Fall 12-21-2018

Examining the Association of Distance to Hospitals with Labor and Delivery Services and Maternal Mortality Rates in Georgia Counties (2010-2016)

Alina Karim

Follow this and additional works at: https://scholarworks.gsu.edu/iph_theses

www.manaraa.com

ABSTRACT

EXAMINING THE ASSOCIATION OF DISTANCE TO HOSPITALS WITH LABOR &
DELIVERY SERVICES AND MATERNAL MORTALITY RATES IN GEORGIA COUNTIES
(2010-2016)

By

ALINA KARIM

12/11/2018

INTRODUCTION: There is no formal research conducted that accounts for maternal mortality rates in the state of Georgia in association to the distance to hospitals that provide labor and delivery services.

AIM: To raise awareness about the number of maternal deaths that occur in Georgia, provide better geographical and financial access to maternal care to bring about reform.

METHODS: A quantitative secondary analysis integrating the spatial aspect of distance to hospitals from a centroid for each county was used to explore how maternal mortality rates differ across the 159 counties in Georgia, aggregating data from years 2010 to 2016. Other sociodemographic factors such as race and ethnicity, health insurance status along with the socioeconomic status namely education, poverty was considered together with population density. Linear regression along with spatial analysis was used to analyze the effect distance has on maternal mortality rates.

RESULTS: The total maternal mortality rates in the state of Georgia were not dependent on the increasing distance to labor and delivery units (L&D) from 2010-2016. Maternal mortality rates among different races (Non-Hispanic Black, Non-Hispanic White and Hispanic/Latino) did not illustrate a direct relationship with distance to L&D units.

DISCUSSION: More reliable and consistent data should be gathered on maternal mortality rates in addition to viewing cases individually, and factoring in how far each mother has to travel to access quality health care services for a healthy and safe delivery along with the sociodemographic and socioeconomic factors.

EXAMINING THE ASSOCIATION OF DISTANCE TO HOSPITALS WITH LABOR &
DELIVERY SERVICES AND MATERNAL MORTALITY RATES IN GEORGIA COUNTIES
(2010-2016)

by

ALINA KARIM

B.Sc., GEORGIA GWINNETT COLLEGE

A Thesis Submitted to the Graduate Faculty
of Georgia State University in Partial Fulfillment
of the
Requirements for the Degree

MASTER OF PUBLIC HEALTH

ATLANTA, GEORGIA
30303

APPROVAL PAGE

EXAMINING THE ASSOCIATION OF DISTANCE TO HOSPITALS WITH LABOR &
DELIVERY SERVICES AND MATERNAL MORTALITY RATES IN GEORGIA COUNTIES
(2010-2016)

by

ALINA KARIM

Approved:

___Dr. Ruiyan Luo_____
Committee Chair

___Dr. Lee Rivers Mobley_____
Committee Member

12/11/2018
Date

Author's Statement Page

In presenting this thesis as a partial fulfillment of the requirements for an advanced degree from Georgia State University, I agree that the Library of the University shall make it available for inspection and circulation in accordance with its regulations governing materials of this type. I agree that permission to quote from, to copy from, or to publish this thesis may be granted by the author or, in his/her absence, by the professor under whose direction it was written, or in his/her absence, by the Associate Dean, School of Public Health. Such quoting, copying, or publishing must be solely for scholarly purposes and will not involve potential financial gain. It is understood that any copying from or publication of this dissertation which involves potential financial gain will not be allowed without written permission of the author.

Alina Karim
Signature of Author

TABLE OF CONTENTS

List of Tables

List of Figures
(Use this page only if you have included figures in your thesis/capstone.)

<div align="center">

Introduction

</div>

1.1 Background

According to the World Health Organization (WHO), approximately 830 women die each day while pregnant or during childbirth[23]. Although globally, this number represents a 44% decrease between 1990 and 2015, maternal mortality is a serious public health issue that needs to be addressed because of the sheer number of women that die in a developed country like the United States. Additionally, to address the magnitude of this public health issue, the United Nations General Assembly (UNGA) developed the Sustainable Development Goals (SDG) which is a set of 17 goals that aim to shape a better sustainable future. For tackling maternal deaths, the SDG # 3 Good Health and Well-Being intends to reduce the global maternal mortality ratio to less than 70 deaths per 100,000 live births by 2030 by better managing intrapartum care and having access to skilled professionals. The UNGA further developed Global Strategy for Women's, Children's and Adolescents' Health, 2016-2030 to diminish barriers to comprehensive quality maternal care, provide improved healthcare access and coverage, reliable and frequent data collection methods to ensure the needs of mothers are adequately met and guarantee accountability to optimize quality of maternal care and equity[13].

Maternal mortality as defined by the WHO is the death of a mother while she is pregnant or within 42 days of termination of pregnancy unrelated to accidental or incidental causes but associated with or aggravated by the pregnancy and its management. This definition does not take into consideration the site and duration of pregnancy at the time of termination[23]. Initially, one would believe that maternal deaths are prevalent only in developing countries due to several factors like lack of access to an adequately equipped labor/ delivery unit, distance to clinics/hospitals, lack of transportation and trained health professionals, varied cultural practices,

inequity in access to healthcare services, numerous and young age at pregnancy increasing the risk and number of preventable deaths among women and girls. Furthermore, the WHO reports that the maternal mortality ratio was 239 per 100,000 live births in developing countries as compared to 12 per 100,000 live births in developed countries[23].

However, current trends in maternal mortality depict a different picture for the United States as a study published in *Obstetrics and Gynecology* stated a 26.6% increase in maternal deaths from 2000 to 2014 as reported by USA Today with more than half of the deaths being preventable[19]. While the worldwide trend drastically decreased within that time frame for other developed countries, maternal mortality in the United States has gradually increased from 7.2 deaths per 100,000 live births in 1987 to 17.8 deaths per 100,000 live births in 2009 and 2011 (CDC)[34] and IndexMundi[24] reports that the US ranks 137 out of the 181 countries for maternal deaths per 100,000 live births. American women are more than three times as likely to die as Canadian mothers in the maternal period and six times as likely to die as Scandinavians. If we consider racial disparities, maternal mortality is highest amongst African American women with 43.5 deaths per 100,000 live births, followed by 14. 4 deaths per 100,000 live births for women of other races and the lowest rate being 12.7 deaths per 100,000 live births for white women (CDC). In addition to this increasing trend, the United States has not published official maternal death statistics in more than ten years that provide real time and reliable data to counter this disturbing public health problem.

Considering this alarming rise in maternal mortality rates, there are several contributing factors like age of mothers, chronic illnesses, education level, insurance status, poverty and racial background, untrained hospital staff, improper immediate care that can prove fatal for the mothers. One factor that is crucial in preventing maternal mortality is that of distance to hospitals

that provide labor and delivery services and taking into consideration the time it takes to reach a hospital. According to the Center for American Progress, only one OB/GYN physician was available for 7,125 women in 2013 which could increase the maternal mortality rates in Georgia where mothers are already at a greater risk of dying due to pregnancy-associated and/or pregnancy related deaths[5]. ProPublica, a non-profit investigative journalism organization along with NPR, a non-profit media organization covered the rise in maternal mortality rates in the United States and discovered five key findings which were responsible for the increase. The issue was with flawed hospital protocols where the hospital personnel are unsure of how to handle treatable complicated situations which can lead to maternal deaths. Furthermore, hospitals with NICUs are unprepared to deal with maternal emergencies in a timely manner and lack trained personnel in the field. A major concern is that medical trainees are not required to actually engage in a live birth before completing their training and thus, the inexperience can prove to be fatal for the mother in an emergency situation. Another issue is the lack of funding by the federal and state governments where only 6% of block grants are allocated towards maternal well-being[41].

The America's Health Rankings website (CDC, National Vital Statistics System) reports that in 2018, Georgia has a maternal mortality rate of 46.2 deaths per 100,000 live births which is more than twice the rate of the United States (20.7 deaths per 100,000 live births) and has increased from 2016 with a rate of 39.3 deaths. The report further provides stratified maternal mortality rates by race/ethnicity and age. The race/ethnicity strata consist of Hispanics with Maternal Mortality Rates (MMR) of 18.1 deaths/100,000 live births followed by Whites (43.2 deaths/100,000 live births) and finally the highest MMR of 66.6 deaths/100,000 live births amongst Black women. The age strata consist of ages 15-24 years, 25-34 years and 35-44 years

with MMR of 15.1, 27.6 and 89.4 deaths per 100,000 live births respectively[3]. The 159 counties in Georgia vary widely as per their demographics, socioeconomic status, land area, population density, and access to healthcare services, proper transport and road access.

1.2 Causes of maternal mortality

The Georgia Maternal Mortality Review Committee (MMRC) consolidated a list of potential contributing factors to maternal mortality in 2012 after reviewing cases for one year so as to enact necessary actions by stakeholders. This consisted of hemorrhage, cardiac disorders, obesity, seizure disorders and suicide/depression. The report highlights lack of awareness of symptoms by the providers and by the women over warning signs, mismanaged treatment and lack of postpartum care. In a later report published by the MMRC in 2017 for the year 2013, cardiomyopathy was found to be the leading cause of pregnancy-related deaths among 32 identified cases, followed by hemorrhage-obstetric hemorrhage (16%) and embolism- amniotic fluid embolism (16%). The other pregnancy-related deaths consisted of mental health conditions, infections, cardiovascular and coronary disease, anesthesia complications and pregnancy specific conditions such as gestational diabetes, hyperemesis and liver disease. Thirteen percent of the 32 identified cases included preeclampsia, autoimmune disease, injuries, and pulmonary disorders. While the mother was pregnant or within a day of postpartum, embolism (13%) was the leading cause of pregnancy related death followed by conditions specific to pregnancy (6%). Furthermore, the leading cause for pregnancy-associated deaths was automobile crashes (19%) from 47 identified cases followed by drug toxicity (15%), homicide (13%) and respiratory conditions (11%)[33].

