Distribution Agreement

In presenting this thesis as a partial fulfillment of the requirements for an advanced degree from Emory University, I hereby grant to Emory University and its agents the non-exclusive license to archive, make accessible, and display my thesis in whole or in part in all forms of media, now or hereafter known, including display on the world wide web. I understand that I may select some access restrictions as part of the online submission of this thesis. I retain all ownership rights to the copyright of the thesis. I also retain the right to use in future works (such as articles or books) all or part of this thesis.

Signature:

_____ _____

Asa Ohsaki Date

Racial Disparities in Pregnancy-Related Mortality across Different Classification Systems of Rurality/Urbanicity

By

Asa Ohsaki

Master of Public Health

Epidemiology

_____

Michael Kramer, Ph.D.

Committee Chair

Racial Disparities in Pregnancy-Related Mortality across Different Classification Systems of Rurality/Urbanicity

By

Asa Ohsaki

Bachelor of Science

Brown University

2015

Epidemiology

Thesis Committee Chair: Michael Kramer, Ph.D.

An abstract of

A thesis submitted to the Faculty of the
Rollins School of Public Health of Emory University

in partial fulfillment of the requirements for the degree of
Master of Public Health
in Epidemiology

2019

Abstract

Racial Disparities in Pregnancy-Related Mortality across Different Classification Systems of Rurality/Urbanicity

By Asa Ohsaki

Objective: A retrospective cohort study was conducted to determine whether the racial disparity in pregnancy-related death varies between rural and urban areas and whether there is interaction between race and rurality, based on different classification systems of rurality and urbanicity.

Methods: Data on pregnancy-related deaths from 12 states participating in the Maternal Mortality Information Application (MMRIA) were abstracted. Data on live births in states and years where pregnancy-related deaths occurred were obtained from NCHS natality records. 2013 NCHS Urban-Rural Classification Scheme for Counties, the 2010 U.S. Census County Codes, and the 2013 USDA Rural-Urban Continuum Codes, were used as the basis for assigning rural-urban designations to counties. MMRIA data, NCHS natality records, and county designations were linked by FIPS codes. Negative binomial generalized estimating equation (GEE) regression models were fit separately to compare incidence density ratios (IDRs) for non-Hispanic black vs. non-Hispanic white women and estimate the interaction between race and rurality.

Results: The adjusted IDR for pregnancy-related death among non-Hispanic black women compared to non-Hispanic white women was similar for the USDA classification, moderately higher for rural compared to urban counties using the NCHS classification, and higher for rural compared to urban counties using the U.S. Census definition. The interaction between race and rurality was significant for the model using the U.S. Census definition but not for the NCHS and USDA definitions.

Conclusion: There is heterogeneity in the racial disparity for pregnancy-related death across rural and urban counties, depending on the classification system used to categorize rurality and urbanicity.

Racial Disparities in Pregnancy-Related Mortality across Different Classification Systems of Rurality/Urbanicity

By

Asa Ohsaki

Bachelor of Science
Brown University
2015

Thesis Committee Chair: Michael Kramer, Ph.D.

A thesis submitted to the Faculty of the

Rollins School of Public Health of Emory University

in partial fulfillment of the requirements for the degree of
Master of Public Health
in Epidemiology

2019

Acknowledgements

I would like to thank my advisor, Michael Kramer, for all of his guidance and support on this project. He helped me formulate my question, obtain multiple sources of data, and conduct the analysis. His mentorship and wisdom were instrumental for the completion of this project.

I would also like to thank Nicole Davis, David Goodman, and Dabo Brantley at the Centers for Disease Control and Prevention, Division of Reproductive Health for providing the data for this project. Without their generosity and time, this project would not have been possible.

Maternal Mortality Review Committee data was provided by the Delaware, Georgia, Hawaii, Illinois, Mississippi, North Carolina, Ohio, and Utah Departments of Health or agencies responsible for maternal mortality review. Any published findings and conclusions are those of the authors and do not necessarily represent the official position of the Delaware, Georgia, Hawaii, Illinois, Mississippi, North Carolina, Ohio, or Utah Departments of Health or agencies responsible for maternal mortality review. We are also grateful to the Building U.S. Capacity to Review and Prevent Maternal Deaths Team at the Centers for Disease Control and Prevention, CDC Foundation, and the Association of Maternal and Child Health Programs; this work was supported in part by funding from Merck, through an award agreement with its Merck for Mothers Program, and through federal appropriations.

Table of Contents

Chapter I. Literature Review **1**
Maternal Mortality in the United States 1
Measurement: NVSS 1
Measurement: Pregnancy Mortality Surveillance System 3
Measurement: Maternal Mortality Review Committees 4
Causes of Maternal Mortality/Risk Factors 5
Racial Disparity in Pregnancy Outcomes 6
Rural /Urban Continuum 10
Chapter II: Manuscript **15**
Introduction 15
Methods 19
Data Sources 19
Statistical Analysis 22
Results 23
Discussion 24
Chapter III: Discussion **27**
References **31**
Tables **35**

Chapter I. Literature Review

Maternal Mortality in the United States

The United States has the highest rate of maternal mortality compared to other developed nations. While maternal mortality decreases globally, the United States' rate is rising (1). According to data from the Pregnancy Mortality Surveillance System, pregnancy-related deaths increased from 7.2 deaths per 100,000 live births in 1987 to 18.0 deaths per 100,000 live births in 2014 (2). The high maternal mortality rate in the United States has attracted significant media attention in recent years, particularly with regards to the black vs. white racial disparity in maternal death (3). Despite the high and rising rate of maternal mortality, 60% of maternal deaths in the United States are preventable (4). A maternal death is considered preventable if it could have been avoided by making one or more reasonable changes to patient, community, provider, facility, and/or systems factors, according to the definition from the Maternal Mortality and Morbidity Review Committee (MMRC) of the Massachusetts Department of Public Health, Bureau of Family and Community Health (5).

Despite the increased attention on maternal mortality, the United States has not reported a national mortality rate since 2007, due to a lack of standardization in measurement across different states (6).

Measurement: NVSS

There are three major national systems of maternal mortality surveillance (7). The CDC's National Center for Health Statistics (NCHS) uses data from the National Vital Statistics System (NVSS) to determine maternal mortality statistics. The NVSS contains all registered deaths in the United States and has collected maternal mortality rates since 1915 (8). Physicians, medical

examiners, or coroners use cause-of-death codes from the International Statistical Classification of Diseases and Related Health Problems, 10th Revision (ICD-10) to indicate cause of death, such as maternal deaths on death certificates (6). The NVSS uses the World Health Organization definition of maternal death, as a death that occurs during pregnancy or within 42 days after the termination of a pregnancy (8). The NVSS calculates a maternal mortality ratio (number of maternal deaths per 100,000 live births). While the NVSS has the strongest historical data, it is not detailed enough to inform prevention strategies (7).

Studies have found measurement issues with NVSS that pose a challenge for accurate analysis and reporting. NVSS captures 35% fewer maternal deaths than the Pregnancy Mortality Surveillance System, another nationwide surveillance system conducted by the CDC. Reasons for this may include issues with ICD coding rules, errors relating to the completion or interpretation of the death certificate, or lack of comprehensive data sources, all of which would lead to a maternal death to be classified as not pregnancy-related (9). It is estimated that physicians, medical examiners, and coroners do not report pregnancy or recent pregnancy on death certificates for over half of such cases (10). Death certificates also do not give a complete picture of the death or understanding of causal factors leading up to death (7). In 2003, the U.S. standard death certificate was revised to include a pregnancy checkbox, with the purpose of improving collection of data on maternal death. The checkbox indicates whether a woman was pregnant at the time of death, or whether there was a temporal relationship to a pregnancy (not pregnant at time of death, but pregnant within 42 days of death) (11). Unfortunately, there was considerable variation in how long it took for states to adopt the death certificate changes. Before the 2003 revision, death certificates in 18 states had a question asking for pregnancy status, but specified different timeframes for data collection. When the U.S. standard death certificate was

revised in 2003, only 4 states added the pregnancy checkbox that same year. As of 2014, all but four states were reporting pregnancy data within the standard 42-day timeframe (6). The variation between states with regards to pregnancy information on death certificates makes it difficult to assess maternal mortality rates across time and location (6). Furthermore, the addition of the pregnancy check box can improve case identification of maternal death, but this also raises the possibility of false positives contributing to increases in pregnancy-related death, especially among women ages 40 and older (12) (13). Despite the problems with measurement, analysis of the U.S. maternal mortality rate that accounts for delays in adoption of the revised death certificate shows supports the increase in the U.S. maternal mortality rate (6).

