MULTI-SCALE IMPACTS OF THE FLINT WATER CRISIS ON MATERNAL HEALTH DISAPRITIES

By

Kionna L. L. Henderson

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ABSTRACT

Maternal health disparities are a growing health concern that disproportionately subject Black women to a three times greater risk of morbidity than White women. When factoring in an environmental hazard, the risk of morbidity for Black women nearly doubles. Maternal health disparities are defined by the difference in the rate of severe maternal morbidity (SMM) between Black and White women. The overall aim of this dissertation is to examine the impact across multiple geographic scales of an environmental hazard on maternal health disparities. A secondary aim is to identify key areas of interventions to reduce adverse outcomes. This dissertation has three independent but linked research objectives. The first objective is to examine the baseline trend of maternal health disparities in Michigan two years prior to the Flint Water Crisis (FWC). The second objective is to determine the impact of the FWC on maternal health of women in Flint, Michigan. The third objective is to examine the different perspectives on the quality of maternal health care services from women who gave birth in Flint post-FWC. The study timeframe overall is 2012 through 2017. Anonymized data was collected from the Michigan Inpatient Database System (MIDB) and used to address Study 1 and Study 2's objectives individually. For Study 3, I collaborated with an ongoing, community-based randomized control trial (RCT) to collect additional maternal health disparity data from their baseline survey. Each study was self-contained and deployed a range of statistical analyses including descriptive statistics, odds ratios, difference-in-difference (DID) models, and logistic regression analyses. At the broadest geographic scale, I found that the maternal health disparity trend in Michigan has increased over time. At the urban geographic scale, I found that despite an environmental hazard posed by the FWC and living within similar socioeconomic and demographic communities as White women, the burden of maternal health disparities still falls on Black women. At the individual scale, I found that Hispanic women

had a greater experience of severe maternal morbidity than non-Hispanic women. I also found that Black women experienced discrimination within the maternal health care system despite delivering in a race concordant city more than White women. In conclusion, there are two driving factors across geographic scales that significantly impact a women's maternal outcome despite an environmental hazard: race and age. Thus, depending on the age range and if a woman identifies as Black, the odds of experiencing a SMM is significantly higher than a White woman in Flint even when accounting for multi-scale factors such as socioeconomic status, place of residence, community factors, delivering in a race concordant city, and the Flint Effect in the presence of an environmental hazard.

This dissertation is dedicated to Erma & Leevell Henderson, Andrika, Alexis, Marvin, Jaelen, my family, and my best friend Brooke that have supported me relentlessly throughout the completion of my degree. I am also dedicating my work to all Black women who feel that the world treats them with less respect and condemns their confidence while attempting to imitate them. I see you; I am you, and this dissertation is for you.

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LIST OF ABBREVIATIONS

FWC Flint Water Crisis

SMM Severe Maternal Morbidity

RCT Randomized Control Trial

ZIP Zone Improvement Plan

DID Difference-in-Difference

CHAPTER 1

INTRODUCTION

In the wake of the coronavirus (COVID-19) pandemic, the maternal health disparity gap substantially widened reducing the life expectancy of Black women by almost three-years (Krishnasamy & Shapiro, 2021). 80% of maternal health deaths are considered preventable (American Hospital Association, 2022). With such a high proportion of preventable deaths, the causes of maternal mortality differ by race: the majority of maternal deaths among Black women are attributed to cardiac conditions while mental health is the driving factor for White women (American Hospital Association, 2022). Severe maternal morbidity (SMM) rates can serve as an indicator for maternal health and health disparities (Centers for Disease Control and Prevention, n.d.). Within the United States (U.S.), SMM rates have nearly doubled over the past decade and are consistently rising with no known direct cause (Maron, 2018; Joseph et al. 2021; Rivara & Fihn, 2020). Understanding driving factors that influence this increase may be a key component in solving the maternal health disparities.

Organizations such as the Centers for Disease Control and Prevention (CDC) cannot determine why SMM rates are rising; however, it is hypothesized that individual related components such as maternal age, obesity, and pre-existing conditions are potential contributing factors (Centers for Disease Control and Prevention, n.d.). Environmental hazards are another factor to consider in the contribution of health disparities in general as minority populations are disproportionately exposed to harmful environments compared to White Americans (Javed et al. 2022; Lee & Mohai, 2011). An environmental hazard exposure can greatly increase maternal morbidity and mortality (Boyles et al. 2021). Adding racial factors to environmental hazards and

maternal health disparities yields a compounded disparity for minority populations (Benova et al. 2014).