The American Heart Association describes peripartum cardiomyopathy (PPCM) as a weakness of the heart muscle which causes a shortness of breath accompanied by swelling of the

hands and feet. It occurs in the final month of pregnancy or up to five months postpartum and can be difficult to detect since the symptoms are that of a third trimester pregnancy. There are a number of risk factors associated with PPCM such as obesity, use of specific medications, alcohol use, being African-American, poor diet but the underlying causes are ambiguous. Hence, eating a well-balanced diet, regular exercise and avoiding alcohol and smoking during pregnancy can aid in maintaining a healthy heart. Further research is required to treat PPCM and the underlying causes[31].

The MMRC recognized areas of concerns that lead to poor maternal health outcomes in Georgia. Factors include the inability to recognize the risk factors and symptoms in a timely fashion by the healthcare providers or patients with lack of follow-up for cardiomyopathy and hemorrhage cases. Obesity was another concern since the reviewed cases for maternal mortality consisted of 58% of the women being morbidly obese (BMI>30) with other coexisting conditions such as diabetes, hypertension, cardiovascular diseases and other pregnancy-related complications. The insufficient BMI assessments pre-pregnancy and lack of regular monitoring of obese women during pregnancy and postpartum were causes for concern. Further, these women who were at an increased risk or suffering from chronic conditions did not receive preconceptual, prenatal, inter-conceptual counseling in order to reduce pregnancy complications. Absence of standardization in treatment procedures and referrals for high risk pregnancies to a more suitable level of care is important to avert preventable maternal deaths[33]. In essence, central and integral to these concerns is the access to healthcare where distance to hospitals can play a vital role in the fate of a mother.

1.3 Medicaid in Georgia

According to the Kaiser Family Foundation's Status of State Action on Expanding Medicaid, currently 37 states (including District of Columbia) have opted for the expansion albeit 14 states have not adopted Medicaid which includes Georgia. When the US Supreme Court decision of 2012 defacto made Medicaid expansion optional for states under the Affordable Care Act that rolled out in 2010, the Georgia governor and lawmakers stated the expansion to be expensive and thus, the Georgia Medicaid program run by the Georgia Department of Community Health implemented in 1967 was continued. However, if the expansion would have progressed in Georgia, the uncompensated care costs would be on the decline as they decreased in the expansion states by $7.4 billion in 2014[36]. Additionally, the Kaiser Family Foundation approximated 240,000 Georgians who either earn too much according to the Georgia Medicaid program guidelines but too little to be eligible to receive subsidies through the health insurance marketplace to enroll for private insurance [28]. Ultimately, this places people in the coverage gap where they are unable to receive healthcare services. Hence, if people are unable or unwilling to pay for the services they received then it further increases the healthcare expenditure in the US. Lack of funding from the federal government and bad debt accumulated through the uninsured population in Georgia due to non-expansion has led to hospital closures, mostly in rural areas. Since 2010, six hospital closures have occurred in Georgia according to according to the research conducted by the North Carolina Rural Health Research Program[4].

For pregnant women in Georgia, the Medicaid program called Georgia Families requires the mother to be at or below 220 percent of the Federal Poverty Line (FPL) which is approximately an annual income of $29,986 for a family size of one in order to be eligible[6]. This

program pays for services like labor and delivery in addition to physician visits, prescriptions, and inpatient and outpatient hospital services. The Georgia Maternal Mortality Review Committee report published in 2017 stated that among the 79 maternal deaths, 52% of those women were receiving Medicaid while 18% were on private insurance and the insurance status for the 23% could not be established for 2013. The report recommended policy changes such as extending insurance coverage to mothers after birth that are at risk for obesity, hypertension or cardiovascular diseases[33]. Even with Medicaid eligibility during pregnancy, a woman could be suffering from chronic illnesses prior to becoming a mother. These conditions can be aggravated if proper medical attention is not sought and postpartum coverage is not provided after the 60-day termination period. The peer-reviewed health policy journal, Health Affairs examined the uninsured rates for mothers for years 2013 and 2016 after the implementation of the Affordable Care Act Medicaid expansion using data from the American Community Survey (ACS). There was a decline in the uninsured rates among new mothers from 15.3 % in 2013 to 6.8 % in 2016, while the decline for non-expansion states was from 25.3 % in 2013 to 17.9 % in 2016[25]. The ACS reported the uninsured rate among Georgian mothers to be 22.4% from 2015- 2016. In order to improve on preventable maternal deaths, continuous coverage is important to monitor the mother's health along with the infant's health[39].

This fractured healthcare system makes it difficult for new mothers who are without insurance or quality coverage to receive the care required pre and post partum. Moreover, the inability to recognize troublesome symptoms and inadequate pregnancy related education and training can lead to an unwanted obstetric emergency which makes caregivers more prone to error. The quality of care provided to the mother and baby greatly matter. To emphasize the importance of this factor, a retrospective cohort study was conducted at Cedars-Sinai Medical

Center in California in 2016 over a 30-month period on all women admitted for delivery. The point of the study was to examine the quality of maternal care. The study concluded that "opportunity for improvement in care" was present in 44% (66 cases) of life-threatening complications during pregnancy and childbirth[29]. Furthermore, the study recognized hemorrhage (71.3%) and preeclampsia/eclampsia (10.7%) as the two most common underlying causes of severe maternal morbidity.

1.4 Race/Ethnicity

Race/Ethnicity play an important role in the outcome of maternal mortality rates since racial and ethnic disparities exist leading to lower quality of health care received by minorities. A literature review was conducted to identify the longitudinal models of health disparities. The study found that stress caused due to prolonged exposure to racial bias and discrimination can lead to poor health outcomes among African American mothers when paired with other chronic illnesses. It states that a woman's health is impacted over the course of her life due the issue of systemic and gender bias[18]. "Weathering" is the term conceived by a professor at the University of Michigan School of Public Health which states how the affect of constant stress wears away the body leading to chronic illnesses that are increasingly witnessed in African Americans at a younger age as compared to Whites[21]. On a national level, the CDC reports that the maternal mortality rate among African American women is approximately three to four times more prevalent than among White women. A nationwide study examined the case-fatality rates and prevalence between White and Black mothers for five conditions namely preeclampsia, eclampsia, abruptio placentae, placenta previa, and postpartum hemorrhage during 1988 through 1999. The study determined that although the prevalence was not remarkably different between the two races, Black women were two to three times more prone to dying from the same

condition than White women hence the case-fatality rates were statistically significant[37]. The Georgia MMRC observed similar trends in maternal mortality rates of 39.1 deaths per 100,000 live births in Non-Hispanic Black mothers as compared to 9.6 deaths per 100,000 live births among Non-Hispanic White mothers between 2001 and 2011 which was four times higher. Furthermore, the MMRC of Georgia reported that in 2013, 47% of the maternal deaths were among African American women followed by 43% among White women. Albeit, the report also mentioned that racial disparities existed where pregnancy related deaths were common among Non-Hispanic Black women by 66% whereas pregnancy associated deaths were common amongst Non-Hispanic White women by 60%[33]. However, it is obvious that the worsening trends in maternal mortality in the United States can be attributed to the alarming mortality crisis among Black mothers.

There are several factors contributing to such devastating maternal outcomes among African American mothers. These factors include but are not limited to low socioeconomic status and persistent poverty, restricted access to prenatal care, poor physical and mental health due to differential access to healthy food, unsafe neighborhoods, no health insurance prior to pregnancy leading to chronic ailments like obesity, diabetes and hypertension. A population-based case-control study of pregnancy-related deaths was conducted to determine if different socioeconomic and medical constituents account for the observed disparity in North Carolina. Here, data was gathered for White and Black mothers over a span of 7 years. The findings reported that the unadjusted odds ratio (95% CI, 2.08, and 4.54) for the increased risk in pregnancy-related deaths among Non-Hispanic Black women was 3.07 as compared to Non-Hispanic White women. The researchers also controlled for other predictors such as age of mother, income, gestational age at delivery, whether prenatal care was received or not and hypertension. They established that

9

being African American was a notable predictor for pregnancy related deaths (p=0.0001) with adjusted odds ratio of 2.65 (95% CI, 1.73, 4.07). This study reiterated that Black women were on the socioeconomically disadvantaged end of the spectrum as they resided in areas with increased poverty, were unlikely to have received prenatal care and were prone to having hypertension[15]. In addition, even if Black women receive Medicaid through the course of their pregnancy, they will most likely lose the coverage during postpartum which is an important time to monitor complications that could lead to death. The quality of care they receive and have access to is important to avoid complications in pregnancies and prevent maternal deaths.

According to first-hand accounts from more than 200 African American mothers, ProPublica and NPR gathered that medical providers did not actively listen to mothers who were experiencing discomfort thus undervaluing and disrespecting their causes for concern. This was mainly a result of racial bias where Black mothers were thought to be poor, uneducated, not worthy, exaggerated the pain and defiant to the medical providers[22]. In fact, a study published in 2016 examined the racial bias in pain assessment and treatment suggestions along with the false beliefs about the biological differences between Whites and Blacks among medical students and medical residents. The study presented alarming results illustrating that Black people feel less pain as compared to Whites thus treatment suggestions for managing pain for African Americans is inadequate. A main effect of target race was observed [$\beta = -0.07$, SE = 0.03, $F(1,85) = 5.50$, P = 0.021, $\eta2p = 0.06$, such that the study participants reported a lower pain rating for the black targets as compared to the white targets[16]. These findings entail that diversity in the medical profession is important to adequately bridge the gender and racial gap to provide services that enhance the health outcomes. Keeping these issues in mind, it is important to address the overall health of a woman even before she conceives and that includes access to quality care.

