G. Watts, and W. Livingood, *The health status of southern children: a neglected regional disparity.* Pediatrics, 2005. 116(6): p. e746-753.

30. Stockwell, E.G., *Infant mortality and socio-economic status: a changing relationship.* Milbank Mem Fund Q, 1962. 40: p. 101-111.

31. Allen, D.M., J.W. Buehler, C.J. Hogue, L.T. Strauss, and J.C. Smith, *Regional differences in birth weight-specific infant mortality, United States, 1980.* Public Health Rep, 1987. 102(2): p. 138-145.

32. Bauman, K.E. and A.E. Anderson, *Legal abortions and trends in fetal and infant mortality rates in the United States.* Am J Obstet Gynecol, 1980. 136(2): p. 194-202.

33. Bird, S.T. and K.E. Bauman, *The relationship between structural and health services variables and state-level infant mortality in the United States.* Am J Public Health, 1995. 85(1): p. 26-29.

34. Brooks, C.H., *The changing relationship between socioeconomic status and infant mortality: an analysis of state characteristics.* J Health Soc Behav, 1975. 16(3): p. 291-303.

35. Kleinman, J.C., *State trends in infant mortality, 1968-83.* Am J Public Health, 1986. 76(6): p. 681-688.

36. Wilson, A.L., L.J. Fenton, and D.P. Munson, *State reporting of live births of newborns weighing less than 500 grams: impact on neonatal mortality rates.* Pediatrics, 1986. 78(5): p. 850-854.

37. Schoendorf, K.C., C.J. Hogue, J.C. Kleinman, and D. Rowley, *Mortality among infants of black as compared with white college-educated parents.* N Engl J Med, 1992. 326(23): p. 1522-1526.

38. O'Campo, P., J.G. Burke, J. Culhane, I.T. Elo, J. Eyster, C. Holzman, L.C. Messer, J.S. Kaufman, and B.A. Laraia, *Neighborhood deprivation and preterm birth among non-Hispanic Black and White women in eight geographic areas in the United States.* Am J Epidemiol, 2008. 167(2): p. 155-163.

39. Bronstein, J.M., E. Capilouto, W.A. Carlo, J.L. Haywood, and R.L. Goldenberg, *Access to neonatal intensive care for low-birthweight infants: the role of maternal characteristics.* Am J Public Health, 1995. 85(3): p. 357-361.

40. Ogburn, W. and D. Thomas, *The influence of business cycle on certain social conditions.* Journal of the American Statistical Association, 1922. 19: p. 324-340.

41. LaVeist, T., *The political empowerment and health status of African Americans: Mapping a new territory.* American Journal of Sociology, 1992. 97(4): p. 1080-1095.

42. McKnight, J.L., *Health and empowerment.* Can J Public Health, 1985. 76 Suppl 1: p. 37-38.

43. Wingate, M.S. and G.R. Alexander, *Racial and ethnic differences in perinatal mortality: the role of fetal death.* Ann Epidemiol, 2006. 16(6): p. 485-491.

44. Kowaleski, J., *State definitions and reporting requirements for live births, fetal deaths, and induced terminations of pregnancy (1997 revision).* N.C.f.H. Statistics, Editor. 1997: Hyattsville, Maryland.

45. Phelan, S.T., R. Goldenberg, G. Alexander, and S.P. Cliver, *Perinatal mortality and its relationship to the reporting of low-birthweight infants.* Am J Public Health, 1998. 88(8): p. 1236-1239.

46. Joseph, K.S. and M.S. Kramer, *Recent trends in infant mortality rates and proportions of low-birth-weight live births in Canada.* CMAJ, 1997. 157(5): p. 535-541.

47. Campbell, M.K., *Assessment of regionalized perinatal programs.* J Dev Physiol, 1991. 15(2): p. 125-131.

48. *Guidelines for prenatal care*, A.A.o.P.A.C.o.O.a. Gynecology, Editor. 1997: Elk Grove, IL and Washington DC p. 1.