When reviewing the literature on maternal health disparities and the impact of environmental hazards, I observed a gap on multi-scale factors that can contribute to the disproportionality of maternal health outcomes. The primary purpose of this dissertation is to examine the impact of maternal health disparities across three geographic scales: state, community, and individual. The second aim is to determine factors that contribute to the impact of an environmental hazard, the Flint Water Crisis (FWC), on maternal health disparities at the community level. Lastly, the third aim of this dissertation is to investigate the perception of systemic discrimination and environmental injustice on maternal health outcomes, SMM. The conceptual model used for this dissertation is the Pathways of Institutional Discrimination on Maternal Health Disparities. Discrimination is used as a proxy for systemic racism (also referred to as structural racism) as there is no standard method to measure racism. The ultimate goal is to use the combined exertion of each of these study through the conceptual framework to provide health and policy recommendation for future researchers and healthcare personnel.

Identifying the Problem

Examining maternal health at the institutional level, I found that U.S. spent approximately 1.4 trillion dollars on nutrition, maternal and child health programs, and vaccines in the 2019 Fiscal Year which is more than any other country (Garber & Skinner, 2008; Papanicolas et al. 2018; The U.S. Government and Global Maternal & Child Health Efforts, 2019). A recent report found that the total estimated cost of maternal morbidity in the U.S. from birth to the child's fifth birthday in 2019 was approximately 32 million dollars which included common morbidity conditions such as sepsis, hemorrhage, and cardiac arrest (O'Neil et al. 2021).

The burden of maternal health disparities is unevenly distributed among women in the U.S. with Black women carrying the bulk of the load (Papanicolas et al. 2018; Barber et al. 2017; World Health Assembly, 2000).

Black women are almost four times more likely to experience a complication during childbirth than White women in the U.S. (Creanga et al. 2014; Howell et al. 2016; Lang & King, 2008). Similarly, Black women have a higher risk of maternal death than White women (Creanga et al. 2014; Tangel et al. 2019). Even when women deliver at the same birthing facility, SMM is greater for Black women compared to White women (Creanga et al. 2014). Many authors have examined health associated factors such as socioeconomic status, occupation, education, and access to healthcare as direct contributing factors of maternal health disparities (Anachebe & Sutton, 2003; American Public Health Association, 2001; Creanga et al. 2014; Grobman et al. 2015; Hasselle, 2018).

Despite the strong associations of these direct and non-race-based factors, studies that control for them show that the maternal health disparity gap still exists (Bauer et al. 2013; Grobman et al. 2015). The explanation for this persistent gap may be that maternal health disparities begin long before a Black woman gives birth. An Illinois statewide study by Love et al. (2010) examined the lifetime effects of the environment on health and found that in order to reduce disparities, actions to improve socioeconomic and neighborhood environment should be taken over the course of a Black woman's lifetime. In agreeance with Love et al. (2010), I suggest that maternal health disparities are inherently present when a Black woman is born due to her race and are magnified due to additional factors such as where she lives, socioeconomic status, occupation, and education, in addition to shocks from environmental hazards.

This dissertation contributes to the scholarship on the geography of maternal health disparities by being the first study to 1) depict multiscale factors that affect maternal health disparities, 2) develop a new framework to show the pathway of discrimination and its impact on maternal health disparities, 3) use the Modified Darden-Kamel Composite Socioeconomic Index in an innovative way, 4) deploy a quasi-experimental design (e.g., difference-in-difference) to determine the effect of the FWC on maternal health, and 5) obtain and report on the perceptions of maternal health post-FWC among women who delivered a child in Flint post-FWC. Much research has been conducted on the spatial impact of residential segregation on maternal and child health outcomes such as low birthweight and infant mortality within Michigan (Grady, 2010; Grady and Darden, 2012; Grady and Enander, 2009). However, the spatial impact of maternal health disparities across all three geographic scales or the impact of the FWC on maternal health have not been investigated. Recent studies have also examined the indirect effect of the FWC on maternal health from women of surrounding areas and the birth outcomes among Black and White and found that the FWC was driven by racism and ultimately affects the health of Black women (Allgood et al. 2022; Kilpatrick et al. 2022). However, to my knowledge, no published scholarly work examines the above contributions of this dissertation across geographic levels. The following section outlines the overall research goals of this dissertation and each study's hypotheses, objectives, and research questions.