1.5 Distance to hospitals (labor/delivery units)

An important factor to consider when an expectant mother faces complications or needs to visit her doctor for regular prenatal and postnatal care is the distance she has to travel to get access to timely care. Distance to labor and delivery units is the main predictor variable for this study to gauge an effect on maternal mortality rates in the state of Georgia between 2010-2016. There have been studies that examined the effect of distance on maternal mortality rates; however, these studies have been conducted mainly on an international level and in developing countries. A secondary analysis of cross-sectional, georeferenced census data was conducted in five rural districts of Southern Tanzania to examine the relationship between distance to obstetric care units providing intrapartum care and maternal mortality (direct and indirect). Multilevel logistic regression was used for adjusted and crude odds ratios (95% CI) for the distance to healthcare facilities on maternal deaths while test for moderation was conducted between the different ethnicities, districts, and wealth and education status. The results depicted that the total pregnancy-related mortality ratio was 712 deaths per 100 000 live births (95% CI 652–777) which increased to 900 deaths per 100 000 live births at distance >25 km, however this was not significant. Distance and direct maternal mortality had a strong association such that number of deaths increased from 111 deaths per 100 000 live births at distance 5 km of a hospital to 422 deaths per 100 000 for those at a distance of 35 km or more[14].

Another international study conducted in two countries, namely Indonesia where an informant-based approach was used and Bangladesh which utilized a retrospective cohort study design. This study considered the distance to obstetric units along with receiving professional help from a health worker and the effects on maternal mortality. The results depicted similar maternal mortality levels in both countries: Indonesia :(320 per 100 000 births (95% CI: 290,

353) and Bangladesh: (318 per 100 000 (95% CI: 272, 369). Moreover, with professional help the odds of maternal mortality increased as the distance to a hospital or health center increased: Indonesia: 1.07 (95% CI: 1.02–1.11), Bangladesh: 1.47 (95% CI: 1.22–1.78). The study found a strong association between seeking professional help and the distance to a hospital or health center since women tend to only seek help when an emergency arises, hence risking their lives. Another reason for the high mortality is that maternal units have limited resources and technology which can jeopardize a woman's well-being and life[35]. Additionally, a study conducted in Niger evaluated the socioeconomic factors, lack of access to healthcare facilities, and inadequate number of trained personnel that influence high mortality rates among the mothers. These factors generated a maternal mortality ratio of 2,640 deaths /100,000 live births with a total of 121 deaths and 4,582 live births recorded. Findings from these studies highlight the need for proper hospital access in lowering maternal deaths [8]. These studies emphasize the importance of reliable healthcare services at a closer distance for ease of access for the pregnant mother.

In the state of Georgia, a total of 69 labor and delivery units were discovered spanning over the 159 counties. Some of the counties like Richmond, Muscogee and Fulton have more than two labor and delivery units (L&D) while some counties did not consist of any L&D units. While calculating the distance for the closest hospital to each county center, it was observed that some of the rural counties lacked proper roads hence making it tougher for the mother to be transported to a hospital in time. Furthermore, rural counties experienced hospital closures, sending county residents to travel further for medical care. In an observational cohort study conducted in the UK, the researchers observed the association of distance to hospitals with mortality for patients with life-threatening emergencies when age, sex, severity of illness and

clinical category were adjusted for. The results demonstrated that as distance increased, the risk of mortality also grew (odds ratio 1.02 per kilometer; 95% CI 1.01-1.03; p<0.001). The results of the study conclude that an absolute increase of 1% in mortality is related to a 10-kilometer increase in straight-line distance[27]. Hence, access to healthcare facilities and proper antenatal care, before, during and after pregnancy are vital in ensuring the health and wellness of the mother as well as the baby.

<center>**Methods and Procedures**</center>

Data Sources and Methods:

2.1 Maternal Mortality and Live Births

Data was collected using the OASIS health data repository, specifically to acquire the number of maternal deaths and live births for all 159 Georgia counties for years 2010, 2011, 2012, 2013, 2014, 2015 and 2016. OASIS is an online tool created by the Georgia Department of Public Health which provides consolidated data on Vital Statistics, Emergency Room visits, hospital discharge, Youth Risk Behavior Survey (YRBS) Behavioral Risk Factor Surveillance Survey (BRFSS), STD, Motor Vehicle Crash, and Population data[12]. The OASIS website provides a wide range of measures, ages, time (years), Geography (Rural/Non-Rural), Races and Ethnicities, Education status, Sex, Disease and Diagnoses, causes of death to select and create informative tables, graphs (trends), maps with valuable public health statistics and different indicators.

This study focused on indicators from the Maternal Child Health section on the website, with the subsection Maternal Deaths. Here, the tables were generated for the number of maternal deaths aged 15 through 55 years with an aggregated timeline of 2010-2016, for 159 Georgia counties. In addition, tables were also generated for different races/ethnicities namely White (Not-Hispanic or Latino), African-American (Not-Hispanic or Latino) and All Races (Hispanic or Latino), separately.

To acquire the number of births in the Georgia counties, the subsection selected was Births under Maternal Child Health as an indicator for mothers aged 15-55 years with an aggregated timeline from 2010-2016 for all GA counties inclusive of all races and ethnicities. Similar to maternal deaths, the number of live births were divided by different races/ethnicities

namely White (Not-Hispanic or Latino), African-American (Not-Hispanic or Latino) and All Races (Hispanic or Latino).

The response variable, Maternal Mortality Rates were calculated after aggregating all the years to obtain the total number of maternal deaths in MS Excel using the formula:

Maternal Mortality Rate

= (Number of Maternal Deaths/Number of live births) * per 100,000 live births

The Maternal Mortality Rates were calculated for the total number of maternal deaths and for the different races/ethnicities.

2.2 Predictors- Distance, Time, Health Insurance Status, Educational Attainment, Persistent Poverty and Population Density

Distance was one of the main predictor variables and it was calculated using Google Maps. QGIS software was not used to determine the distances since Google Maps takes real traffic into account and calculates the distance along the roads whereas a GIS software would determine the 'straight line' distances. The aim was to examine the distance from the center of each of the counties to the closest hospitals which provided labor and delivery services to mothers. Firstly, all the hospitals in Georgia were researched to ensure that they offered labor and delivery services. A map from the Georgia Hospital Association[30] which listed hospitals was used to identify them in each county in Georgia along with a Google search. Some of the counties had more than one hospital; the hospital that was closest to the county center was selected. Some counties lacked any hospitals with labor/delivery services; hence a county map was used to locate the surrounding counties that catered to this. The closest distance from one county and the surrounding county/counties hospitals was chosen. The hospital address was input into the "starting point" field and the name of the county was entered into the "destination"

field for the distance and this was carried out for all 159 counties. Google Maps makes use of the centroid point for each of the county to measure the center point and compute the distances to hospitals. Specifically, the distance with the 'fastest route, usual traffic' was selected where the unit of distance measurement was in miles. In total, 69 hospitals were identified for all the Georgia counties.

Another predictor taken into consideration was Time, to gauge the travel time to labor/delivery units in each of the county. Google Maps provides the shortest time along with the fastest route to the hospital. For the purpose of this research, the fastest route was chosen over the shortest time since distance was being considered as the main explanatory variable.

The data for health insurance status for years 2010 through 2016 was publicly available through from the US Census bureau (SAHIE or small area health insurance estimates)[40]. The percentage of population under age 65 without health insurance was selected for all years for which the data was aggregated. This was calculated by combining all the percentages divided by the number of years.

Educational attainment data for the counties was gathered from the American Community Survey. The proportion of population aged 25+ years with a graduate or professional degree and the proportion of population aged 25+ years with less than a high school diploma or equivalent was used in the analysis[39]. Since the data was already aggregated, no further calculations were carried out for these predictors. This was used in the analysis since varying levels of education have a relationship with maternal mortality. According to a cross-sectional study conducted by Karlsen et al. in 24 countries over a span of 2 years, women who have attained lower levels of education are at a higher risk of dying when compared to women with

higher levels of education. Thus, including educational attainment in the study seemed reasonable[17].

Population density was obtained using the land area and population for each of the 159 counties. This factor was used to measure the urban-rural differences which may be needed to get a distance affect. Land area[11] was gathered from the county maps of Georgia for each of the counties and the population was acquired from Georgia demographics[10].

Population Density =Number of People ÷ Land

FIPS or the Federal Information Processing Standards were included to create maps in QGIS and perform regression using GeoDa software. FIPS are unique numeric codes set by the National Institute of Standards and Technology to identify different counties in the United States[42]. A process called Geocoding uses these geocodes to link data to maps by making use of the area appropriate geographic coordinates to create translational maps.

Counties that are persistently poor for three decades was a binary variable included in the study where 0 represented not poor and 1 represented poverty. The data was acquired from the US Census Bureau a geospatial factors file hat was state and county specific[39]. Living in a poor area with limited access to healthcare services can negatively impact a pregnant woman's health according to the United Nations Population Fund, which also states that maternal mortality rates are reflective of disparities between the wealthy and poor nations more than any other measure of health[38].

The names of hospitals situated in the different counties and unemployment rates for different counties for years 2010-2016 was included however the latter variable was not used in model estimates.

2.3 Spatial Analysis

QGIS

QGIS is an open-source Geographic Information Systems (GIS) application that allows editing, viewing and analyzing geospatial data[32]. In order to visually represent the relationship between maternal mortality rates among Non-Hispanic Black women and the distance to the hospitals, QGIS was used to create translational, descriptive maps. A bivariate map illustrating this relationship was created accompanied by univariate maps for total maternal mortality rates, maternal mortality rates among Hispanic/Latinos, Non-Hispanic Whites and Blacks maintaining cut points across the maps for comparison.