49. Wise, P.H., L.R. First, G.A. Lamb, M. Kotelchuck, D.W. Chen, A. Ewing, H. Hersee, and J. Rideout, *Infant mortality increase despite high access to tertiary care: an evolving relationship among infant mortality, health care, and socioeconomic change.* Pediatrics, 1988. 81(4): p. 542-548.

50. Van Mullem, C., A.E. Conway, K. Mounts, D. Weber, and C.A. Browning, *Regionalization of perinatal care in Wisconsin: a changing health care environment.* WMJ, 2004. 103(5): p. 35-38.

51. Rogowski, J.A., J.D. Horbar, D.O. Staiger, M. Kenny, J. Carpenter, and J. Geppert, *Indirect vs direct hospital quality indicators for very low-birth-weight infants.* JAMA, 2004. 291(2): p. 202-209.

52. Paneth, N., *The role of neonatal intensive care in lowering infant mortality*, in *A pound of prevention: The case for university maternity care in the U.S.*, A. Press, Editor. 1992. p. 49-63.

53. Bode, M.M., M. O'Shea T, K.R. Metzguer, and A.D. Stiles, *Perinatal regionalization and neonatal mortality in North Carolina, 1968-1994.* Am J Obstet Gynecol, 2001. 184(6): p. 1302-1307.

54. Gerber, S.E., D.G. Dobrez, and P.P. Budetti, *Managed care and perinatal regionalization in Washington State.* Obstet Gynecol, 2001. 98(1): p. 139-143.

55. Kamath, B.D., T.L. Box, M. Simpson, and J.A. Hernandez, *Infants born at the threshold of viability in relation to neonatal mortality: Colorado, 1991 to 2003.* J Perinatol, 2008. 28(5): p. 354-360.

56. Paneth, N.S. and M.R. Rip, *The uses of epidemiology in the evaluation of regional perinatal services.* Soz Praventivmed, 1994. 39(1): p. 3-10.

57. Phibbs, C.S., L.C. Baker, A.B. Caughey, B. Danielsen, S.K. Schmitt, and R.H. Phibbs, *Level and volume of neonatal intensive care and mortality in very-low-birth-weight infants.* N Engl J Med, 2007. 356(21): p. 2165-2175.

58. Schoendorf, K.C. and A.M. Branum, *The use of United States vital statistics in perinatal and obstetric research.* Am J Obstet Gynecol, 2006. 194(4): p. 911-915.

59. Statistics, N.C.f.H., *2000-2002 linked birth/infant death dataset*, C.f.D.C.a.P. United States Department of Health and Human Services, Editor. 2000-2002.

60. Cai, J., G.L. Hoff, F. Okah, P.C. Dew, G. Zaborac, X. Somoza, L. Jones, P. Livingston, M.J. Everhardt, and R. Archer, *Fetal mortality: timing of racial disparities.* J Natl Med Assoc, 2007. 99(11): p. 1258-1261.

61. Kessner, D.M., J. Singer, C.E. Kalk, and E.R. Schlesinger, *Infant Death: An analysis by maternal risk and health care*, I.o.M.a.N.A.o. Sciences, Editor. 1973: Washington DC.

62. Alexander, G.R., *The accurate measurement of gestational age--a critical step toward improving fetal death reporting and perinatal health.* Am J Public Health, 1997. 87(8): p. 1278-1279.

63. Martin, J.A. and F. Menacker, *Expanded health data from the new birth certificate, 2004.* Natl Vital Stat Rep, 2007. 55(12): p. 1-22.

64. *Healthy People 2010: Understanding and improving health*, U.S.D.o.H.a.H. Services, Editor. 2000, Government Printing Office: Washington DC.

65. Singh, G.K. and S.M. Yu, *Infant mortality in the United States: trends, differentials, and projections, 1950 through 2010.* Am J Public Health, 1995. 85(7): p. 957-964.

66. *America's health starts with healthy children: How do states compare?* 2008, Robert Wood Johnson Foundation: Commission to Build a Healthier America. p. 1-23.