Measurement: Pregnancy Mortality Surveillance System

The Pregnancy Mortality Surveillance System (PMSS) is a CDC-run surveillance system that collects death certificates from 52 reporting areas (50 states, New York City, Washington D.C.), along with linked birth or fetal death certificates, for women who died during pregnancy or within 1 year of pregnancy. Medical epidemiologists determine the cause of death and temporal relationship to pregnancy using codes established by the American College of Obstetricians and Gynecologists (ACOG) and the CDC Maternal Mortality Study Group (2). The PMSS measures a national pregnancy-related mortality ratio (number of pregnancy-related deaths per 100,000 live births) (7). The CDC defines a pregnancy-related death as "the death of a woman during pregnancy or within one year of the end of a pregnancy from a pregnancy complication, a chain of events initiated by pregnancy, or the aggravation of an unrelated condition by the physiologic effects of pregnancy." A pregnancy-associated, but not related death is "death of a woman during pregnancy or within one year of the end of pregnancy from a

cause that is not related to pregnancy" (4). A study comparing measures from PMSS and NVSS showed that PMSS was able to identify about 35% more deaths as pregnancy-related than NVSS reported as maternal (9). The PMSS provides the most clinically relevant measure of maternal mortality, but is still limited to information from death and birth certificates (7).

Measurement: Maternal Mortality Review Committees

Maternal Mortality Review Committees (MMRCs) identify and conduct a comprehensive review of maternal deaths to help identify areas of intervention for local, state, and national prevention strategies (7). Like PMSS, MMRCs rely on linkage of death certificates to birth and fetal death records, but MMRCs draw from a wider range of information, including medical and, when available social informants and other sources, that allow for a more complete picture of the causes leading to each case of maternal death. MMRCs are ideally composed of experts from a variety of fields, including public health, medicine, midwifery, forensic pathology, and mental health. The MMRC, the state vital records office, and epidemiologists partner to assess deaths among reproductive-aged women and determine whether any of these deaths can be classified as pregnancy-related. Medical abstractors review case information from sources such as prenatal care records, hospital records, and social services, and compile case narratives and materials on each pregnancy-related death. MMRCs decide whether the death was preventable, identify factors that lead to death, and provide recommendations to prevent death from these causes (4). MMRCs also promote preventive efforts, including provider education on placental disorders and peripartum cardiomyopathy in Florida and partnering with the Division of Highway Traffic Safety in New Jersey to add a traffic light and crosswalk to a part of a road that was associated with two maternal deaths (14).

MMRCs have existed since the 1930s, but have received increased attention in recent years and states as a way to prevent maternal death. The number of MMRCs has grown from about 19 in 2010 to about 34 by 2017 (14). The CDC partnered with the Association of Maternal and Child Health Programs (AMCHP) in 2012 to assess existing MMRCs, and found that MMRCs typically faced funding issues, lacked standard guidelines for review and standard data entry systems, and had few opportunities to network with other MMRCs (15). To tackle these challenges and improve the MMRC process, the CDC, the CDC Foundation, and AMCHP, along with financial support from Merck, partnered for an initiative known as *Building U.S. Capacity to Review and Prevent Maternal Death* (14). Through this initiative, partners created the Maternal Mortality Review Information Application (MMRIA), a standardized data collection and analysis tool (16). They also created Review to Action, a web-based portal designed to assist, empower, and connect fellow MMRCs (17). Finally, a report containing data from nine MMRCs using the MMRDS was published, focusing on causes of death, preventability, and opportunities for prevention (4). A key strength of *Building U.S. Capacity to Review and Prevent Maternal Death* is the focus on data-driven recommendations, which will hopefully help improve maternal mortality and morbidity (14).

Causes of Maternal Mortality/Risk Factors

Many risk factors are hypothesized to be contributing to the increase in maternal mortality. The increase in chronic health conditions such as obesity (18), heart disease (19), diabetes (20), and hypertensive disorders puts pregnant women at higher risk of adverse outcomes, especially cardiovascular conditions (21). More women are delaying childbirth in the U.S. (22). Advanced maternal age puts women at greater risk of complications, including

preterm delivery, poor fetal growth, fetal distress, and severe preeclampsia (23). From 2011 to 2013, less than 15% of live births were to women aged 35 and older, but this age group accounted for 30% of pregnancy-related deaths (22).

Over time, the proportion of traditional "direct" causes of pregnancy-related death, including hemorrhage, hypertensive disorders, and infection decreased and the proportion of "indirect" causes, including cardiovascular and non-cardiovascular medical conditions, cardiomyopathy, and cerebrovascular accidents increased. Cardiovascular diseases in particular showed a dramatic increase as cause of death (24). Estimates of causes of maternal mortality from 1987 to 1990 show that the most common causes of maternal mortality during this time period were hemorrhage, embolism, and hypertensive disorders of pregnancy (25). Estimates from 2011 to 2013 show that the most common causes of maternal mortality were cardiovascular disease (15.5%), other conditions reflecting preexisting illness (14.5%), infection (12.7%), hemorrhage (11.4%), and cardiomyopathy (11.0%) (26).

Racial Disparity in Pregnancy Outcomes

The black-white racial disparity in multiple pregnancy outcomes is well-documented. With regards to maternal mortality, black women have experienced an approximately four-fold the risk of death from pregnancy complications as white women for the past 5 decades (27). This disparity continues to widen (28). 46% of maternal deaths among African-American women considered preventable, as opposed to 33% among white women (5). The disparity between black and white maternal deaths is lowest among teenagers and increases with age (26). Maternal deaths are the "tip of the iceberg," and are a small fraction of the women who experience life-threatening complications as a result of pregnancy. Severe maternal morbidity occurs 50 times as

often as maternal death, and as with maternal death, black women are much more likely to experience severe maternal morbidity than white women (29).

Black and white women have different rates of pregnancy risk factors, which may contribute to disparity in maternal mortality outcomes. The rate of unintended pregnancy, which is associated with adverse pregnancy outcomes, is significantly higher among black women compared to white women (30). Black women are less likely to enter prenatal care during the first trimester of pregnancy compared to white women, although this disparity is decreasing (31). During prenatal care, black women are less likely to receive counseling from healthcare providers regarding smoking cessation and alcohol use (32). They are more likely to have preexisting medical conditions. African-American women have significantly higher rates of chronic hypertension before pregnancy compared to other women, at a rate of 25.0 per 1000 deliveries as opposed to 10.5 per 1000 deliveries for non-black women (33). African-American do not have elevated risk of gestational diabetes mellitus in comparison to white women (34), but 15.0% of African-American women of reproductive age have diabetes compared to 4.8% of white women, and 75.6% of African-American with diabetes are likely undiagnosed compared to 22.8% of white women (35). Among women of reproductive age, black women are 2.25 times more likely to be overweight or obese than white women, a disparity that loses significance once education, household income, and health insurance coverage are controlled for (36). Black women who died of pregnancy-related causes in a 2015 analysis of PMSS pregnancy-related deaths were younger, less educated, more likely to be unmarried, start prenatal care later in pregnancy, and die of ectopic pregnancy complications compared to white women (22). Black women are more likely to consume illicit drugs during pregnancy, but are significantly less likely

to smoke or consume alcohol compared to white women (30) . Black women have higher rates than white women for many risk factors associated with adverse outcomes in pregnancy.

Existing risk factors, however, do not account for all the disparity between black and white women. Evidence shows that certain conditions are deadlier for black women than for white women. A comparison of the prevalence of preeclampsia, eclampsia, abruptio placentae, placenta previa, and postpartum hemorrhage among black and white women showed that while black women do not have significantly higher prevalence of these complications as compared to white women, black women were 2 to 3 times more likely to die from these conditions as white women (27). Analysis of severe maternal morbidity in New York City shows that the racial disparity between black and white women persists even after stratifying by education, neighborhood poverty, and pre-pregnancy BMI. A black non-Latina woman with a college degree or higher is more likely to experience severe maternal morbidity (SMM) than white women who has not graduated from high school. Black non-Latina women who live in low-poverty zip codes have higher rates of SMM than white women who live in high-poverty zip codes, and those who had normal pre-pregnancy BMI had higher rates of SMM than white women who were obese pre-pregnancy (37).