GeoDa

GeoDa is a software package that carries out spatial analysis, geovisualization, spatial autocorrelation and spatial modeling where it translates data into insightful information. The Center for Data Science at the University of Chicago states that GeoDa possesses powerful tools such as "spatial statistical tests for visualizing maps, linking data views of spatial and non-spatial distributions, and enabling real-time exploration of spatial and statistical patterns[9]." This package was used to verify the spatial autocorrelation since the dataset consisted of the distance to hospitals from each of the county center. Spatial autocorrelation checks for how similar neighbors are to one another being in close proximity[2]. It would be counterintuitive to assume that maternal mortality rates are similar in neighboring counties hence spatial analysis was conducted by assigning spatial weights to describe the nearby neighbors. The weights were defined using Queen Contiguity[1]. Thus, a regression was chosen to check for the Moran's I statistic which tests for spatial dependence where the null hypothesis states that observations are scattered in a spatially random fashion while the alternative is the presence of spatial dependence

for the variable of interest[26]. Using GeoDa, a classic model was run with total maternal rates as the dependent variable and covariates such as educational attainment, distance, persistent poverty, and uninsured rates.

The original dataset consisted of 159 observations for the 159 counties of Georgia, including all the variables mentioned above, however no statistically significant results were determined. Therefore, another stacked dataset was created in MS Excel to model the gathered data and test the relationship between maternal mortality rates among different races/ethnicities and the various predictors namely Population Density, Persistent Poverty, Educational Attainment, and Distance to hospitals.

Using the stacked dataset that consisted of dummy variables for the different races/ethnicities, the multiple linear regression procedure was performed in SAS to test for a relationship between distance to the closest labor and delivery units from the county center and how maternal mortality rates differ across Non-Hispanic Blacks, Hispanics/Latinos and Non-Hispanic Whites. The latter race/ethnicity was used as a comparison group.

Results

After performing a correlation matrix analysis for the maternal mortality rates for all races/ethnicities, the variables that seemed to have a positive correlation with the response variable were percentage of population under age 65 without health insurance for years 2010-2016 (UI1016), time (minutes) taken to get to the closest hospital from the county centroid, distance (miles) from center of county (centroid) to closest maternity/labor unit, and counties that are persistently poor for three decades in 2010 (PP8010). The only variable that illustrated a negative correlation was proportion of population aged 25+ yrs with a graduate or professional degree from 2010-2014 (G25UPL). Hence, these variables were included throughout the analysis.

3.1 Spatial Autocorrelation

Testing for spatial autocorrelation in GeoDa, the Moran's I (error) was not statistically significant (p-value= 0.61797), hence there was no spatial autocorrelation in the ordinary least squares residuals (OLS) thereby deeming a spatial regression model unnecessary. Moran's I is a test statistic that measures for spatial autocorrelation which evaluates how proximate objects are compared to other nearby objects as in how one county is similar to another county. This was conducted to check if the observations in the dataset were independent from one another since an assumption for classical linear regression is that observations cannot be dependent on one another. Additionally, this was used to get parameter estimators that were unbiased and efficient.

Table 1. Diagnostics for Spatial Dependence (GeoDa) for Total Maternal Mortality Rates and Various Predictors in Georgia Counties (2010-2016)

Variable	Coefficient	Std. Error	t-Statistic	Probability
CONSTANT	180.089	166.329	1.08272	0.28062
EDUCATION	-0.604197	2.49429	-0.242232	0.80892
UINSURED	-5.41973	5.48055	-0.988904	0.32426
DISTANCE	0.00512394	1.33886	0.0038271	0.99659
PERSISTENT POVERTY	30.6996	39.7025	-0.773241	0.44057

DIAGNOSTICS FOR SPATIAL DEPENDENCE
FOR WEIGHT MATRIX: MATERNAL MORTALITY RATES
(Row-standardized weights)

TEST	MI/DF	VALUE	PROB
Moran's I (error)	0.0089	0.4987	0.61797
Lagrange Multiplier (lag)	1	0.3175	0.57308
Robust LM (lag)	1	2.2323	0.13515
Lagrange Multiplier (error)	1	0.0317	0.85864
Robust LM (error)	1	1.9464	0.16297
Lagrange Multiplier (SARMA)	2	2.2640	0.32239

3.2 Multiple Linear Regression

Thus, the association between maternal mortality rates and the different predictors was analyzed using the multiple linear regression procedure in SAS. Transformation of the main predictor variable: distance and the dependent variable were performed so as to enhance the model and change the shape of the distribution. The result for the first equation inclusive with a

transformation of log+1 for the total maternal mortality rates and distance along with the other predictors except for time did not show any significance: ($F (5, 153) = 1.12$, $p > 0.3534$), with an adjusted R^2 value of 0.0037. Hence, none of the predictors (distance, persistent poverty, population density, percent uninsured and educational attainment) significantly contribute to maternal mortality in Georgia counties and there is a lack of correlation.

Another simple linear regression was calculated to predict the total maternal mortality rates based on the distance to hospitals from the center of each of the county for each of the counties was considered. However, there was no significance as ($F (1, 157) = 3.76$, $p > 0.0543$), with and adjusted R^2 value of 0.0172. Distance to hospitals did not significantly contribute to the total maternal mortality rates in Georgia counties from 2010 to 2016.

3.3 Stacked Dataset

Since the dataset consisted of maternal mortality rates for different races and ethnicities, a stacked dataset was created in Excel with dummy variables for race/ethnicity categorized into Non-Hispanic Blacks, Non-Hispanic Whites and Hispanics. Differences among the maternal mortality rates for the races/ethnicities in regards to the distance the mothers had to travel to labor/delivery units were assessed. An interaction term between distance (without the transformation) and race/ethnicity for Non-Hispanic Blacks and Hispanics/Latinos along with the main effects for race/ethnicity and distance was used to model the presence of any significance on maternal mortality rates for different races stacked which underwent a log+1 transformation. The Hispanics/Latinos were added to the model to compare with the Black population. Further, adding the interaction term to the model was a way of determining how race and place affect the maternal mortality rates in Georgia as opposed to using just the main effects in the model. The results indicate that maternal mortality rates do not necessarily depend on the race/ethnicity of

22

the mother or the long distance she has to travel to get access to healthcare services. Four models were examined to gauge the impact of distance and race/ethnicity on maternal mortality rates in Georgia counties over a period of 2010 through 2016.

3.4 Models (Statistical Analysis)

Model 1 includes race/ethnicity, distance to labor and delivery units and their interaction. The regression equation that predicted maternal mortality rates for the different races/ethnicities obtained for Model 1 was *2.47- 0.03(Distance)–0.52(Race/Ethnicity=Black)-1.94(Race/Ethnicity=Hispanic)+ 0.02 (Distance*Black)+ 0.02 (Distance*Hispanic)* with an adjusted R^2 value of 0.1266. The interaction terms were found to be non-significant. Another comparison model (Model 2) only includes the main effects of race/ethnicity, distance to labor and delivery units. The regression equation for this model was *2.21-0.01(Distance)-0.07(Race/Ethnicity=Black)-1.62(Race/Ethnicity=Hispanic).*

The adjusted R^2 value 0.1263. The main effects model (Model 2) suggests that as distance to labor and delivery units increases by 1 mile, the maternal mortality rates are expected to decrease by 0.01 deaths per 100,000 live births while controlling for race/ethnicity. The regression results for both the models are depicted in Table 2. Model 2 shows that distance is statistically significant (p-values=0.024) and the maternal mortality rates in Hispanics/Latinos is significantly lower than in Whites (p-values < 0.0001). However, these models were heteroscedastic when the model specification test was performed in SAS. In order to correct the standard errors, the White test was used to provide a robust model with the most reliable estimates. The statistical significance was maintained for distance and race/ethnicity for Hispanics and the coefficients remained unchanged with the p-values increasing for the other predictors. Figure 1. shows the

funnel-shaped heteroscedasticity for the residuals vs. the predicted values for the maternal

mortality rates for the different races in the Georgia counties.

Table 2. Model Comparison with and without interactions (Distance*Race/Ethnicity) on

Maternal Mortality Rates in Georgia Counties- (2010-2016)

Model 1 and 2 comparison including Distance, Race/Ethnicity and Interaction between Distance & Race/Ethnicity

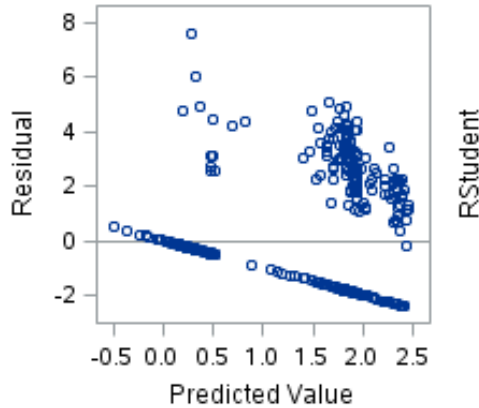| Variable	Model 1		Model 2	
	Estimates	**Pr> |t|**	**Estimates**	**Pr> |t|**
Intercept	2.47	<.0001	2.21	<.0001
Distance	-0.03	0.0128	-0.01	0.0204
Race/Ethnicity= Black	-0.52	0.1827	-0.07	0.7691
Race/Ethnicity= Hispanic	-1.94	<.0001	-1.62	<.0001
Race/Ethnicity*Distance [Black]	0.02	0.1536	-	-
Race/Ethnicity*Distance [Hispanic]	0.02	0.3077	-	-

Figure 1.   Fit diagnostics for Maternal Mortality Rates in

Georgia (2010-2016) for different races/ethnicities

Another 2 models were fitted to visualize the relationship of maternal mortality rates

(transformation of log+1) with socioeconomic factors like educational attainment and persistent

poverty, population density and health insurance status, distance and the interaction term

inclusive of distance and race/ethnicity for Non-Hispanic Blacks, and finally the comparison

variable for Hispanics. The regression equation that was obtained for Model 3 consisting of the

interaction terms *(Distance*Race/Ethnicity=Black)* and *(Distance*Race/Ethnicity=Hispanics)*

along with the main effects illustrated statistical significance for the Hispanic/Latino

race/ethnicity (p-value<.0001) and for population density (p-value= 0.0006) with an adjusted R^2

value of 0.1573. The predicted maternal mortality rates for different races for Model 3 were

similar to Models 1 and 2. For population density, it can be deduced that as population density

increased by 1 square mile, the average maternal death rates increased by 0.0002 deaths per

100,000 live births, controlling for race and other factors. The interaction between distance and

race/ethnicity is not significant in Model 3. When the interaction terms were removed as in

Model 4, the statistical significance for Hispanics/Latinos and population density were

unaffected. The White test for heteroskedasticity was conducted to determine if the model was

heteroskedastic. Since the models were heteroscedastic, the White test was used to correct the

standard errors and provide robust models with the most reliable estimates. The heteroscedasticity consistent p-values were still statistically significant for Hispanic/Latino mothers and population density (p-value=<.0001) for Models 3 and 4 (Table 3.)