1.1 Research Goals

The overarching themes of this dissertation are to 1) examine the impact of an environmental hazard on maternal health disparities across three geographic scales (i.e., state, city, and individual) and 2) determine common driving factors that influence maternal health disparities. The study's timeframe includes pre-FWC (2012 through 2013), during-FWC (2014 through

2015), and post-FWC (2016 through 2017). These time periods were chosen to align with key points in the FWC timeline. Since the FWC began in April of 2014 when the municipal water source was switched to the Flint River, the pre-FWC baseline period was set for 2012 through 2013. During-FWC data was selected for the 2014 to 2015 timeframe which also captures data up to October 2015, when the water source was switched back. The post-FWC timeframe includes any immediate ongoing effects that might occur.

1.2 Study Hypotheses & Objectives

The main objective of this dissertation was to compare maternal health outcomes across three geographical scales in three complementary research articles. My primary hypothesis is that the influence of institutional discrimination may directly and/or indirectly through environmental injustice contribute to a significant maternal health disparity gap that disproportionately affects women from marginalized populations more than White women across varying geographic scales. The marginalized population identified in this dissertation are Black women. If policymakers address and eliminate the institutional discrimination that are embedded in structural entities such as housing, more equitable and just infrastructures can be built to combat health disparities.

1.3 Study One

The first paper in this dissertation includes the broadest geographic scale, the state. The study assessed the maternal health disparity trend overtime between Black and White women across the state of Michigan using maternal records from the Michigan Inpatient Database (MIDB) system. The MIDB houses all in-patient hospital records for the state of Michigan. In addition to identifying the maternal health disparities overtime, I compared the difference in SMM within ZIP codes that housed more varying proportions of Black populations. To my knowledge, this is

the first study to examine the statewide community level impact of the proportion of Black populations on maternal health disparities. By conducting analysis at this level, I was able to set the baseline foundation for the remainder of the research studies and observe a continuum of effects of disparities from the broadest (state) to finest (individual) scale.

Study One objectives, research goals, and hypotheses

The objectives of the first study are to 1) identify the maternal health disparity trend in Michigan two years prior to the FWC and 2) determine the overall maternal health disparity trend for the state of Michigan for women who reside in ZIP codes of varying proportions of Black residents. The follow are the research questions to be addressed in this study:

1. What is the maternal health disparity between Black and White women in the state of Michigan between 2012 and 2013?
2. Which patient and community factors are associated with this disparity?
3. Does living in ZIP codes with a higher proportion of Black population correlate to higher rates of SMM?

My hypotheses for this study are as follows:

1. The maternal health disparity rate in Michigan is greater than the national rate.
2. Patient and community factors do not explain the maternal health disparity rate observed in the state of Michigan.
3. ZIP codes with higher percentages of Blacks experience higher rates of SMM for both Black and White women.

1.4 Study Two

The second paper is conducted at a narrower scale than the first study, the community level. For this paper, I identified a demographically comparable city in Michigan that is similar to Flint

but, did not experience the water crisis to determine the effect of the FWC on maternal health. This is a key component to this study, as one's place of residence can significantly influence one's quality of life or lack thereof (White et al. 2012). While there are studies on the FWC and its impact on children (Hanna-Attisha et al. 2016; Trejo et al. 2021; Zahran et al. 2017), there is a gap in the literature on the FWC and its impact on maternal health (i.e., SMM). Community factor data for this geographic level was also obtained from the American Community Survey. To determine which city to compare to Flint, U.S. Census Bureau data was used. Study Two used the difference-in-difference quasi experimental design which acts like a randomized control trial (RCT) and controls for changes over time between two groups: treatment group (Flint) and control group (similar city) (Wing et al. 2018). Examining the disparity rate at this geographic level and comparing Flint to a socioeconomic and demographically similar city in Michigan that did not experience the water crisis allows for determining city level factors that possibly influence maternal health disparities.