The “weathering” hypothesis suggests that the effects of social inequality, including the experience of being discriminated against due to race, causes deterioration in health as a response to continued social and environmental insult or having to cope with stressful situations, in ways that accumulate across age (38). Weathering can be understood and studied through the concept of allostatic load, the cumulative negative effects of the body being forced to repeatedly adapt to various stressful environments or situations. This is mediated through regulatory systems such as the hypothalamic-pituitary-adrenal axis, the sympathetic nervous system, the

cardiovascular system, and metabolic processes (39). This "wear and tear" harms the body and increases with age. Higher allostatic loads are linked to lower cognitive and physical functioning, and higher risk for the incidence of cardiovascular disease (40). A study comparing allostatic load across age and race calculated an allostatic load score using an algorithm that took 10 biomarkers into account (systolic and diastolic blood pressure, body mass index, glycated hemoglobin, albumin, creatinine clearance, triglycerides, C-reactive protein, homocysteine, and total cholesterol). Poor black women have the highest scores, and blacks who are not poor have higher allostatic load than poor whites, reflecting the persistence of racism across age and SES (41).

Weathering is also theorized to impact reproductive health outcomes. Comparing low birth weight (LBW) and very low birth weight (VLBW) outcomes among black and white women shows that increasing maternal age is associated with higher odds of low birth weight and very low birth weight infants for black but not white women. Black women in low-income areas experience a 3-fold increase in odds of LBW and a 4-fold increase in odds of VLBW between ages 15 and 34, suggesting that the effects of discrimination and racism against black women are cumulative (38). It is crucial to consider the role of structural racism plays in perpetuating racial disparities in health outcomes.

Research indicates that race also affects treatment and outcomes in the healthcare system (42). About three-fourths of black women deliver in one-fourth of U.S. hospitals, which are more likely to be teaching hospitals, have high delivery volume, and have a higher proportion of Medicaid deliveries. Even after adjustment for patient risk factors, both black and white patients who deliver in predominantly black-serving hospitals have a higher risk of severe maternal morbidity, which suggests that hospitals that serve a higher proportion of black patients are more

likely to have lower quality of care (43). African-American women are more likely to be low-income than their white counterparts, making them less likely to have employer-based health insurance (44). Within the healthcare system, black patients consistently receive lower quality of care than white patients, even after adjusting for factors such as age, insurance status and socioeconomic status (42). Racial bias persists among healthcare providers. Most healthcare professionals have low to moderate levels of implicit racial/ethnic beliefs, which are positive towards whites and negative towards people of color. Implicit bias against people of color in a medical setting is significantly associated with poorer patient-provider interaction, treatment decisions, treatment adherence, and patient health outcomes (45). A study on racial bias with regards to pain assessment reveals that about half of white medical students and residents endorse false beliefs about biological difference between black and white patients, increasing the likelihood of inaccurate treatment and lower assessment of black patients' pain (46). In particular, black women's experiences of pain or distress are often discounted, which can lead to tragic results such as in the cases of Shalon Irving and Kira Johnson, both of whom did not have their concerns taken seriously shortly before their deaths (3, 47).

The experience of being a black woman in America has significant, often deadly consequences for health. The crisis of maternal mortality is especially severe among black women, and the role of race cannot be ignored in discussions of maternal health in the U.S.

Rural/Urban Continuum

Geographic location plays an important role as a social determinant of health. Currently, about 15% of the U.S. population (46 million) live in rural areas (48). Residents of rural areas have higher rates of excess death for five leading causes (heart disease, cancer, unintentional

injury, chronic lower respiratory disease, and stroke) than those in urban areas. Rural populations are more likely to be uninsured, rely on Medicaid or Medicare for health insurance, have fewer healthcare providers, travel further for necessary healthcare, and experience higher levels of chronic disease (49). Rural-urban disparities also vary by geographic location. The highest rates of adverse health outcomes are in large central metro counties of the Northeast and Midwest and in nonmetro counties in the South and West (50).

Women who live in rural areas have worse health outcomes than urban women and face significant barriers to access and coverage (51). As of 2011, approximately 16.7% of U.S. women lived in rural areas (52). Rural women experience higher rates of poor health status, suicide, cerebrovascular disease deaths, and risk factors such as obesity and smoking than their urban counterparts. Rural women are also less likely to access reproductive health services (51).

Rural counties face significant challenges with regards to specialized healthcare access. Health care professionals tend to practice in urban and suburban areas as opposed to rural areas. Although 21% of the U.S. population lives in rural areas, only about 10% of physicians practice in rural areas, a shortage that has persisted for decades (53). About 15% of mothers give birth in rural hospitals, and a majority of these women deliver on Medicaid. Medicaid typically reimburses hospitals less for pregnancy, which adds to the financial burden of obstetric care in rural settings (54). From 2004-2014, 9% of rural counties in America lost all hospital obstetric services, while 45% of rural counties did not have any hospital obstetric services during this time. Of the 179 rural counties that lost all hospital obstetric services, 69 were in geographically isolated areas, making access to care in these areas even more difficult. Counties with higher percentages of non-Hispanic black women of reproductive age had higher odds of lacking hospital obstetric services (55). Losing hospital obstetric services in rural counties that are not

adjacent to urban areas is significantly associated with an increase in out-of-hospital births, preterm births, and births in hospitals without obstetric units (56). Rural counties suffer from a shortage of healthcare professionals, and the density of ob-gyns decreases with increasing rurality (57). The lack of obstetric care may require women to travel further to receive adequate pre-conceptional, prenatal, and delivery care. 93.4% of reproductive-aged women who live in metropolitan areas live within a 30-minute drive of the nearest hospital offering perinatal care, while only 49.8% of those in rural towns and 28.8% of those in isolated rural areas do. (58). Living far from obstetric care while pregnant can have disastrous, life-threatening outcomes for both mothers and babies.

There are several classification systems that are used to define urban and rural areas in the U.S. The systems relevant to this study are from the NCHS, the U.S. Census, and the USDA.

The National Center for Health Statistics (NCHS) categorizes counties using a six-level classification system in order to study the association between location/urbanization and health outcomes (59). There are four metropolitan levels and two nonmetropolitan areas. In order of decreasing urbanization, the categories are large central metro, large fringe metro, medium metro, small metro, micropolitan, and noncore. Counties are categorized according to the Office of Budget and Management's (OMB) definitions of metropolitan versus micropolitan statistical areas, population size, and location of principal city populations within metropolitan statistical areas (MSAs) (60). This measurement system takes economic and social interdependence into account. Residents of large fringe metros generally have better health measures than those of either large central metros or rural counties, with lower rates of premature mortality, teenage childbearing, and number without dental or health insurance (59).

The U.S. Census categorizes counties as completely rural, mostly rural, and mostly urban. Census blocks are the smallest unit of measurement in this system. Total population thresholds, density, land use, and distance are used to categorize census blocks into urbanized areas (50,000 or more people) and urban clusters (more than 2,500 and less than 50,000 people). The remaining territory is categorized as rural. At the county level, completely rural counties have a 100% rural population, mostly rural counties have a population that is 50% or more rural, and mostly urban counties have a population that is less than 50% rural (61). Although analysis of more recent U.S. Census rural-urban classifications for us in health research is not available, limitations of using the 1990 U.S. Census rural-urban classifications include lack of variation within the definition of rural and economic interdependence, which may have an impact on healthcare services (62).

The USDA Rural-Urban Continuum Codes subdivides the OMB metro and nonmetro categories into three metro and six nonmetro categories by urbanization and adjacency to metro areas. The three metro categories are separated by population into areas with 1 million or more, 250,000 to 1 million, or fewer than 250,000). Nonmetro areas are classified according to population and adjacency to a metro area into urban population of 20,000 or more that is adjacent to a metro area, urban population of 20,000 or more not adjacent to a metro area, urban population of 2,500 to 19,999 adjacent to a metro area, urban population of 2,500 to 19,999 not adjacent to a metro area, completely rural or less than 2,500 urban population adjacent to a metro area, and completely rural or less than 2,500 urban population not adjacent to a metro area (63). This takes adjacency to a larger economy into account, but not the scale of the adjacent area that contains the larger economy (62).

The relationship between race and rural vs. urban location as it pertains to maternal mortality is worth investigating. A recent study comparing pregnancy-related deaths in Georgia found that although the overall pregnancy-related mortality ratio did not differ across rural (population less than 35,000), nonrural (population greater than 35,000), and metropolitan counties, black women had significantly higher pregnancy-related mortality ratios than white women in nonrural and metropolitan counties but not in rural counties (64). Although non-Hispanic blacks are more likely to live in large metro counties, racial distribution can vary by region. 16% of the population in nonmetro counties in the South is non-Hispanic black, as opposed to less than 3% in the Northeast, Midwest, and West (50).