To reinstate, Models 1 and 2 (Table 2.) present that distance to labor and delivery units matters where maternal mortality rates are concerned for the different races in Georgia counties. In addition, models 3 and 4 suggest that population density matters thus as the population increases per square mile, the maternal mortality rates increase as well, controlling for others. All four models indicate that maternal mortality rates of Hispanic/Latino is lower than in Non-Hispanic Whites.

Table 3. Model Comparison for Maternal Mortality Rates in Georgia Counties with Distance and Race/Ethnicities, Sociodemographic and Socioeconomic Factors, with and without interaction (Distance*Race/Ethnicity) -(2010-2016)

Model 3 including Distance, Race/Ethnicity, Interaction between Distance & Race/Ethnicity and Socioeconomic and Sociodemographic Factors

Variable	Model 3		Model 4	
	Estimates	Pr>|t|	Estimates	Pr>|t|
Intercept	2.47	0.0085	2.21	<.0001
Distance	-0.02	0.1737	-0.01	0.7047
Race/Ethnicity= Black	-0.52	0.1750	-0.07	0.7651
Race/Ethnicity= Hispanic	-1.94	<.0001	-1.62	<.0001
Race*Distance [Hispanic]	0.02	0.2990	-	-

Race*Distance [Black]	0.02	0.1463	-	-
Uninsured Rate	-0.02	0.5502	-0.02	0.5503
Educational Attainment	0.0003	0.9869	0.0003	0.9869
Persistently Poor Counties	-0.08	0.6973	-0.08	0.6974
Population Density	0.0002	0.0006	0.0002	0.0006

Table 4. Descriptive Statistics for Maternal Mortality Rates in Georgia Counties for 2010-2016 (Total and different races/ethnicities)

Maternal Mortality Rates (n=159)	Mean	Standard Deviation	Minimum	Maximum
Non-Hispanic Blacks [Live Births, n=159]	80.13	162.20	0	869.57
Hispanics [Live Births, n=159]	23.99	214.05	0	2631.58
Non-Hispanic Whites [Live Births, n=159]	39.56	61.47	0	298.06
All Races/Ethnicities	52.93	71.06	0	568.18

The descriptive statistics for total maternal mortality rates and among each of the races with the mean, standard deviation, minimum and maximum values is illustrated in Table 4. for all 159 counties in the state of Georgia. The minimum is 0 deaths per 100,000 live births while the maximum is among the Hispanics where live births occurred in all 159 counties with 2631.58 deaths per 100,000 live births (M=23.99, SD=214.05). This occurred in Jones county where the number of births for 2010-2016 was 38 with one maternal death occurring within that time frame. Another reason is the low population of Hispanics/Latinos in the county. The maximum maternal mortality rate for Black mothers where live births were experienced in 159 counties, is 869.57 deaths per 100,000 live births (M=81.16, SD= 162.98) in Qutiman county which has a high Non-Hispanic Black population followed by 298.06 deaths per 100,000 live births (M=3.96, SD= 6.15) for Non-Hispanic White mothers in Crisp county with a high White population. The maximum for total maternal mortality rate for all races/ethnicities is 568.18 deaths per 100,000 live births (M=52.93, SD= 71.06) in Quitman county.

3.5 Mapping (QGIS)

Maps using the QGIS, geographic information system application were used to create the outcome variables which include the Total Maternal Mortality Rates, Maternal Mortality Rates among Non-Hispanic Blacks, Non-Hispanic Whites and Hispanics/Latinos. A bivariate map to reflect to illustrate the maternal mortality rates amongst the Non-Hispanic Black population with the distance to visualize how far typically a Black mother has to travel to receive adequate care.

This map created using QGIS (Figure 2.) depicts the total maternal mortality rates in Georgia counties from 2010-2016, with a quantile classification scheme where the rates are sorted from low to high and a ramped or sequential color scheme for illustrating concentration of maternal mortality rates, where higher concentration (96.02-568.18 deaths per 100,000 live

births) is a darker shade. Here 26 out of the 159 counties fall into the last category, and a majority of the counties fall under the first category (0-0 deaths/100,000 live births).

Figure 3. adheres to the same color and classification scheme where the map illustrates the maternal mortality rates among Non-Hispanic Black women. The cut points for each of the 5 categories are maintained; however, since Quitman County had a higher rate, the range for the last category had to be increased to 870 deaths/100,000 live births with 36 counties. Likewise, in Figure 4. which shows the maternal mortality rates for Hispanics/Latinos, the range for the last category is increased to 2632 deaths/100,000 live births with 5 counties. Majority of the counties did not report maternal deaths for Hispanic/Latino women.

The highest mortality rate for Non-Hispanic White mothers is 298.06 deaths/100,000 live births in Crisp County which has a higher Non-Hispanic White population than Non-Hispanic Blacks and Hispanic/Latinos. Maternal mortality rates were at 0 deaths/ 100,000 live births for 87 of the counties, while 25 counties were in the last quantile with a rate of 96-568 deaths/100,000 live births. The number of counties and the rates are higher in Non-Hispanic Blacks when compared with the Non-Hispanic Whites. Further, the quantiles had the same cut points as for total maternal mortality rates to maintain consistency across the maps in Figure 5. These maps demonstrate the visible differences in maternal mortality rates among the different races/ethnicities across the Georgia counties.

Even though the multiple linear regression models did not demonstrate a significant relationship between distance to labor/delivery units and maternal mortality rates among Non-Hispanic Black mothers, a bivariate map was created to visually represent this association since highest maternal death rates are linked to Black women. The legend shows the various associations of the two variables, the vertical axis represents the different categories of distance

from low to high along with the sequential color scheme using blue. Mortality rates among black mothers is represented on the horizontal axis of the legend with varying shades of blue, ranging from low to high as well. Two counties namely Wilkes and Lincoln show that as distance to healthcare services increases, maternal mortality rates also increases (Distance= 58.04 - 87 miles, MMRB= 42 - 870 deaths/ 100,000 live births). Seven counties fall into the mid-distance and high maternal mortality rate category (Distance= 29.37- 58.04 miles, MMRB= 42 - 870 deaths/ 100,000 live births). Additionally, two counties show that as the distance increased, the maternal mortality rate was 0. There are no counties on the map that had MMRB of 0.10 - 42 deaths/100,000 live births when distance to the labor/delivery units was 29.37 - 58.04 miles and when distance was 58.04 - 87 miles. In 39 counties, the map illustrates that Black women have to travel a distance of 0.70 - 29.37 miles where the maternal mortality rate is 42 - 870 deaths/ 100,000 live births.

The multiple linear regressions were conducted on the interaction terms that consisted of the distance and the race/ethnicity variable for Non-Hispanic Black mothers, in addition to Hispanic/Latino mothers to look at the relationship with maternal mortality rates among all races. With the coefficient for the interaction terms not being statistically significant, it can be said that distance does not have an impact on maternal mortality rates in Non-Hispanic Black women when compared to Hispanic/Latino women in Georgia counties from 2010-2016. However, the models illustrated that maternal death rates decreased as distance increased. Saturated models were used to look at the relationship of maternal mortality rates among all races with the predictors such as the multiplicative terms, race/ethnicity with Non-Hispanic White mothers as the reference group, educational attainment, population density, persistent poverty, health insurance status and distance. The regression analysis showed that the association between the interaction terms along with the sociodemographic and socioeconomic factors and maternal mortality rates was not statistically significant. The variables that were found to be statistically significant were population density and Hispanic/Latino mothers. As population density increased by 1 square mile, the average maternal mortality rates increased demonstrating that more women might be giving birth requiring that area or county to have more hospitals with labor and delivery units to cater to the growing population. Additionally, it is possible that these hospitals could have been more rigorous in collecting data on maternal deaths and reporting it to the state's maternal mortality review committee since they are adequately staffed and funded. The Georgia Maternal Mortality Review Committee (MMRC) reported that in 2013, 73 percent of the maternal deaths happened in urban counties as based on the 2000 Census where these counties had a population of 35,000 or more, annually[33].

4.1 Race/Ethnicity

Hailing from a Hispanic/Latino ethnic background constituted to a decrease in maternal mortality rates. This could be indicative of the underreporting of Hispanic/Latino population in the census as stated by OASIS (Online Analytical Statistical Information System) or low to zero population in certain counties in Georgia[12]. Moreover, the Georgia review committee accounted for the demographic factors in 2013 where 6 deaths out of a total of 79 maternal deaths were attributed to women of Hispanic/Latino descent. Thus, it is possible that no births or maternal deaths occur in these counties hence the inverse relationship witnessed in all four models since only 9 counties had maternal mortality rates associated with them as compared to 58 counties for Non-Hispanic Blacks and 71 counties for Non-Hispanic Whites observed in the created dataset. An observational study analyzed sociodemographic factors such as race/ethnicity and age on maternal mortality rates from 2008-2009 and 2013-2014 for 27 states including Georgia along with District of Columbia. This study reported that maternal death rates per 100,000 live births for the Hispanic population did not increase considerably (15.1 in 2008-2009 to 15.8 deaths in 2013-2014) when compared with Non-Hispanic Blacks (46.7 in 2008-2009 to 56.3 in 2013-2014) and Non-Hispanic Whites (15.9 to 20.3 deaths per 100,000 live births) within the same time periods. It suggested that the high maternal mortality rates in Non-Hispanic White women as compared to Hispanic/Latino women was due to a significant rise in the population for White women[19].