Study Two objectives, research questions, and hypothesis

The objectives of Study Two are to 1) investigate if there is a Flint Effect that impacts maternal health disparities at the city level using the difference-in-difference method and 2) examine the maternal health disparity patterns between Black and White women in Flint from 2012 through 2017 in three phases of the FWC: pre-FWC (2012 through 2013), during-FWC (2014 through 2015), and post-FWC (2016 through 2017). The following are research questions to be addressed in this study:

1. Are Black women in Flint, MI more likely than White women to bear the burden of maternal morbidity post-FWC or during-FWC compared to pre-FWC?
2. What was the effect of the FWC on maternal health disparities in Flint?

Below is my hypothesis for Study Two:

1. Flint will have a higher maternal health disparity after the FWC due to factors that contribute to environmental injustice and institutional discrimination compared to a city of similar socioeconomic and demographic factors.

1.5 Study Three

Lastly, the finest geographic scale, individual, investigated the perceptions of maternal health care services received and quality of care during childbirth among women who delivered a child in Flint from 2021-2022. Data for this study was obtained through a collaboration with an ongoing community-based, randomized control trial (RCT) in Flint called Supporting Parents and Raising Resilient Kids (SPARRK) study. Study Three determined the perceptional impact of institutional discrimination and the impact of the FWC on health through a survey questionnaire. Study Three obtained the individual perceptions of maternal health care in Flint and determined the proposed proximity of the residential area of these women to the lead ranges from the FWC.

Study Three objectives, research questions, and hypothesis

The objectives of Study Three are to 1) determine if the environmental exposure and maternal health disparity gap influences the perception of Black women on the health care system compared to White women, 2) investigate if Black and White women who live in the same neighborhood experience similar maternal health care quality and FWC impacts, and 3) examine the perception of maternal health discrimination post-FWC. Below are the research questions for this study:

1. How do women in Flint perceive their overall health improved after the FWC?
2. Did women's perceptions on maternal health services and quality improve after the Flint Water Crisis?

My hypothesis for Study Three is stated below.

1. The maternal healthcare system in Flint did not improve even after the national attention on the Flint Water Crisis due to prolonged urban irrelevancy and discrimination.

1.6 Conclusion

In summary, these three studies will contribute greatly to the Health Geography literature and fill the gap on multiscale factors that influence maternal health disparities, and on the impact of the FWC on maternal health in Flint, Michigan. The next chapter will discuss the conceptual model developed for this dissertation and a literature review that provides background knowledge on maternal health disparities, its relationship with environmental hazards, and the FWC. The three main studies are presented in chapters three, four, and five. The concluding chapter will summarize the key findings of each chapter and provide recommendations to aid in reducing maternal health disparities.

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CHAPTER 2

PATHWAYS OF INSTITUTIONAL DISCRIMINATION ON MATERNAL HEALTH DISPARITIES

2.1 Chapter Overview

This chapter provides critical review context on maternal health disparities and environmental impacts on health in general along with background information on the core site. First, the chapter explains the conceptual framework, Pathways of Institutional Discrimination on Maternal Health Disparities, developed for this dissertation. Next, the chapter provides a literature review of maternal health disparities and environmental impacts on health. The chapter then closes with an overview of demographic change in Flint, Michigan.

2.2 Conceptual Framework

The theoretical framework for this dissertation, Pathways of Institutional Discrimination on Maternal Health Disparities (PID-MHD), integrates three conceptual models. First, I examined the Public Health Critical Race Theory (PHCRT), which applies the four main concepts of Critical Race Theory (i.e., race consciousness, contemporary orientation, centering in the margins, and praxis) to disparities in health, income, and residential living spaces (Ford & Airhihenbuwa, 2010). However, the PHCRT does not account for pathways by which the health of marginalized populations might be affected either directly or indirectly at various socioeconomic and demographic levels. To link this, I used a segment of the maternal morbidity framework created by the World Health Organization to account for maternal healthcare services and quality of care received (Filippi et al. 2018). This model suggests that the pathway by which health systems and quality of care affect women's labor and delivery, which can cause maternal morbidities that range from less severe to mortality. I applied this pathway to all themes in my