67. Goldenberg, R.L., G.R. Cutter, K.G. Nelson, and J. Foster, *Effects of very low birth weights on fetal and neonatal mortality rates in Alabama.* Public Health Rep, 1989. 104(5): p. 488-492.

68. Thompson, L.A., D.C. Goodman, C.H. Chang, and T.A. Stukel, *Regional variation in rates of low birth weight.* Pediatrics, 2005. 116(5): p. 1114-1121.

69. Luke, B. and M.B. Brown, *Maternal risk factors for potential maltreatment deaths among healthy singleton and twin infants.* Twin Res Hum Genet, 2007. 10(5): p. 778-785.

70. Goza, F.W., E.G. Stockwell, and K.S. Balistreri, *Racial differences in the relationship between infant mortality and socioeconomic status.* J Biosoc Sci, 2007. 39(4): p. 517-529.

71. Polednak, A.P., *Black-white differences in infant mortality in 38 standard metropolitan statistical areas.* Am J Public Health, 1991. 81(11): p. 1480-1482.

72. Sohler, N.L., P.S. Arno, C.J. Chang, J. Fang, and C. Schechter, *Income inequality and infant mortality in New York City.* J Urban Health, 2003. 80(4): p. 650-657.

73. Gage, T.B., F. Fang, E. O'Neill, and H. Stratton, *Maternal age and infant mortality: a test of the Wilcox-Russell hypothesis.* Am J Epidemiol, 2009. 169(3): p. 294-303.

74. Lee, K.S., N. Paneth, L.M. Gartner, and M. Pearlman, *The very low-birth-weight rate: Principal predictor of neonatal mortality in industrialized populations.* J Pediatr, 1980. 97(5): p. 759-764.

75. Kramer, M.S., C.V. Ananth, R.W. Platt, and K.S. Joseph, *US Black vs White disparities in foetal growth: physiological or pathological?* Int J Epidemiol, 2006. 35(5): p. 1187-1195.

76. Papiernik, E., G.R. Alexander, and N. Paneth, *Racial differences in pregnancy duration and its implications for perinatal care.* Med Hypotheses, 1990. 33(3): p. 181-186.

77. Wilcox, A.J., *On the importance--and the unimportance--of birthweight.* Int J Epidemiol, 2001. 30(6): p. 1233-1241.

78. Phipps, M.G., M. Sowers, and S.M. DeMonner, *The risk for infant mortality among adolescent childbearing groups.* J Womens Health (Larchmt), 2002. 11(10): p. 889-897.

79. David, R.J. and J.W. Collins, Jr., *Differing birth weight among infants of U.S.-born blacks, African-born blacks, and U.S.-born whites.* N Engl J Med, 1997. 337(17): p. 1209-1214.

80. Rosenberg, K.D., R.A. Desai, and J. Kan, *Why do foreign-born blacks have lower infant mortality than native-born blacks? New directions in African-American infant mortality research.* J Natl Med Assoc, 2002. 94(9): p. 770-778.

81. LaVeist, T.A., *Simulating the effects of poverty on the race disparity in postneonatal mortality.* J Public Health Policy, 1990. 11(4): p. 463-473.

82. Laveist, T.A., *Segregation, poverty, and empowerment: health consequences for African Americans.* Milbank Q, 1993. 71(1): p. 41-64.

83. Sims, M., T.L. Sims, and M.A. Bruce, *Urban poverty and infant mortality rate disparities.* J Natl Med Assoc, 2007. 99(4): p. 349-356.

84. Shi, L., L.H. Green, and S. Kazakova, *Primary care experience and racial disparities in self-reported health status.* J Am Board Fam Pract, 2004. 17(6): p. 443-452.

85. Bird, S.T., *Separate black and white infant mortality models: differences in the importance of structural variables.* Soc Sci Med, 1995. 41(11): p. 1507-1512.

86. Collins, J.W., Jr., R.J. David, R. Symons, A. Handler, S.N. Wall, and L. Dwyer, *Low-income African-American mothers' perception of exposure to racial discrimination and infant birth weight.* Epidemiology, 2000. 11(3): p. 337-339.