The difference in Hispanic/Latino, Non-Hispanic Black and Non-Hispanic White maternal mortality rates is evident when observing the counties with the highest rates for Blacks followed by Whites and finally Hispanics. In the created dataset for the 159 Georgia counties, when the maternal death rates among Whites were highest in Crisp county (298.06

deaths/100,000 live births), the rates were at 0 for Blacks and Hispanics. Similarly, when the maternal death rate was 869.57 deaths/100,000 live births in Quitman county, the two races/ethnicities were 0 deaths/100,000 live births for that county. This was true for Hispanic/Latino women living in Jones county who had a maternal death rate of 2631.58 deaths/100,000 live births compared to a 0 deaths/100,000 live births maternal mortality rate for Blacks and Whites.

4.2 Risk Factors

Structural risk factors which include low education, low income, high migrant population and living in socioeconomically disadvantaged areas increases the maternal health gap leading to poor health outcomes for a woman. As mentioned earlier, the Center for American Progress Action Fund analysis was carried out for various factors concerning a woman's economic security, leadership, and health state published in 2013 which stated that only one OB/GYN is available for 7,125 women in Georgia. It gave the state an overall rank of being 41 out of the 50 states and a grade of F for women's overall well-being. The Center for American Progress Action Fund reported that approximately 21% of the women are poverty stricken out of which 29.9 percent are African-American women, ranking Georgia as the seventh-highest in the country for women living in poor conditions[5]. Furthermore, if a woman lives in a rural area, she is likely to be poor, have inadequate access to quality healthcare, travel further to a labor and delivery unit and lack comprehensive medical insurance or transportation. Risk factors and their effects tend to be magnified in such situations specifically in disadvantaged locales. The maternal mortality rate in rural areas for all women in Georgia was 50.3 deaths/100,000 live births compared to 38.2 deaths/100,000 live births in non-rural areas. For African American women living in rural areas, the rate was 79.7 as compared to 57.8 deaths/100,000 live births in

urban areas which is a stark difference with Non-Hispanic Whites with 43.9 deaths/100,000 live

births in rural areas and 35.3 deaths/100,000 live births in non-rural areas[12]. The number of

maternal deaths in Georgia (2010-2016) in urban areas was higher especially among the Non-

Hispanic Black women because of the high population density in counties such as DeKalb,

Gwinnett, Clayton and Fulton, since urbanized areas consist of deprived neighborhoods that lack

quality care.

4.3 Data

Apart from the structural risk factors mentioned above, there are a number of other

contributing factors that might have led to the observed results. Firstly, relying solely on death

certificates to gather data on the number of maternal deaths which have limited to zero options,

varies across states for recognizing pregnancy-related deaths. The check box was created in an

effort to combat undercounts in maternal mortality data through an effort by the National Center

for Health Statistics. The limited option includes a check box to verify if the woman who died

was pregnant or had been within the last year prior to her decease. While this has helped identify

maternal deaths, it has also led to errors in acquiring data and perhaps inflating the numbers

since detailed information regarding the death is not stated on the certificates. Instead, an article

by ProPublica reported that the death certificates require either the immediate, intermediate or

underlying cause of death which can ignore the connection between the pregnancy that lead to

the individuals death. Additionally, the article mentioned that data collected from states such as

Colorado, Ohio, Georgia and Delaware with maternal mortality review committees reported that

15% of the women stated as pregnant were not actually pregnant within the previous year.

Furthermore, it states that it is not necessary that an OB/GYN or trained personnel complete the

information on the certificate thus widening the gap in misinformation regarding the actual cause of death of the woman[7].

The federal government has not published data on maternal mortality since 2007 as it wanted all states to adopt the check box system for the sake of consistency. However, it should be noted that unpublished data and inappropriate data management could affect its quality which in turn can lead to inaccurate results. On a state level, even with a maternal mortality review committee in place for Georgia, it has published two reports for years 2012 and 2013 in 2015 and 2017, respectively. The lack of funding in one-third of the states meant that review committees were unable to perform their functions and provide insights that could have led to the enactment of preventative measures and better maternal health data. Hence, there is a lack of initiatives that tackle maternal mortality in the United States. One of the reasons could be that other health issues are given a higher priority which translates into more monetary, institutional and legal resources allocated towards them and less towards maternal mortality. To demonstrate this point, NPR reported that "At the federally funded Maternal-Fetal Medicine Units Network, the preeminent obstetric research collaborative in the U.S., only four of the 34 initiatives listed in its online database primarily target mothers, versus 24 aimed at improving outcomes for infants (the remainder address both)"[20]. Furthermore, the article stated that the United Kingdom has greatly reduced deaths due to preeclampsia since they recognized maternal deaths as "system failures" and the U.K should be regarded as a model for preventing maternal deaths. The U.K was able to do so through the creation of a national review committee that takes the initiative to rigorously collect and analyze data from the onset of pregnancy through complications in childbirth. It also holds the hospitals, doctors and nurses accountable for any errors that could have been prevented

throughout this experience. Thus, funding, collection and analysis of data on a case by case basis is necessary to decrease maternal mortality rates in the United States.

4.4 Limitations

The study is not without limitations which will be addressed in this section. Firstly, it is possible that there are no maternal deaths accounted for in certain counties due to variations in death certificates from county to county which may or may not have pregnancy listed as the cause of death. It could be that no maternal deaths occurred in the counties for the years examined in this study (2010-2016). Moreover, certain counties may not have had any births due to the population distribution which may consist of for example, an ageing population. Secondly, since the distance a mother travels to access labor and delivery services was calculated from the center of the county, it is not necessary that the mother goes to a hospital within the county that she resides in or that her health insurance covers the doctor in her county. The gap in inconsistent data collection for maternal deaths could be another reason for limited knowledge on the number of deaths occurring.

4.5 Future Research

Further research could include looking at the number of maternal deaths that have occurred in Georgia counties on an individual or case by case basis to determine the hospitals (labor and delivery units) that a mother frequents and the distance traveled. For analyzing maternal mortality, generalized linear regression models, Poisson regression or zero-inflated regression for the number of maternal deaths could be conducted to account for the zeroes in the data.

Figure 2.

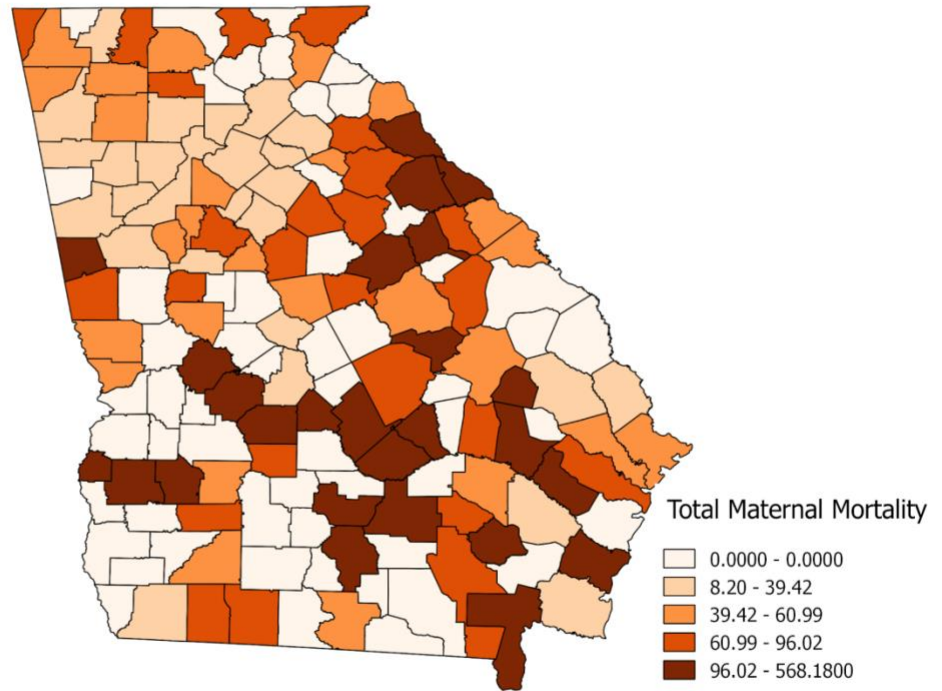Maternal Mortality Rates in Georgia Counties
(2010-2016)

Total Maternal Mortality

- 0.0000 - 0.0000
- 8.20 - 39.42
- 39.42 - 60.99
- 60.99 - 96.02
- 96.02 - 568.1800

Figure 3.