model as previous research on the PHCRT and the impact of discrimination provides empirical evidence that the individual and community factors may impact maternal health outcomes as well. Lastly, the breadth of the PID-MHD conceptual framework is from the Pathways to Racial and Ethnic Disparities in SMM & Mortality (Howell, 2018). This model examines the pathways of race/ethnicity disparities on maternal health and the role of social determinants such as individual factors, neighborhood factors, healthcare and health systems factors. The model falls short in accounting for the substantial impact of institutional and societal discrimination, especially since the burden of maternal morbidities fall on Black women.

By combining concepts from the aforementioned concepts, the final model developed was the Pathways of Institutional Discrimination on Maternal Health Disparities (**Figure 2.1**). The model is comprised of the following elements: 1) the implicit bias towards race and marginalization of minorities encourages discrimination among these groups; 2) discrimination in social and institutional environments such as housing can impact these groups across socioeconomic scales including individual and community as well as how they are treated within the healthcare system & quality of care; 3) these socioeconomic factors may differentially influence labor & delivery conditions; 4) differences within these conditions can lead to the following maternal morbidity outcomes: recovery, non-severe morbidity, severe morbidity, and mortality. For this dissertation, I focused on severe maternal morbidities (SMM) as it serves as an indicator for maternal health disparities.

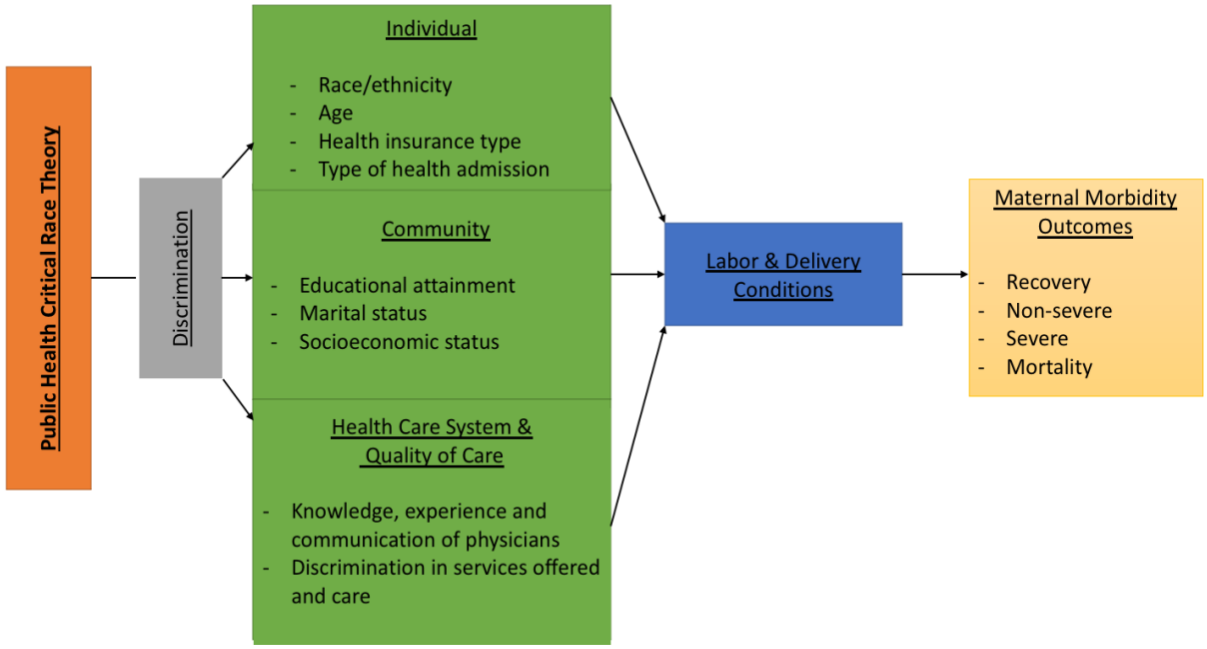

Figure 2.1: Pathways of Institutional Discrimination on Maternal Health Disparities