Chapter II. Manuscript

Introduction

The maternal mortality rate in the United States is highest among developed countries and continues to rise, despite decreasing globally (1). Multiple risk factors are thought to contribute to the increase. Increases in chronic conditions such as obesity (18), heart disease (19), diabetes, and hypertensive disorders put women at higher risk of adverse health outcomes such as cardiovascular conditions (21). More women are delaying childbirth, and advanced maternal age increases the likelihood of including preterm delivery, poor fetal growth, fetal distress, and severe preeclampsia (23). Despite the high and rising rate of maternal mortality, 60% of maternal deaths in the United States are preventable (4). Estimates from 2011 to 2013 show that the most common causes of maternal mortality were cardiovascular disease (15.5%), other conditions reflecting preexisting illness (14.5%), infection (12.7%), hemorrhage (11.4%), and cardiomyopathy (11.0%) (26).

Within the trend of rising maternal mortality, black women have experienced an approximate four-fold risk of death from pregnancy complication in comparison to white women for the past 50 years, a disparity that is continuing to increase over time (27, 28).

Black women are more likely than white women to have pregnancy risk factors that increase the likelihood of adverse pregnancy outcomes. Black women have higher rates of unintended pregnancy (30), are more likely to be late to prenatal care or receive inadequate prenatal care (65), and have preexisting medical conditions such as chronic hypertension (33), diabetes (35), obesity (36) in comparison to white women. In addition, black women are more likely to be low-income than white women and therefore less likely to be covered by employer-based health insurance (44).

Risk factors alone, however, cannot account for all the disparity between black and white women. The same conditions may be deadlier for black women than white women. Although black women do not have a significantly higher prevalence of preeclampsia, eclampsia, abruptio placentae, placenta previa, and postpartum hemorrhage, they are 2-3 times more likely to die from the conditions than white women (27). The racial disparity between black and white women for severe maternal morbidity persists after stratifying by education, neighborhood poverty, and pre-pregnancy BMI. Black women with at least a college degree are more likely to experience severe maternal morbidity than white women who do not have a high school degree (37).

A potential explanation for the persistent racial disparity in outcomes which cannot be fully explained by individual risk factors is the experience of race and how it gets "under the skin." The weathering hypothesis suggests that continual social and environmental insult due to race causes deterioration in health that accumulates across age (38). Allostatic load refers to the cumulative negative effects on a number of regulatory systems, including the hypothalamic-pituitary-adrenal axis, the sympathetic nervous system, the cardiovascular system, and metabolic processes of repeatedly being forced to respond to stressful environments or situations (39). Higher allostatic load has been associated with lower cognitive and physical functioning, as well as higher risk for cardiovascular disease (40). Comparison of allostatic load scores (calculated using an algorithm that uses 10 biomarkers) across race and age shows that blacks have higher mean allostatic scores than whites at all ages, and the disparity increases with age. Poor black women have the highest scores, and blacks who are not poor have higher allostatic load than poor whites, reflecting the persistence of racism across age and socioeconomic status (41).

Patterns of racial disparities in reproductive health outcomes support the weathering hypothesis. A comparison of low birth weight shows that increasing maternal age is associated with higher odds of low birth weight and very low birth weight infants for black but not white women. Black women in low-income areas experience a 3-fold increase in odds of LBW as compared to white women, and a 4-fold increase in odds of VLBW between ages 15 and 34, suggesting that the effects of discrimination and racism against black women accumulate with age (38).

Race also affects receipt and quality of medical treatment. Black patients consistently receive poorer care than white patients, even after adjusting for age, insurance status and socioeconomic status (42). Racism among medical professionals is rooted in the history of medicine. A systematic review of implicit racial/ethnic bias among healthcare professionals found that most have low to moderate levels of bias, in the direction of positive attitudes toward whites and negative attitudes towards people of color. Implicit bias is significantly associated with worse patient-provider interactions, treatment decisions, treatment adherence, and patient health outcomes (45).

Rurality is another social determinant of health that influences health outcomes. People living in rural areas have higher rates of excess death for heart disease, cancer, unintentional injury, chronic lower respiratory disease, and stroke. They are more likely to be uninsured, use Medicaid or Medicare, have fewer healthcare providers, travel further for care, and experience chronic disease (49). In particular, rural women generally have poorer health status and are less likely to access reproductive health services (51).

Rural counties face significant challenges in health care, particularly obstetrics. 9% of rural counties in the U.S. lost all hospital obstetric services from 2004-2014, and 45% of rural

counties did not have any hospital obstetric services during this time. Losing hospital obstetric services in rural counties that are not adjacent to urban areas is significantly associated with an increase in out-of-hospital births, preterm births, and births in hospitals without obstetric units. Women living in rural areas must travel further to seek obstetric care, an added barrier which is associated with fewer prenatal visits (56).

With regards to the classification of urban and rural areas, different classifications of urban and rural areas are often used in social science but these measures are less frequently used in epidemiological research (62). It is unclear whether using different classification systems yields similar patterns of disparities across geographic location. The implications of the different measurement schemes on health outcomes is a gap in the literature.

The impact of race and rurality is important to study given the significant disparity between black and white mothers and the increasing challenges in rural healthcare. A study investigating pregnancy-related deaths in Georgia found that the pregnancy-related mortality ratio between black and white women was highest in metropolitan Atlanta at 51.6 deaths per 100,000 live births vs. 12.4 deaths per 100,000 births. It was significant but less drastic in nonrural areas at (50.3 vs. 12.0), and not significantly different in rural areas (39.4 vs. 22.4) (64). Although non-Hispanic blacks are more likely to live in large metro counties, racial distribution can vary by region. 16% of the population in nonmetro counties in the South is non-Hispanic black, as opposed to less than 3% in the Northeast, Midwest, and West (50). The loss of obstetric services is not uniform across counties – counties with higher percentages of non-Hispanic black women of reproductive age have higher odds of lacking hospital obstetric services (55). The experience of being black may intensify the challenges of giving birth in a rural setting. This

study investigates whether maternal mortality ratios vary across different measurements of the rural/urban continuum, and assess whether there is an interaction between race and rurality.

Methods

Data Sources

Data on maternal deaths in 12 participating states was abstracted from the Maternal Mortality Review Information Application (MMRIA). MMRIA is a Building U.S Capacity to Review and Prevent Maternal Deaths initiative, a partnership between the Center for Disease Control and Prevention's (CDC) Division of Reproductive Health, the Association of Maternal & Child Health Programs and the CDC Foundation (7). MMRIA is used to collect information on maternal deaths from state-level Maternal Mortality Review Committees (MMRCs) (66). Information on pregnancy-related deaths was available for the following states and years: Alabama, 2013; Delaware, 2009-2016; Georgia, 2012-2013; Hawaii, 2015; Illinois, 2015; Maryland, 2009; Mississippi, 2016; North Carolina, 2015; New Hampshire, 2013; Ohio, 2008-2016; Utah, 2015-2016; West Virginia, 2010. Pregnancy-related mortality is defined as the death of a woman during pregnancy or within a year of the end of a pregnancy, where the pregnancy is causal to the death (i.e. complications due to pregnancy, chain of events initiated by the pregnancy, aggravation of an unrelated condition due to pregnancy) (2). Deaths missing a FIPS county code were excluded. The number of deaths was aggregated by county of residence, race, and year of maternal death to produce the numerator for the pregnancy related mortality ratio. Analysis was limited to non-Hispanic black and non-Hispanic white maternal deaths.

Data on live births was obtained from NCHS natality records. The number of live births was aggregated by county, race, and year to produce the denominator for the pregnancy related

mortality ratio. The dataset was limited to non-Hispanic black and non-Hispanic white live births. Because individual-level covariates were not available from the MMRIA dataset, county-level data was used to create ecological summaries of maternal education, age, and preterm birth. The number of live births with the variable in question were divided by the total number of live births in that county, race, and year category to obtain the percentages. Ecological covariates included percentage of live births to mothers with less than a high school education, percentage of live births to mothers older than 35 years of age, and percentage of live births that were preterm.