87. Lu, M.C. and N. Halfon, *Racial and ethnic disparities in birth outcomes: a life-course perspective.* Matern Child Health J, 2003. 7(1): p. 13-30.

88. Singh, G.K. and M.D. Kogan, *Persistent socioeconomic disparities in infant, neonatal, and postneonatal mortality rates in the United States, 1969-2001.* Pediatrics, 2007. 119(4): p. e928-939.

89. Paulson, J., *Unregistered deaths among extremely low birthweight infants--Ohio, 2006.* MMWR CDC Surveill Summ, 2007. 115(1): p. e44-e51.

90. Hessol, N.A. and E. Fuentes-Afflick, *Ethnic differences in neonatal and postneonatal mortality.* Pediatrics, 2005. 115(1): p. e44-51.

91. Iyasu, S., J.E. Becerra, D.L. Rowley, and C.J. Hougue, *Impact of very low birthweight on the black-white infant mortality gap.* Am J Prev Med, 1992. 8(5): p. 271-277.

92. Luke, B. and M.B. Brown, *The changing risk of infant mortality by gestation, plurality, and race: 1989-1991 versus 1999-2001.* Pediatrics, 2006. 118(6): p. 2488-2497.

93. Wen, S.W., L.M. Chen, C.Y. Li, M.S. Kramer, and A.C. Allen, *The impact of missing birth weight in deceased versus surviving fetuses and infants in the comparison of birth weight-specific feto-infant mortality.* Chronic Dis Can, 2002. 23(4): p. 146-151.

94. Alexander, G.R., M. Kogan, D. Bader, W. Carlo, M. Allen, and J. Mor, *US birth weight/gestational age-specific neonatal mortality: 1995-1997 rates for whites, hispanics, and blacks.* Pediatrics, 2003. 111(1): p. e61-66.

95. Kramer, M.R. and C.R. Hogue, *Place matters: variation in the black/white very preterm birth rate across U.S. metropolitan areas, 2002-2004.* Public Health Rep, 2008. 123(5): p. 576-585.

96. Allen, C.L., T.M. Hulsey, and H. T.C., *The influence of race on fetal outcome.* American Journal of Perinatology, 2005. 22(5): p. 245-248.

97. Yudkin, P.L., L. Wood, and C.W. Redman, *Risk of unexplained stillbirth at different gestational ages.* Lancet, 1987. 1(8543): p. 1192-1194.

98. Ananth, C.V., K.S. Joseph, Y. Oyelese, K. Demissie, and A.M. Vintzileos, *Trends in preterm birth and perinatal mortality among singletons: United States, 1989 through 2000.* Obstet Gynecol, 2005. 105(5 Pt 1): p. 1084-1091.

99. Gregory, G.A., J.A. Kitterman, R.H. Phibbs, W.H. Tooley, and W.K. Hamilton, *Treatment of the idiopathic respiratory-distress syndrome with continuous positive airway pressure.* N Engl J Med, 1971. 284(24): p. 1333-1340.

100. Richardson, D.K., J.E. Gray, S.L. Gortmaker, D.A. Goldmann, D.M. Pursley, and M.C. McCormick, *Declining severity adjusted mortality: evidence of improving neonatal intensive care.* Pediatrics, 1998. 102(4 Pt 1): p. 893-899.

101. Pollack, L.D., *An effective model for reorganization of perinatal services in a metropolitan area: a descriptive analysis and historical perspective.* J Perinatol, 1996. 16(1): p. 3-8.

102. Horbar, J.D., G.J. Badger, E.M. Lewit, J. Rogowski, and P.H. Shiono, *Hospital and patient characteristics associated with variation in 28-day mortality rates for very low birth weight infants. Vermont Oxford Network.* Pediatrics, 1997. 99(2): p. 149-156.