2.3 Defining Maternal Health Disparities

The World Health Organization (WHO) defines maternal health as the health status of a women in three stages: pregnancy, childbirth, and postnatal (World Health Assembly, 2000). WHO states that maternal morbidity is "…any health condition attributed to and/or aggravated by pregnancy and childbirth that has a negative impact on the woman's wellbeing" (Firoz et al. 2013; World Health Assembly, 2000). There is a great deal of research on the importance of improving maternal health quality to reduce maternal mortality and morbidity (Hasselle, 2018; Lang & King, 2008; Maternal, Infant, and Child Health, 2020). Across the world – and in the U.S. - maternal health care often falls short of quality health services, accessibility, assistance, and necessities needed to achieve a successful birth and quality of life (Amnesty International, 2011). This inadequacy of maternal health is unevenly distributed by race in the U.S., as Black

women bear the burden of this health issue by having a morbidity and mortality rate three times more than White women (Taylor, 2020).

Previous research has contributed maternal health disparities to factors such as education, income, and place of residence. However, when reviewing the literature, I found that none of these factors fully explain root causes or the pathway of maternal health disparity gap. One study examined if there was a difference in the quality of delivery hospitals that serve Black and White women (Howell et al. 2016). The study found that Black women still had the highest risk of adverse maternal health outcomes even when delivering at a hospital that serves predominantly White women (Howell et al. 2016). It is known in the health literature that the racial composition of one's neighborhood influences the quality and quantity of physicians (Gaskin et al. 2012; Landrine & Corral, 2009; Piccolo et al. 2015). Therefore, neighborhoods with a high minority population tend to have a lower number and quality of physicians (Gaskin et al. 2012). This study provides evidence that Black women will still have a higher rate of morbidity regardless of their place of residence or delivery hospital. The findings above are essential to my argument of institutional/systemic discrimination being driving forces in maternal health disparities.

The Centers for Disease Control and Prevention (CDC) has 21 indicators of SMM (**Table 2.1**) that are unexpected during the process of delivery. These indicators may negatively affect a woman's health or even lead to death (Reproductive Health, n.d.). While maternal mortality is not the primary outcome in this dissertation, it is strongly associated with SMM (Centers for Disease Control and Prevention, 2021). The CDC defines maternal mortality as death during pregnancy or within a year of birth for any cause (About the Pregnancy Mortality Surveillance System, n.d.). Nationally, there are approximately 700 pregnancy related death per year due to pregnancy or delivery complication (Maternal Mortality, n.d.). Thus, identifying pathways to

encourage interventions in maternal health disparities by addressing SMM may contribute to the reduction of maternal deaths.

Table 2.1: The CDC's 21 indicators of severe maternal morbidity

Severe Maternal Morbidity Indicators
• Acute myocardial infraction • Aneurysm • Acute renal failure • Adult respiratory distress syndrome • Amniotic fluid embolism • Cardiac arrest • Conversion of cardiac rhythm • Disseminated intravascular coagulation • Eclampsia • Heart failure during surgery or procedure • Puerperal cerebrovascular disorders • Pulmonary edema • Severe anesthesia complications • Sepsis • Shock • Sickle cell disease • Air and thrombotic embolism • Blood products transfusion • Hysterectomy • Temporary tracheostomy • Ventilation

In reviewing twenty-five maternal health related articles that span over a time period of two decades, the common conclusion observed was that Black women in the U.S. face maternal health disparities that result in morbidity and mortality across all socioeconomic levels and factors such as genetics (David & Collins Jr., 1997), social determinants (Howell, 2018), and socioeconomic status (American Public Health Association, 2001; Braveman et al. 2005.). These articles point to the underlying reason for maternal health disparities - racism. The theme of race plays vital role in maternal health outcomes and it is a known factor that racism impacts health

(Brondolo et al. 2009). For this reason, I used a portion of the Critical Race Theory (CRT) concept in my conceptual framework, PID-MHD, to examine the data observed in this dissertation. CRT defines race as a social concept developed by scholars to explain the institutional systems that place the White populations in better social, political, and economic positions than Black people (Curry, 2020). Racism, the act of oppressing specific racial groups for the acceleration of another group, and discrimination among social and institutional systems is embedded in the CRT framework (Racism, n.d.). Unfortunately, various forms of racism affect individuals differently that create disparity, especially within the maternal and child health field (Dominguez, 2008). Within maternal health, discrimination ranges across medical, systemic, institutional, environmental, and residential platforms which may influence the outcomes of maternal health.