Rural/urban measurement systems from the National Center for Health Statistics (NCHS), the United States Census Bureau, and United States Department of Agriculture Economic Research Service were used to categorize counties. The 2013 NCHS Urban-Rural Classification Scheme for Counties classifies counties according to three criteria: their status as metropolitan, micropolitan, and noncore statistical areas as based on the Office of Management and Budget's 2010 standards, the population size of metropolitan statistical areas (MSAs), and the location of principal city populations within the largest MSAs (1 million or more). The six categories of classification, in order of decreasing urbanization, are large central metro (in MSAs of 1 million or more and contain the entire population of the largest principal city of the MSA, have their entire population contained in the largest principal city of the MSA, or contain at least 250,000 inhabitants of any principal city of the MSA), large fringe metro (counties in MSAs of 1 million or more that do not qualify as large central metro counties), medium metro (counties in MSAs of populations of 250,000 to 999,999), small metro (counties in MSAs of populations less than 250,000), micropolitan, and noncore. The NCHS guidelines are typically used to understand urban-rural health differences (60). The 2010 U.S. Census County Codes categorizes counties as

completely rural, mostly rural, and mostly urban according to what percentage of the population is rural. Determination of urbanicity done at the block level, taking total population threshold, density, land use, and distance into account to create urbanized areas and urban clusters. Rural is defined as the population, housing, and territory not within an urbanized area or urban cluster. Completely rural counties have a 100% rural population, mostly rural counties have a population that is 50% or more rural, and mostly urban counties have a population that is less than 50% rural (61). The 2013 USDA Rural-Urban Continuum Codes subdivides OMB 2013 metro and nonmetro categories into three metro and six nonmetro categories according to degree of urbanization and adjacency to metro areas. Among the metro counties, the three levels are separated by population in metro areas (1 million or more, 250,000 to 1 million, or fewer than 250,000). The nonmetro counties are distinguished by population and adjacency to a metro area: urban population of 20,000 or more that is adjacent to a metro area, urban population of 20,000 or more not adjacent to a metro area, urban population of 2,500 to 19,999 adjacent to a metro area, urban population of 2,500 to 19,999 not adjacent to a metro area, completely rural or less than 2,500 urban population adjacent to a metro area, and completely rural or less than 2,500 urban population not adjacent to a metro area (63). For the purposes of this study, each of the measurement systems was split into a dichotomous variable to determine county assignment as rural or non-rural. The levels of the 2013 NCHS measurement system were categorized by metro vs. nonmetro status. For the U.S. Census system, the completely rural and mostly rural categories were assigned as rural and the mostly urban level was assigned as urban. For the USDA system, metro counties and nonmetro counties adjacent to metro areas were grouped together as metro/metro-adjacent, and nonmetro counties that were not adjacent to metro areas were grouped as non-metro-adjacent.

The MMRIA dataset, live births dataset, and county rural/urban measurements were linked using county FIPS codes for this retrospective cohort study. Live births in states and years where a black or white maternal death was recorded in MMRIA were included to create a denominator of live births where mothers were at risk for maternal death.

Statistical Analysis

Generalized estimating equation (GEE) models with negative binomial regression were used to determine whether the association between race and maternal death varies across different measurements of rural vs. urban, and whether there is interaction between race and rurality. Negative binomial regression was used to account for overdispersion in the dataset. Models were fit separately to compare outcomes for NCHS, U.S. Census, and USDA rural/urban classification systems. Confounders included percentage of live births to mothers with less than a high school education, percentage of live births to mothers older than 35 years of age, percentage of live births that were preterm, and year.

Target associations were estimated for each regression given a series of confounders. The interaction term of race*rurality was tested using the Wald chi-square test statistic. The Incidence Density Ratios (IDRs) were reported for several sets of confounders per each classification system.

Analysis was conducted using SAS 9.4. and p-values less than 0.05 were considered insignificant.

Results

There were 1,636 counties included in this analysis (Table 1). This includes all counties in states where a pregnancy-related death occurred. The NCHS and U.S. Census classifications resulted in similar proportions of rural and urban counties. Using NCHS definitions resulted in 46.5% urban and 56.5% rural counties. The U.S. Census classification system led to 44.0% of counties assigned as urban and 56.0% assigned as rural. The USDA classification system designated 85.8% of counties as urban or urban-adjacent and 14.2% of counties as rural or not urban-adjacent.

Table 2 describes the demographic characteristics of the pregnancy-related deaths and the NCHS natality data in states participating in MMRIA. There were 1,757,863 total live births and 262 total pregnancy-related deaths in the linked dataset. Among the live births, 391,934 (22.3%) were black. 109 (41.6%) of pregnancy-related deaths were non-Hispanic black. A majority of live births occurred in non-rural or metro/metro-adjacent areas. Of live births, 19.4% were rural using NCHS classifications, 16.0% were rural using U.S. Census classifications, and 3.2% were not metro-adjacent using USDA classifications. Of the maternal deaths, 21.4% were rural using NCHS classifications, 17.2% were rural using U.S. Census classifications, and 3.8% were not metro-adjacent using USDA classifications.

Several GEE models with negative binomial regression were fit to compare IDRs across the three rural-urban designations and assess interaction between race and rurality for each. The unadjusted IDR for the risk of pregnancy-related deaths between non-Hispanic black and non-Hispanic white mothers using the NCHS rural/urban designations was 2.58 (95% CI: 1.40, 4.75) in rural counties and was 2.62 (95% CI: 2.01, 3.43) in urban areas. Adjusting for percentage of live births to mothers with less than a high school education, percentage of live births to mothers

older than 35 years, percentage of live births that were preterm, and year of pregnancy-related death resulted in an IDR of 2.65 (95% CI: 1.30, 5.39) in rural areas and 2.31 (95% CI: 1.51, 3.53). The interaction term was not significant (p=0.689 for the adjusted model). Using the U.S. Census classification system resulted in an unadjusted black-white IDR of 4.11 (95% CI: 2.31, 7.32) in rural counties and 2.37 (95% CI: 1.81, 3.11) in urban counties; an adjusted IDR 4.08 (95% CI: 2.10, 7.94) in rural counties and 2.10 (95% CI: 1.37, 3.21) in urban counties. The interaction was significant for the adjusted model (p=0.045). The USDA classification system resulted in an unadjusted IDR of 2.04 (95% CI: 0.61, 6.76) in rural counties and 2.50 (95%: 1.97, 3.18) in urban areas. The adjusted IDR for the USDA classifications was 2.15 (95% CI: 0.63, 7.32) in rural counties and 2.29 (95% CI: 1.53, 3.43) in urban counties. The interaction was not significant for the adjusted model.

Discussion

Analysis of MMRIA data from selected years and states shows that non-Hispanic black women experience higher rates of maternal death than non-Hispanic white women, a disparity that shows some variation across rural and urban areas depending on the rural-urban classification system. The disparity between non-Hispanic black and non-Hispanic white women is supported by the literature (27). The adjusted IDR comparing the risk of pregnancy-related death for non-Hispanic black women as compared to non-Hispanic white women is similar across USDA definitions of rural and urban, modestly higher for NCHS rural vs. urban counties, and almost twice as high for U.S. Census rural counties as urban counties, although the confidence intervals overlap. The interaction term was not significant for models using NCHS

and USDA definitions, but was significant for the U.S. Census definition model. The interaction between rurality and race is only significant when using the U.S. Census definition of rurality.

Strengths of the study include innovative use of rural-urban categorization systems to apply to maternal mortality. Using three different classification systems allows for the counties to be analyzed according to different criteria. The NCHS system relies on OMB status as metropolitan, micropolitan, or noncore statistical areas, population size and principal city location for county distinction (60). The U.S. Census uses total population threshold, density, land use, and distance into account (61), and the USDA system takes adjacency to metro counties into account (63). In order to study rural-urban disparities, it is important to also understand the systems of measurement that can be used to classify areas as rural or urban. The measurement of urbanicity and rurality remains a gap in the literature that is important to study, especially in the context of understanding health disparities. In terms of capturing pregnancy-related deaths, MMRIA dataset captures pregnancy-related deaths through state-level MMRCs. The thorough data collection and standardization process ideally allows for more accurate ascertainment of pregnancy-related deaths, preventability of deaths, and identify opportunities for prevention (7).

The study has several weaknesses that should be noted. Individual-level covariate data was limited in the MMRIA aggregated dataset. Ecological covariates were calculated from the NCHS natality dataset. Percent of live births to mothers with less than a high school education was used as a proxy for education, percent of live births to mothers older than 35 was used as a proxy for maternal age, and percent of live births that were preterm was used as a proxy for preterm birth. Because these are proxies for confounders, there is the possibility for error if the proxies do not directly estimate the covariates, particularly in counties with a small number of

live births. Ecological covariates raise the possibility for ecological bias, as the ecological covariates included in the model may not apply to an individual's outcome. Furthermore, covariates were limited to what was available in the NCHS natality dataset. Factors such as obesity, hypertension, cardiovascular disease, and income could not be included as confounders in the regression, leading to potential bias away from the null due to lack of adjustment.