Maternal Mortality Rates in Georgia Counties- Blacks (2010-2016)

MMRB
- 0 - 0
- 8 - 39
- 39 - 61
- 61 - 96
- 96 - 870
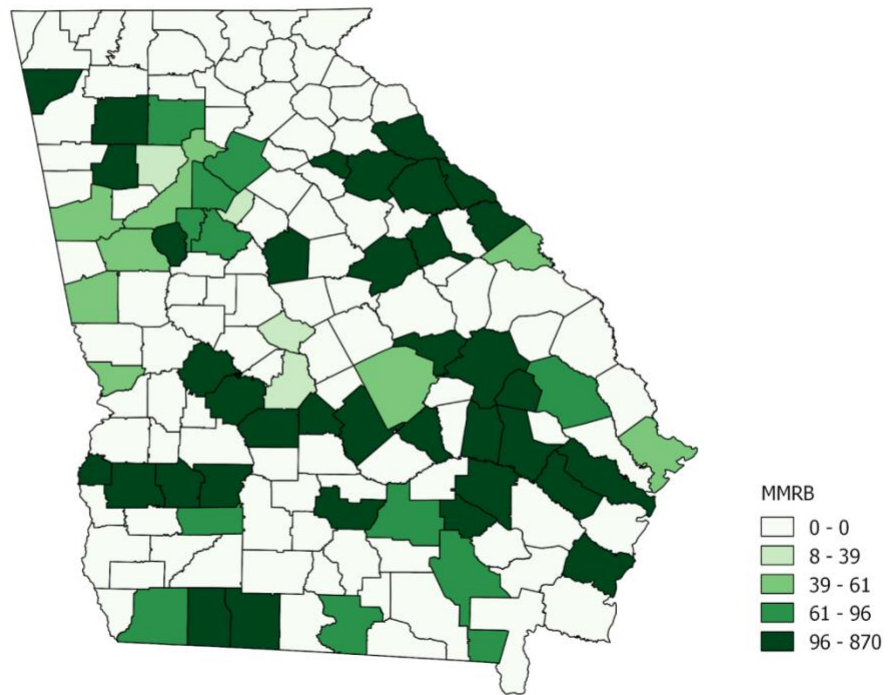
Figure 4.

Maternal Mortality Rates in Georgia Counties-Hispanics (2010-2016)

MMRH
- 0 - 0
- 8 - 39
- 39 - 61
- 61 - 96
- 96 - 2632

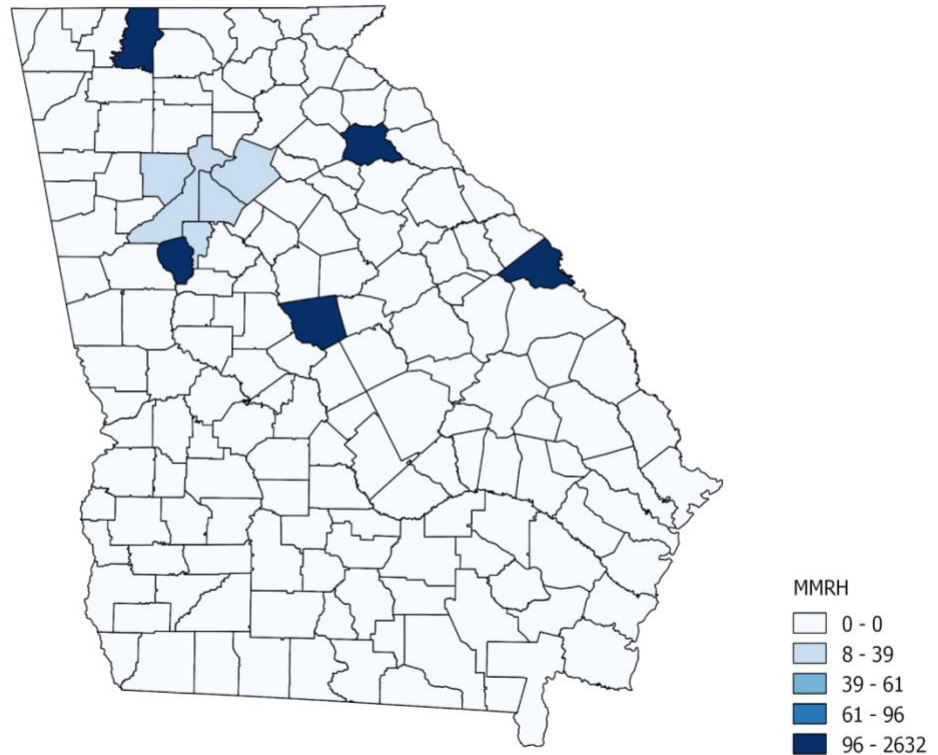**Figure 5.**

Maternal Mortality Rates in Georgia Counties-Whites (2010-2016)

MMR [159]

- ☐ 0.0000 - 0.0000 [87]
- ☐ 8- 39 [18]
- ☐ 39-61 [12]
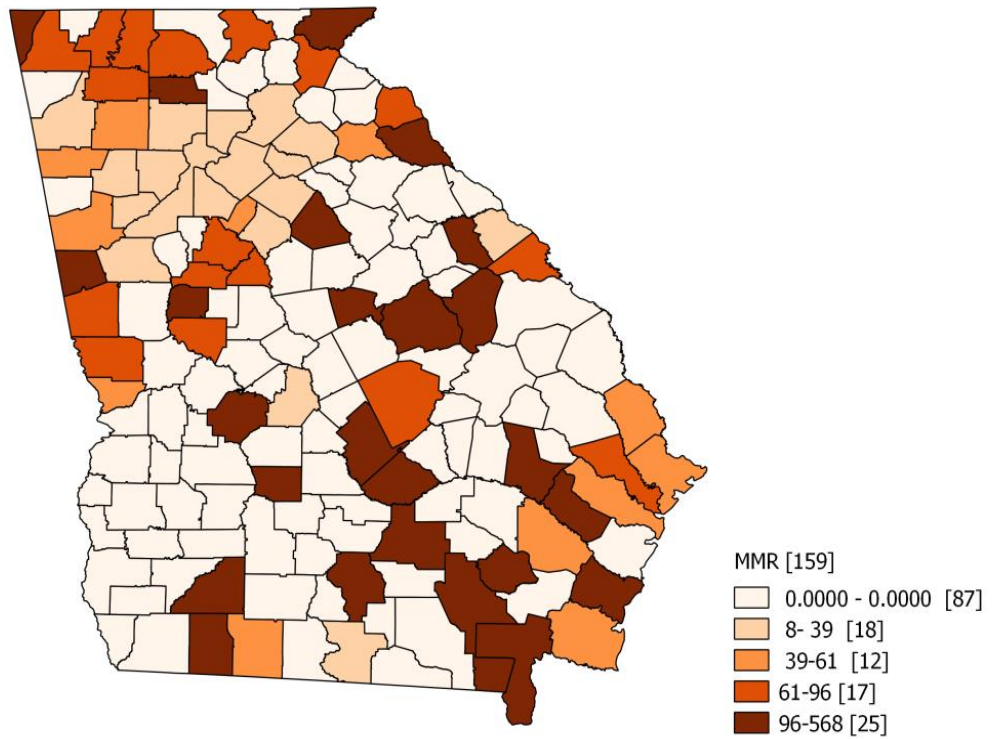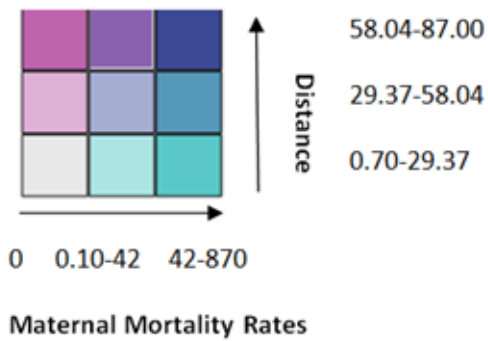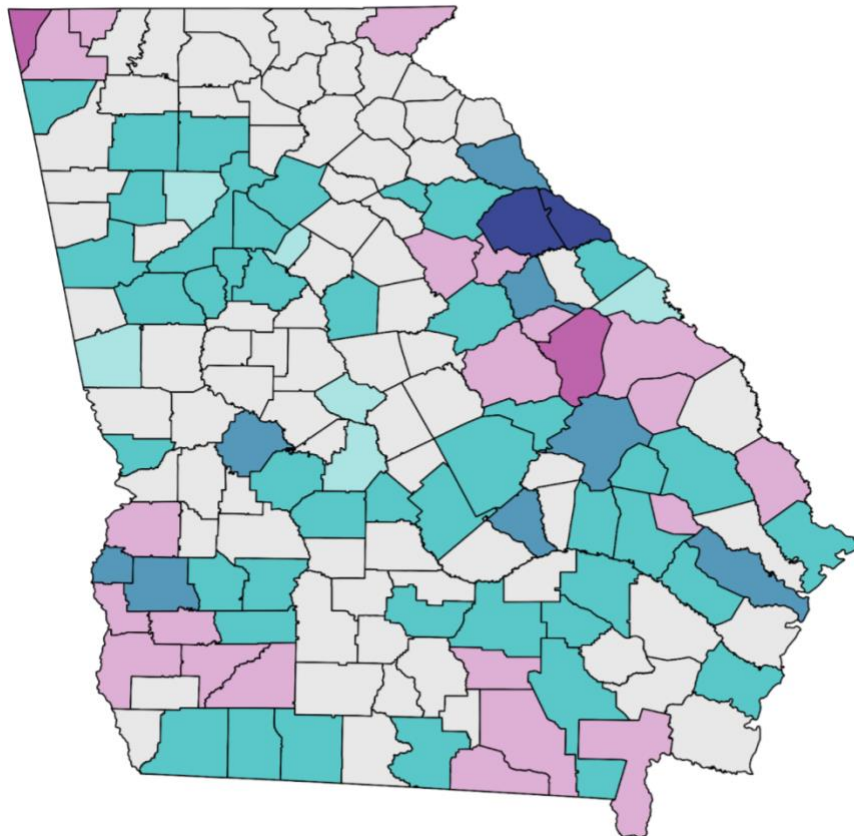- ☐ 61-96 [17]
- ☐ 96-568 [25]

Figure 6.