2.4 Obstetric/Medical Racism

A recent study interviewed Black women within the U.S. to determine the extent of obstetric racism and obstetric violence in the maternal health field (Davis, 2019). The author defined obstetric racism as "a combination of obstetric violence and medical racism" (Davis, 2019). These two terms are further defined, as being mistreated at any point and time during maternal healthcare procedures and being diagnosed and/or treated differently due to the patient's race (Davis, 2019). Factors such as stereotyping and discrimination during a maternal procedure can be viewed as obstetric racism and contribute to negative health outcomes such as morbidity and mortality. The author of this article states that this type of racism is a threat to positive birth outcomes (Davis, 2019).

Another example of how obstetric racism can affect maternal health outcomes from the thought process of a physician who is racist, or stereotypes patients based on race. In David &

Collins Jr. (1997), the authors explored the different birth weights of Black U.S. born infants, African born infants, and White U.S. born infants. The common maternal and child health literature at that time proposed that Black women were genetically incapable of producing a normal weight baby due to their origins to West African ancestry (David & Collins Jr., 1997). The authors tested the theory of racial differences in birth weights between Black U.S. born women and immigrant African born women in Illinois. However, the study found that Black U.S. born infants still had lower birth weights than White U.S. born and African born babies (David & Collings Jr., 1997). Surprisingly, African infant birth weights were found to be more similar to White U.S. born infant birth weights (David & Collings Jr., 1997) than to Black U.S. born infant birth weights. This paper's primary literature consensus (i.e., Black women not being genetically capable of delivery a normal birth weight infant) and others like it are stereotypes about Black women that potentially contributes to the root cause of maternal health disparities (Davis, 2019). For instance, if a physician has a predetermined negative mindset about Black women and their infants, the physician could potentially not provide adequate and equitable care to these mothers. Further research on this phenomenon is needed, but it is important to begin the conversation to identify all paths that lead to maternal health disparities.

It is important to note that maternal health disparities are not limited to White physicians as same race physicians do not experience better maternal health outcomes. A recent study by Greenwood et al. (2020) found a significant association between physician-patient concordance and reduced Black infant mortality. While this finding is a positive outcome for Black babies, Black mother's mortality did not improve. Another study following the approach of Greenwood et al. (2020), studied almost 2 million births in Florida to determine if physician-patient racial concordance affected maternal health outcomes (Towning & Purohit, 2020). The study found

that deliveries where the infant was Black and the delivering physician was White, experienced over 400 more cases of infant mortality compared to White infants (Towning & Purohit, 2020). It is evident that race influences the health outcome of childbirth. It is reasonable to assume that same race physician-patient interactions might reduce the mortality rate of Black mothers and their infants; however, this is not the case as seen in Towning & Purohit (2020). Based on this evidence and this dissertations' conceptual framework, racism or discrimination appears to contribute to maternal morbidities by affecting Black women well before they arrive in the delivery room; its impact merely resurfaces during the child birthing process.

There are several studies that support the theory, directly or indirectly, of racism or discrimination differentially affecting maternal health long before delivery (Bower et al. 2018; Hilmert et al. 2014; Rosenthal & Lobel, 2020). For example, Rosenthal & Lobel (2020) found that gendered racism has an impact on reproductive health of Black and Latina women. The term 'gendered racism' was defined as an exposure to "oppression due to race/ethnicity and gender" (Rosenthal & Lobel, 2020). The authors hypothesized that there is a relationship between stereotype related gendered racism and birth control trust among Black and Latina women that contributes to reproductive health disparities (Rosenthal & Lobel, 2020).What is noteworthy about this article is the list of stereotypes of Black women: Black women are often single mothers, promiscuous, and on welfare or some sort of public assistance (Rosenthal & Lobel, 2020). As a result, the study found a positive relationship between racism and gendered racism, sexism, and birth control mistrust on pregnancy related stress among Black and Latina women (Rosenthal & Lobel, 2020).