There is also the issue of what data was available for this analysis. Only MMRIA data from complete years of data collection was included in this analysis. The full range of maternal mortality in the U.S. is not captured through this dataset. Although MMRIA is considered to be the most accurate and complete source of data on maternal mortality in the United States, there is the potential for misclassification of pregnancy-related deaths. While the MMRIA standardizes the identification of pregnancy-related death, there remains the potential for systematic and random error (7).

This study contributes to the literature because given the persistent racial disparity in maternal mortality and the public health importance of maternal and child health, it is important to study the many reasons that non-Hispanic black women experience higher rates of maternal death. The disparity expands to other areas of maternal and child health - severe maternal morbidity occurs 50 times as often as maternal death, and as with maternal death, black women are much more likely to experience severe maternal morbidity than white women (29). As rural health in the U.S. faces continuing challenges with regards to physician shortage and hospital closure, identifying ways in which black women may face specific, unique challenges in maternal health based on how rural or urban their surroundings are could be necessary for intervention and treatment.

Chapter III. Discussion

This study shows that the disparity in IDR for pregnancy-related deaths (in selected states participating in MMRIA) between non-Hispanic black and non-Hispanic white women shows heterogeneity between rurality and urbanicity depending on which rural-urban classification system was used. First, it is important to note that non-Hispanic black women face at least twice the risk of maternal death compared to white women, which is supported by the literature (2, 22, 24-27, 66, 67). This elevated risk is consistent across rural-urban county designations based on the 2013 NCHS Urban-Rural Classification Scheme for Counties, the 2010 U.S. Census County Codes, and the 2013 USDA Rural-Urban Continuum Codes.

The risk of pregnancy-related death for non-Hispanic black women compared to non-Hispanic white women can vary across rural and urban counties depending on the classification system used to define rural vs. urban. Negative binomial regression models were fit separately for each rural-urban classification system and assess the interaction between race and rurality, adjusting for percentage of live births to mothers with less than high school education, percentage of live births to mothers older than 35 years of age, percentage of live births that were preterm, and year of pregnancy-related death. The adjusted IDR using the USDA classification shows that non-Hispanic black women have similar increased risk of pregnancy-related death in comparison to non-Hispanic white women in both rural and urban counties, with risk in urban counties slightly higher. The model based on the NCHS classification scheme results in an adjusted IDR for non-Hispanic black women that is moderately higher in rural areas compared to urban areas. The U.S. Census system model showed the largest difference in adjusted IDR between rural and urban areas. The interaction between rurality and race was only significant for the adjusted U.S. Census model.

There has been little research applying different classification systems to study health outcomes, but is important to understand these classifications because different definitions will have an impact on our understanding of rural and urban disparities. The NCHS system categorizes counties by OMB status as metropolitan, micropolitan, or noncore statistical areas, the population size of metropolitan statistical areas (MSAs), and the location of principal city populations within the largest MSAs (60). The U.S. Census scheme uses total population thresholds, density, land use, and distance to categorize counties (61). The USDA system categorizes counties by population and adjacency to metro areas (63). Comparing NCHS, U.S. Census, and USDA classification schemes confirms that using different definitions results in different risks for black vs. white pregnancy-related death across rural and urban counties. The interaction between rurality and race is only significant in the model using the U.S. Census County Codes.

In addition to the novel application of rural-urban classifications to maternal mortality data, the MMRIA dataset consists of data collected from state-level MMRCs. In an ideal situation, a fully-functional MMRC collects robust, accurate data to inform policy, process, clinical care, and public health, provide data-driven solutions to guide prevention and policy, and eventually reduce maternal mortality and morbidity (14). The Report from Nine Mortality Review Committees notes that state and local-level MMRCs could be a gold standard for understanding preventability of maternal deaths and identifying strategies to reduce maternal deaths as more MMRCs share data (66).

Although MMRIA data is collected in a standardized manner, this analysis was limited to data from 12 states during selected years from MMRIA, and thus does not capture the full range of pregnancy-related death in the United States. Individual-level covariates from MMRIA were

limited. Ecological covariates were calculated based on NCHS natality data, leaving open the possibility for ecological bias. A wider range of confounders could not be included in this analysis due to data limitations, which is a potential source of bias. Although MMRIA provides a platform for standard data collection, there is still the potential for heterogeneity between different state-level MMRCs. Maternal deaths may be misclassified, leading to inaccurate measurements of risk.

This study contributes to the literature because it takes a novel approach to understanding both racial and rural/urban disparities in pregnancy-related death. There have been few studies utilizing a variety of rural-urban classification schemes to understand rural/urban disparities in health outcomes. Given the persistent disparity between non-Hispanic black and non-Hispanic white maternal mortality and the continual increase of pregnancy-related death among black women, it is important to understand how rurality or urbanicity may be contributing to this burden. Rural and urban areas can differ greatly in terms of prevalence of chronic conditions, certain risk behaviors, and access to healthcare (50). In particular, the lack of obstetric care is more likely in rural counties with a higher proportion of non-Hispanic black women, indicating that black women in rural areas face specific healthcare access challenges due to race (55). Specific geographic barriers may affect black women differently, increasing the likelihood of a higher allostatic load.

Additional research should be conducted to further analyze how different rural-urban classification systems may impact the measurement of rural/urban disparities for a variety of health outcomes. An interesting future direction would be investigating the difference between urban, rural, and suburban maternal mortality outcomes. Suburbs were originally constructed to specifically constructed to be predominantly white and affluent through deliberate discriminatory

policies and residential segregation, but economic and racial diversity in the suburbs has significantly increased in recent years (68). Due to the economic instability of the 2000s, more residents living below the federal poverty line reside in suburbs as opposed to cities and rural areas (69). The rising inequality in the suburbs, especially among people of color, warrants research and discussion especially because the suburbs are typically viewed as areas of relative wealth and economic security that are safe from the health problems of urban centers and rural areas.

References

1. Collaborators GBDMM. Global, regional, and national levels of maternal mortality, 1990-2015: a systematic analysis for the Global Burden of Disease Study 2015. *Lancet* 2016;388(10053):1775-812.
2. Pregnancy Mortality Surveillance System. Division of Reproductive Health, National Center for Chronic Disease Prevention and Health Promotion; 2018. (https://www.cdc.gov/reproductivehealth/maternalinfanthealth/pregnancy-mortality-surveillance-system.htm). (Accessed December 21, 2018).
3. Martin N MR. Black Mothers Keep Dying After Giving Birth. Shalon Irving's Story Explains Why [electronic article]. Advance Access: October 20, 2018.
4. Hassdedt K. DS, Ansari-Thomas Z. Immigrant Women's Access to Sexual and Reproductive Health Coverage and Care in the United States. The Commonwealth Fund, 2018:1-10.
5. Berg CJ, Harper MA, Atkinson SM, et al. Preventability of pregnancy-related deaths: results of a state-wide review. *Obstet Gynecol* 2005;106(6):1228-34.
6. MacDorman MF, Declercq E, Cabral H, et al. Recent Increases in the U.S. Maternal Mortality Rate: Disentangling Trends From Measurement Issues. *Obstet Gynecol* 2016;128(3):447-55.
7. St Pierre A, Zaharatos J, Goodman D, et al. Challenges and Opportunities in Identifying, Reviewing, and Preventing Maternal Deaths. *Obstet Gynecol* 2018;131(1):138-42.
8. Hoyert DL. Maternal mortality and related concepts. *Vital Health Stat 3* 2007(33):1-13.
9. MacKay AP, Berg CJ, Duran C, et al. An assessment of pregnancy-related mortality in the United States. *Paediatr Perinat Epidemiol* 2005;19(3):206-14.
10. Horon IL, Cheng D. Enhanced surveillance for pregnancy-associated mortality--Maryland, 1993-1998. *JAMA* 2001;285(11):1455-9.
11. Report of the Panel to Evaluate the U.S. Standard Certificates. National Center for Health Statistics, 2000:1-225.
12. Horon IL, Cheng D. Effectiveness of pregnancy check boxes on death certificates in identifying pregnancy-associated mortality. *Public Health Rep* 2011;126(2):195-200.
13. Davis NL, Hoyert DL, Goodman DA, et al. Contribution of maternal age and pregnancy checkbox on maternal mortality ratios in the United States, 1978-2012. *Am J Obstet Gynecol* 2017;217(3):352 e1- e7.
14. Zaharatos J, St Pierre A, Cornell A, et al. Building U.S. Capacity to Review and Prevent Maternal Deaths. *J Womens Health (Larchmt)* 2018;27(1):1-5.
15. Goodman D, Stampfel C, Creanga AA, et al. Revival of a core public health function: state- and urban-based maternal death review processes. *J Womens Health (Larchmt)* 2013;22(5):395-8.
16. C S. CDC Foundation Partnership To Help Reduce Maternal Mortality In The United States. CDC Foundation; 2016. (https://www.cdcfoundation.org/pr/2016/cdc-foundation-partnership-help-reduce-maternal-mortality-united-states). (Accessed December 22, 2018).
17. About Us. Review to Action. (https://reviewtoaction.org/about-us). (Accessed December 22, 2018).
18. Fisher SC, Kim SY, Sharma AJ, et al. Is obesity still increasing among pregnant women? Prepregnancy obesity trends in 20 states, 2003-2009. *Prev Med* 2013;56(6):372-8.