103. Mehta, S., H.D. Atherton, P.J. Schoettker, R.W. Hornung, P.H. Perlstein, and U.R. Kotagal, *Differential markers for regionalization.* J Perinatol, 2000. 20(6): p. 366-372.

104. Cifuentes, J., J. Bronstein, C.S. Phibbs, R.H. Phibbs, S.K. Schmitt, and W.A. Carlo, *Mortality in low birth weight infants according to level of neonatal care at hospital of birth.* Pediatrics, 2002. 109(5): p. 745-751.

105. Gould, J.B., A.R. Marks, and G. Chavez, *Expansion of community-based perinatal care in California.* J Perinatol, 2002. 22(8): p. 630-640.

106. Vieux, R., J. Fresson, J.M. Hascoet, B. Blondel, P. Truffert, J.C. Roze, J. Matis, G. Thiriez, C. Arnaud, L. Marpeau, and M. Kaminski, *Improving perinatal regionalization by predicting neonatal intensive care requirements of preterm infants: an EPIPAGE-based cohort study.* Pediatrics, 2006. 118(1): p. 84-90.

107. Dobrez, D., S. Gerber, and P. Budetti, *Trends in perinatal regionalization and the role of managed care.* Obstet Gynecol, 2006. 108(4): p. 839-845.

108. Alidina, S., S. Ardal, P. Lee, L. Raskin, A. Shennan, and L.M. Young, *Regionalization reigns--but is care being delivered accordingly? An evaluation of perinatal care delivery in a regionalized child health network.* Healthc Manage Forum, 2006. 19(2): p. 22-26.

109. Rautava, L., L. Lehtonen, M. Peltola, E. Korvenranta, H. Korvenranta, M. Linna, M. Hallman, S. Andersson, M. Gissler, J. Leipala, O. Tammela, and U. Hakkinen, *The effect of birth in secondary- or tertiary-level hospitals in Finland on mortality in very preterm infants: a birth-register study.* Pediatrics, 2007. 119(1): p. e257-263.

110. Gessner, B.D. and P.T. Muth, *Perinatal care regionalization and low birth weight infant mortality rates in Alaska.* Am J Obstet Gynecol, 2001. 185(3): p. 623-628.

111. Callaghan, L.A., D.W. Cartwright, P. O'Rourke, and M.W. Davies, *Infant to staff ratios and risk of mortality in very low birthweight infants.* Arch Dis Child Fetal Neonatal Ed, 2003. 88(2): p. F94-97.

112. Howell, E.A., P. Hebert, S. Chatterjee, L.C. Kleinman, and M.R. Chassin, *Black/white differences in very low birth weight neonatal mortality rates among New York City hospitals.* Pediatrics, 2008. 121(3): p. e407-415.

113. Paneth, N., J.L. Kiely, S. Wallenstein, and M. Susser, *The choice of place of delivery. Effect of hospital level on mortality in all singleton births in New York City.* Am J Dis Child, 1987. 141(1): p. 60-64.

114. Paneth, N., J.L. Kiely, and M. Susser, *Age at death used to assess the effect of interhospital transfer of newborns.* Pediatrics, 1984. 73(6): p. 854-861.

115. Morales, L.S., D. Staiger, J.D. Horbar, J. Carpenter, M. Kenny, J. Geppert, and J. Rogowski, *Mortality among very low-birthweight infants in hospitals serving minority populations.* Am J Public Health, 2005. 95(12): p. 2206-2212.

116. Luft, H.S., *Regionalization of medical care.* Am J Public Health, 1985. 75(2): p. 125-126.

117. Larson, E.H., L.G. Hart, and R.A. Rosenblatt, *Is non-metropolitan residence a risk factor for poor birth outcome in the U.S.?* Soc Sci Med, 1997. 45(2): p. 171-188.

118. Mori, R., M. Fujimura, J. Shiraishi, B. Evans, M. Corkett, H. Negishi, and P. Doyle, *Duration of inter-facility neonatal transport and neonatal mortality: systematic review and cohort study.* Pediatr Int, 2007. 49(4): p. 452-458.