Relationship between distance (miles) to labor/delivery units and maternal mortality rates among Black women in Georgia counties (2010-2016)

References:

1. Anselin, L. (2018, March 16). Contiguity-Based Spatial Weights. Retrieved from https://geodacenter.github.io/workbook/4a_contig_weights/lab4a.html

2. ArcGIS. (n.d.). How Spatial Autocorrelation Works. Retrieved from http://pro.arcgis.com/en/pro-app/tool-reference/spatial-statistics/h-how-spatial-autocorrelation-moran-s-i-spatial-st.htm

3. CDC WONDER Mortality Files. (2018). Health of Women and Children. Retrieved from https://www.americashealthrankings.org/explore/health-of-women-and-children/measure/maternal_mortality/state/ALL

4. Cecil G. Sheps Center for Health Services Research. (n.d.). 90 Rural Hospital Closures: January 2010 - Present. Retrieved October 13, 2018, from http://www.shepscenter.unc.edu/programs-projects/rural-health/rural-hospital-closures/

5. Center for American Progress Action Fund. (2013). The State of Women in Georgia. Retrieved November 16, 2018, from https://cdn.americanprogress.org/wp-content/uploads/2013/09/StateofWomen_Georgia.pdf

6. Family Medicaid. (n.d.). Retrieved from https://dfcs.georgia.gov/sites/dfcs.georgia.gov/files/related_files/site_page/DFCS. Family Medicaid 7.15.pdf

7. Fields, R., & Sexton, J. (2017, October 27). How Many American Women Die From Causes Related to Pregnancy or Childbirth? No One Knows. Retrieved from https://www.propublica.org/article/how-many-american-women-die-from-causes-related-to-pregnancy-or-childbirth

8. Garba, M & Nayama, M & P Alio, A & L Holloway, M & S Hamisu, B & M Salihu, H. (2011). Maternal mortality in Niger: a retrospective study in a high-risk maternity. African journal of medicine and medical sciences. 40. 393-7.

9. GEODA: AN INTRODUCTION TO SPATIAL DATA ANALYSIS. (n.d.). Retrieved November 15, 2018, from https://spatial.uchicago.edu/geoda

10. Georgia Counties by Population. (n.d.). Retrieved from https://www.georgia-demographics.com/counties_by_population

11. Georgia Counties Ranked by Area. (n.d.). Retrieved October 15, 2018, from http://www.countymapsofgeorgia.com/countiesbyarea.shtml

12. Georgia Department of Public Health. (n.d.). OASIS Web Query - Maternal Child Health (MCH) - Maternal Mortality. Retrieved from https://oasis.state.ga.us/oasis/webquery/qryMaternalDeath.aspx

13. Goal 3 .:. Sustainable Development Knowledge Platform. (2018). Retrieved October 13, 2018, from https://sustainabledevelopment.un.org/sdg3

14. Hanson, Claudia, Jonathan Cox, Godfrey Mbaruku, Fatuma Manzi, Sabine Gabrysch, David Schellenberg, Marcel Tanner, Carine Ronsmans, and Joanna Schellenberg. "Maternal Mortality and Distance to Facility-Based Obstetric Care in Rural Southern Tanzania: A Secondary Analysis of Cross-Sectional Census Data in 226 000 Households." The Lancet Global Health 3, no. 7 (July 2015): e387–95. https://doi.org/10.1016/S2214-109X

15. Harper, Margaret A., Mark A. Espeland, Elizabeth Dugan, Robert Meyer, Kathy Lane, and Sharon Williams. "Racial Disparity in Pregnancy-Related Mortality Following a Live Birth Outcome." *Annals of Epidemiology* 14, no. 4 (April 2004): 274–79. https://doi.org/10.1016/S1047-2797(03)00128-5.

16. Hoffman, K. M., Trawalter, S., Axt, J. R., & Oliver, M. N. (2016). Racial bias in pain assessment and treatment recommendations, and false beliefs about biological differences between blacks and whites. Proceedings of the National Academy of Sciences of the United States of America, 113(16), 4296-301.

17. Karlsen, Saffron, Lale Say, João-Paulo Souza, Carol J. Hogue, Dinorah L. Calles, A. Metin Gülmezoglu, and Rosalind Raine. "The Relationship between Maternal Education and Mortality among Women Giving Birth in Health Care Institutions: Analysis of the Cross Sectional WHO Global Survey on Maternal and Perinatal Health." *BMC Public Health* 11, no. 1 (July 29, 2011): 606. https://doi.org/10.1186/1471-2458-11-606.

18. Lu, Michael C., and Neal Halfon. "Racial and Ethnic Disparities in Birth Outcomes: A Life-Course Perspective." *Maternal and Child Health Journal* 7, no. 1 (March 2003): 13–30.

19. MacDorman, Marian F., Eugene Declercq, Howard Cabral, and Christine Morton. "Recent Increases in the U.S. Maternal Mortality Rate: Disentangling Trends From Measurement Issues." *Obstetrics and Gynecology* 128, no. 3 (September 2016): 447–55. https://doi.org/10.1097/AOG.0000000000001556

20. Martin, ProPublica N., & Montagne, R. (2017, May 12). Focus On Infants During Childbirth Leaves U.S. Moms In Danger. Retrieved from https://www.npr.org/2017/05/12/527806002/focus-on-infants-during-childbirth-leaves-u-s-moms-in-danger

21. Martin, N., & Montagne, R. (2017, December 7). Nothing Protects Black Women From Dying in Pregnancy and Childbirth. Retrieved from https://www.propublica.org/article/nothing-protects-black-women-from-dying-in-pregnancy-and-childbirth

22. Martin, ProPublica, N., & Montagne, R. (2017, December 07). Black Mothers Keep Dying After Giving Birth. Shalon Irving's Story Explains Why. Retrieved November 10, 2018, from https://www.npr.org/2017/12/07/568948782/black-mothers-keep-dying-after-giving-birth-shalon-irvings-story-explains-why

23. Maternal mortality. (2018, February 16). Retrieved October 10, 2018, from https://www.who.int/news-room/fact-sheets/detail/maternal-mortality

24. Maternal Mortality Rate. (2018, January 1). Retrieved from https://www.indexmundi.com/g/r.aspx?v=2223

25. McMorrow, S., & Kenney, G. (2018, September 19). Despite Progress Under The ACA, Many New Mothers Lack Insurance Coverage. Retrieved November 22, 2018, from https://www.healthaffairs.org/do/10.1377/hblog20180917.317923/full/

26. Moran's I. (2016, August 25). Retrieved from https://www.statisticshowto.datasciencecentral.com/morans-i/

27. Nicholl, J., West, J., Goodacre, S., & Turner, J. (2007). The relationship between distance to hospital and patient mortality in emergencies: an observational study. Emergency medicine journal : EMJ, 24(9), 665-8.

28. Norris, L. (2018, July 27). Georgia and the ACA's Medicaid expansion: Eligibility, enrollment and benefits. Retrieved October 13, 2018, from https://www.healthinsurance.org/georgia-medicaid/

29. Opportunities for improvement in care among women with severe maternal morbidity. John A. Ozimek, Rhonda M. Eddins, Naomi Greene, Daniela Karagyozyan, Sujane Pak, Melissa Wong, Mark Zakowski, Sarah J. Kilpatrick, Am J Obstet Gynecol. 2016 Oct; 215(4): 509.e1–509.e6. Published online 2016 May 19. doi: 10.1016/j.ajog.2016.05.022

30. Our Hospitals: Data & Finance. (2017, April 18). Retrieved from https://www.gha.org/Data-Finance/Maps

31. Peripartum Cardiomyopathy (PPCM). (2015, July 31). Retrieved November 22, 2018, from https://www.heart.org/en/health-topics/cardiomyopathy/what-is-cardiomyopathy-in-adults/peripartum-cardiomyopathy-ppcm

32. QGIS. (n.d.). Retrieved October 26, 2018, from https://www.qgis.org/en/site

33. *Reducing Maternal Mortality in Georgia: 2013* (Rep.). (2017). Retrieved https://dph.georgia.gov/sites/dph.georgia.gov/files/MCH/Perinatal/Maternal_Mortality_Report_Nov2017_FINAL.Screen.pdf

34. Reproductive Health:Pregnancy Mortality Surveillance System. (2018, August 07). Retrieved October 10, 2018, from

https://www.cdc.gov/reproductivehealth/maternalinfanthealth/pregnancy-mortality-surveillance-system.htm

35. Scott, S., M. E. Chowdhury, E. S. Pambudi, S. N. Qomariyah, and C. Ronsmans. "Maternal Mortality, Birth with a Health Professional and Distance to Obstetric Care in Indonesia and Bangladesh." Tropical Medicine & International Health 18, no. 10 (October 2013): 1193–1201. https://doi.org/10.1111/tmi.12175.

36. The Henry J. Kaiser Family Foundation:Status of State Action on the Medicaid Expansion Decision. (2018, November). Retrieved from https://www.kff.org/

37. Tucker, M. J., Berg, C. J., Callaghan, W. M., & Hsia, J. (2007). The Black-White disparity in pregnancy-related mortality from 5 conditions: differences in prevalence and case-fatality rates. American journal of public health, 97(2), 247-51.

38. UNFPA. (2012). The Social Determinants of Maternal Death and Disability. Retrieved from https://www.unfpa.org/resources/social-determinants-maternal-death-and-disability

39. US Census Bureau. (2018, November 29). American Community Survey (ACS). Retrieved from https://www.census.gov/programs-surveys/acs/

40. US Census Bureau. (2018, March 22). Small Area Health Insurance Estimates (SAHIE) Program-Interactive Tool. Retrieved November 16, 2018, from https://www.census.gov/programs-surveys/sahie.html

41. U.S. Has The Worst Rate Of Maternal Deaths In The Developed World.NPR.org. Retrieved November 22, 2018. https://www.npr.org/2017/05/12/528098789/u-s-has-the-worst-rate-of-maternal-deaths-in-the-developed-world

42. What are FIPS codes? (n.d.). Retrieved October 22, 2018, from https://support.esri.com/en/technical-article/000002594