19. Kuklina E, Callaghan W. Chronic heart disease and severe obstetric morbidity among hospitalisations for pregnancy in the USA: 1995-2006. *BJOG* 2011;118(3):345-52.
20. Albrecht SS, Kuklina EV, Bansil P, et al. Diabetes trends among delivery hospitalizations in the U.S., 1994-2004. *Diabetes Care* 2010;33(4):768-73.
21. Kuklina EV, Ayala C, Callaghan WM. Hypertensive disorders and severe obstetric morbidity in the United States. *Obstet Gynecol* 2009;113(6):1299-306.
22. Creanga AA, Berg CJ, Syverson C, et al. Pregnancy-related mortality in the United States, 2006-2010. *Obstet Gynecol* 2015;125(1):5-12.
23. Cavazos-Rehg PA, Krauss MJ, Spitznagel EL, et al. Maternal age and risk of labor and delivery complications. *Matern Child Health J* 2015;19(6):1202-11.
24. Berg CJ, Callaghan WM, Henderson Z, et al. Pregnancy-Related Mortality in the United States, 1998 to 2005. *Obstet Gynecol* 2011;117(5):1230.
25. Berg CJ, Atrash HK, Koonin LM, et al. Pregnancy-related mortality in the United States, 1987-1990. *Obstet Gynecol* 1996;88(2):161-7.
26. Creanga AA, Syverson C, Seed K, et al. Pregnancy-Related Mortality in the United States, 2011-2013. *Obstet Gynecol* 2017;130(2):366-73.
27. Tucker MJ, Berg CJ, Callaghan WM, et al. The Black-White disparity in pregnancy-related mortality from 5 conditions: differences in prevalence and case-fatality rates. *Am J Public Health* 2007;97(2):247-51.
28. Moaddab A, Dildy GA, Brown HL, et al. Health Care Disparity and Pregnancy-Related Mortality in the United States, 2005-2014. *Obstet Gynecol* 2018;131(4):707-12.
29. Callaghan WM, Mackay AP, Berg CJ. Identification of severe maternal morbidity during delivery hospitalizations, United States, 1991-2003. *Am J Obstet Gynecol* 2008;199(2):133 e1-8.
30. Beck LF, Morrow B, Lipscomb LE, et al. Prevalence of selected maternal behaviors and experiences, Pregnancy Risk Assessment Monitoring System (PRAMS), 1999. *MMWR Surveill Summ* 2002;51(2):1-27.
31. Alexander GR, Kogan MD, Nabukera S. Racial differences in prenatal care use in the United States: are disparities decreasing? *Am J Public Health* 2002;92(12):1970-5.
32. Kogan MD, Kotelchuck M, Alexander GR, et al. Racial disparities in reported prenatal care advice from health care providers. *Am J Public Health* 1994;84(1):82-8.
33. Samadi AR, Mayberry RM, Zaidi AA, et al. Maternal hypertension and associated pregnancy complications among African-American and other women in the United States. *Obstet Gynecol* 1996;87(4):557-63.
34. Hedderson M, Ehrlich S, Sridhar S, et al. Racial/ethnic disparities in the prevalence of gestational diabetes mellitus by BMI. *Diabetes Care* 2012;35(7):1492-8.
35. Britton LE, Hussey JM, Crandell JL, et al. Racial/Ethnic Disparities in Diabetes Diagnosis and Glycemic Control Among Women of Reproductive Age. *J Womens Health (Larchmt)* 2018;27(10):1271-7.
36. Vahratian A. Prevalence of overweight and obesity among women of childbearing age: results from the 2002 National Survey of Family Growth. *Matern Child Health J* 2009;13(2):268-73.
37. Severe Maternal Morbidity in New York City, 2008–2012. New York, NY: New York City Department of Health and Mental Hygiene, 2016:1-36.

38. Geronimus AT. Black/white differences in the relationship of maternal age to birthweight: a population-based test of the weathering hypothesis. *Soc Sci Med* 1996;42(4):589-97.
39. McEwen BS, Seeman T. Protective and damaging effects of mediators of stress. Elaborating and testing the concepts of allostasis and allostatic load. *Ann N Y Acad Sci* 1999;896:30-47.
40. Seeman TE, Singer BH, Rowe JW, et al. Price of adaptation--allostatic load and its health consequences. MacArthur studies of successful aging. *Arch Intern Med* 1997;157(19):2259-68.
41. Geronimus AT, Hicken M, Keene D, et al. "Weathering" and age patterns of allostatic load scores among blacks and whites in the United States. *Am J Public Health* 2006;96(5):826-33.
42. Nelson A. Unequal treatment: confronting racial and ethnic disparities in health care. *J Natl Med Assoc* 2002;94(8):666-8.
43. Howell EA, Egorova N, Balbierz A, et al. Black-white differences in severe maternal morbidity and site of care. *Am J Obstet Gynecol* 2016;214(1):122 e1-7.
44. Racial and Ethnic Disparities in Women's Health Coverage and Access to Care. Henry J. Kaiser Family Foundation, 2004:1-8.
45. Hall WJ, Chapman MV, Lee KM, et al. Implicit Racial/Ethnic Bias Among Health Care Professionals and Its Influence on Health Care Outcomes: A Systematic Review. *Am J Public Health* 2015;105(12):e60-76.
46. Hoffman KM, Trawalter S, Axt JR, et al. Racial bias in pain assessment and treatment recommendations, and false beliefs about biological differences between blacks and whites. *Proc Natl Acad Sci U S A* 2016;113(16):4296-301.
47. E. C. 'An amazing first step': Advocates hail Congress's maternal mortality prevention bill [electronic article].
48. Leading Causes of Death in Rural America. Centers for Disease Control and Prevention; 2017. (https://www.cdc.gov/ruralhealth/cause-of-death.html). (Accessed December 20 2018).
49. Hart LG, Larson EH, Lishner DM. Rural definitions for health policy and research. *Am J Public Health* 2005;95(7):1149-55.
50. Meit M KA, Gilbert T, Yu AT, Tanenbaum E, Ormson E, TenBroeck S, Bayne A, Popat S, NORC Walsh Center for Rural Health Analysis. The 2014 Update of the Rural-Urban Chartbook. Rural Health Reform Policy Research Center, 2014:1-136.
51. ACOG Committee Opinion No. 586: Health disparities in rural women. *Obstet Gynecol* 2014;123(2 Pt 1):384-8.
52. Women's Health USA 2013. Rockville, Maryland: U.S. Department of Health and Human Services, Health Resources and Services Administration, 2013.
53. Rural Practice, Keeping Physicians In (Position Paper). American Academy of Family Physicians, 2014.
54. Kozhimannil KB, Hung P, Prasad S, et al. Rural-urban differences in obstetric care, 2002-2010, and implications for the future. *Med Care* 2014;52(1):4-9.
55. Hung P, Henning-Smith CE, Casey MM, et al. Access To Obstetric Services In Rural Counties Still Declining, With 9 Percent Losing Services, 2004-14. *Health Aff (Millwood)* 2017;36(9):1663-71.

56. Kozhimannil KB, Hung P, Henning-Smith C, et al. Association Between Loss of Hospital-Based Obstetric Services and Birth Outcomes in Rural Counties in the United States. *JAMA* 2018;319(12):1239-47.
57. Rayburn WF, Klagholz JC, Murray-Krezan C, et al. Distribution of American Congress of Obstetricians and Gynecologists fellows and junior fellows in practice in the United States. *Obstet Gynecol* 2012;119(5):1017-22.
58. Rayburn WF, Richards ME, Elwell EC. Drive times to hospitals with perinatal care in the United States. *Obstet Gynecol* 2012;119(3):611-6.
59. NCHS Urban-Rural Classification Scheme for Counties. CDC/National Center for Health Statistics; 2017. (https://www.cdc.gov/nchs/data_access/urban_rural.htm). (Accessed December 21, 2018).
60. Ingram DD FS. 2013 NCHS urban–rural classification scheme for counties. *Vital Health Stat*: National Center for Health Statistics, 2014.
61. Ratcliffe M. BC, Holder K., Fields A. Defining Rural at the U.S. Census Bureau. U.S. Census Bureau, 2016:1-8.
62. Hall SA, Kaufman JS, Ricketts TC. Defining urban and rural areas in U.S. epidemiologic studies. *J Urban Health* 2006;83(2):162-75.
63. Documentation. United States Department of Agriculture; 2013. (https://www.ers.usda.gov/data-products/rural-urban-continuum-codes/documentation/). (Accessed).
64. Platner M, Loucks TL, Lindsay MK, et al. Pregnancy-Associated Deaths in Rural, Nonrural, and Metropolitan Areas of Georgia. *Obstet Gynecol* 2016;128(1):113-20.
65. Gadson A, Akpovi E, Mehta PK. Exploring the social determinants of racial/ethnic disparities in prenatal care utilization and maternal outcome. *Semin Perinatol* 2017;41(5):308-17.
66. Report from Nine Maternal Mortality Review Committees. *Building US Capacity to Review and Prevent Maternal Deaths*, 2018.
67. Louis JM, Menard MK, Gee RE. Racial and ethnic disparities in maternal morbidity and mortality. *Obstet Gynecol* 2015;125(3):690-4.
68. Schnake-Mahl AS, Sommers BD. Health Care In The Suburbs: An Analysis Of Suburban Poverty And Health Care Access. *Health Aff (Millwood)* 2017;36(10):1777-85.
69. E. K. The Growth and Spread of Concentrated Poverty, 2000 to 2008-2012. Brookings Institute, 2014.

Table 1. Rural-Urban Classification of Counties Based on NCHS[a], U.S. Census[b], and USDA[c] Definitions in States with non-Hispanic Black and non-Hispanic White Pregnancy-Related Deaths[d] from States Participating in MMRIA[e]

Classification System	No.	%	Rural/Urban Assignment	No.	%
NCHS					
1: Large central metro	36	2.2			
2: Large fringe metro	271	16.6	Urban: 1-4	711	46.5
3: Medium metro	230	14.1			
4: Small metro	174	10.6			
5: Micropolitan	469	28.7	Rural: 5-6	925	56.5
6: Noncore	456	27.9			
U.S. Census					
1: Mostly urban	719	44.0	Urban: 1	719	44.0
2: Mostly rural	775	47.4	Rural: 2-3	917	56.1
3: Completely rural	142	8.7			
USDA					
1: Counties in metro areas with pop. > 1 million	307	18.8			
2: Counties in metro areas with pop. 250,000-1 million	230	14.1	Urban/Urban-adjacent: 1-4, 6, 8	1,403	85.8
3: Counties in metro areas with pop. <250,000	174	10.6			
4: Urban pop. > 20,000, adjacent to metro	256	15.7			
5: Urban pop. >20,000, not adjacent to metro	22	1.3			
6: Urban pop. 2,500-19,999, adjacent to metro	347	21.2			
7: Urban pop. 2,500-19,999, not adjacent to metro	159	9.7	Rural/Not urban-adjacent: 5, 7, 9	233	14.2
8: Completely rural/urban pop.<2,500, adjacent to metro	89	5.4			
9: Completely rural/urban pop.<2,500, not adjacent to metro	52	3.2			

[a]2013 NCHS Urban-Rural Classification Scheme for Counties

[b]2010 U.S. Census County Codes

[c]2013 USDA Rural-Urban Continuum Codes

[d]Pregnancy-related defined by the Centers for Disease Control and Prevention as "death of a woman during pregnancy or within one year of the end of a pregnancy from a pregnancy complication, a chain of events initiated by pregnancy, or the aggravation of an unrelated condition by the physiologic effects of pregnancy"

[e]MMRIA data for the following states and years: Alabama, 2013; Delaware, 2009-2016; Georgia, 2012-2013; Hawaii, 2015; Illinois, 2015; Maryland, 2009; Mississippi, 2016; North Carolina, 2015; New Hampshire, 2013; Ohio, 2008-2016; Utah, 2015-2016; West Virginia, 2010

Table 2. Characteristics of non-Hispanic Black and non-Hispanic White Pregnancy-Related Deaths[a] from MMRIA[b] and Live Births from NCHS Natality Data[c]

	Live Births (n=1,757,863)		Deaths (n=262)	
	No.	%	No.	%
Race				
Black	391,923	22.3	109	41.6
White	1,365,940	77.7	153	58.4
NCHS[d]				
Rural	341,059	19.4	56	21.4
Non-rural	1,416,804	80.6	206	78.6
U.S. Census[e]				
Rural	280,297	16.0	45	17.2
Non-rural	1,477,566	84.1	217	82.8
USDA[f]				
Rural/not urban-adjacent	56,656	3.2	10	3.8
Urban/urban-adjacent	1,701,207	96.8	252	96.2

[a]Pregnancy-related defined by the Centers for Disease Control and Prevention as "death of a woman during pregnancy or within one year of the end of a pregnancy from a pregnancy complication, a chain of events initiated by pregnancy, or the aggravation of an unrelated condition by the physiologic effects of pregnancy

[b]MMRIA data for the following states and years: Alabama, 2013; Delaware, 2009-2016; Georgia, 2012-2013; Hawaii, 2015; Illinois, 2015; Maryland, 2009; Mississippi, 2016; North Carolina, 2015; New Hampshire, 2013; Ohio, 2008-2016; Utah, 2015-2016; West Virginia, 2010

[c]National Center for Health Statistics Natality Data

[d]2013 NCHS Urban-Rural Classification Scheme for Counties

[e]2010 U.S. Census County Codes

[f]2013 USDA Rural-Urban Continuum Codes

Table 3. Estimated Incidence Density Ratio (IDR) for the Risk of Pregnancy-Related Death[a] for non-Hispanic Black vs. non-Hispanic White Mothers from MMRIA[b] and NCHS Natality Data[c] across Rural-Urban Classifications Based on NCHS[d], U.S. Census[e], and USDA Definitions[f]

	Unadjusted IDR	95% CI	Interaction p-value	Adjusted IDR[g]	95% CI	Interaction p-value
NCHS						
Rural	2.58	1.40, 4.75	0.960	2.65	1.30, 5.39	0.689
Urban	2.62	2.01, 3.43		2.31	1.51, 3.53	
U.S. Census						
Rural	4.11	2.31, 7.32	0.091	4.08	2.10, 7.94	0.045
Urban	2.37	1.81, 3.11		2.10	1.37. 3.21	
USDA						
Rural	2.04	0.61, 6.76	0.746	2.15	0.63, 7.32	0.921
Urban	2.50	1.97, 3.18		2.29	1.53, 3.43	

[a]Pregnancy-related death defined by the Centers for Disease Control and Prevention as "death of a woman during pregnancy or within one year of the end of a pregnancy from a pregnancy complication, a chain of events initiated by pregnancy, or the aggravation of an unrelated condition by the physiologic effects of pregnancy

[b]MMRIA data for the following states and years: Alabama, 2013; Delaware, 2009-2016; Georgia, 2012-2013; Hawaii, 2015; Illinois, 2015; Maryland, 2009; Mississippi, 2016; North Carolina, 2015; New Hampshire, 2013; Ohio, 2008-2016; Utah, 2015-2016; West Virginia, 2010

[c]National Center for Health Statistics Natality Data

[d]2013 NCHS Urban-Rural Classification Scheme for Counties

[e]2010 U.S. Census County Codes

[f]2013 USDA Rural-Urban Continuum Codes

[g]Adjusted for % of live births to mothers with less than high school education, % of live births to mothers older than 35 years of age, % of live births that were preterm, and year of pregnancy-related death