Another paper examining the relationship between stereotype gendered racism and maternal health by Oseguera (2019) interviewed women to capture their lived experiences of

gendered and obstetric racism (Oseguera, 2019). The author viewed the study through the same lens as a portion of this dissertation using the CRT. The study concluded that Black women continuously experience racism through discrimination and being stereotyped in everyday life and they also encounter these factors from physicians and other health professionals who assist with pregnancy and delivery (Oseguera, 2019). Gravlee (2009) further investigates the impacts of racism and discrimination on health by describing the means by which race negatively affects an individual's physical biology due to "racial inequities, injustices, and discrimination in the health field." For instance, a person's race can determine how that person is given preventative strategies, treatment options, and quality care; these race-based differences in care pose a threat of further disparity in the health field (Gravlee, 2009).

Likewise, these effects are seen in maternal and child health metrics such as preterm birth rate. Bower et al. (2018) identified the relationship between experienced racism and birth outcomes. This study found that approximately 15% of the study population experienced an act of racism at least a year before delivery and are more likely to have a preterm birth (Bower et al. 2018). Additionally, the authors concluded that racism affects the emotions of the mother which could contribute to risk of adverse birth outcomes such as preterm birth. This study measured racism within a year of pregnancy and delivery.

Furthermore, a study by Hilmert et al. (2014) studied the effect of lifetime racism on blood pressure during pregnancy and its influence on fetal growth. Similar to the previous study, this study found that racism does impact the health and birth outcomes among Black women and their infants (Hilmert et al. 2014). Likewise, to Bower et al. (2018), this study hypothesized that racism contributes to adult physiological, increased body mass index (BMI), and reduced socio-economic status (Hilmert et al. 2014). This review presents a consensus that exposure to racism

before and during pregnancy, obstetric racism, and being stereotyped and discriminated against within the healthcare setting are determining factors for the mother and infant's health outcomes.

2.5 Systemic, Structural, & Institutional Racism

When exploring the impact of racism on maternal health, is it essential to include the branches of racism that repeatedly disadvantage Blacks in America from progressing as well as Whites in America. The three systems of racial oppression as referred to in this literature review are systemic or structural, and institutional. Systemic racism is interchangeable used as structural racism and refers to the oppressive systems put into place by the government, state officials, policy holders, and other related legal personnel for groups of minorities, especially Blacks in America. Institutional racism is the withholding or exclusion of Blacks and other minorities in America from services and opportunities that Whites have (Glover & Miguel, 2020).

An example of the impact of structural racism on maternal health is introduced in a literary overview provided by Taylor (2020). This study aimed to expose the historical context of reproductive oppression in the U.S. (Taylor, 2020). The author finds that structural racism encourages health disparities that falls on Black women (Taylor, 2020), noting that "black bodies are at times dominated by whites to maintain a system of slavery." (Taylor, 2020).

Taylor's (2020) research supports the theory that Black women are impacted by stressors in life such as being the head of household, being discriminated against, experiencing microaggressions in school or the workplace, and experiencing racism, discrimination, and stereotyping through interactions with health care professionals. The barriers put into place reach back to the 1800s when Dr. J. Marion Sims, the "Father of Modern Gynecology", violated a Black women's body and conducted surgical procedures on her without anesthesia because he believed Black women tolerated pain more than whites (Holland, 2017). Medical theories that

are based on beliefs similar to those of Dr. Sims are present in the medical field today (Bailey et al. 2021; Boateng et al. 2021; Zewude & Sharma, 2021).

Another study examined the impact of structural racism on maternal and child health by measuring the effect of systemic racism and income on low birth weight or small-for-gestational age birth using indicators such as inequalities in education and employment (Wallace et al. 2015) The study did find a significant relationship between low birth weight and structural racism across all levels of socioeconomic status (Wallace et al. 2015).

Similarly, a study by Chambers et al. (2020) found the same relationship when studying the impact of structural racism and discrimination on pregnant and early post-partum Black women in Oakland, California (Chambers et al. 2020). The study found a relationship between women's neighborhood race composition, neighborhood income, and women's experiences of racial discrimination (Chambers et al. 2020). The study concluded that Black women in neighborhoods with a high black population and low income that are exposed to racial discrimination were more likely to have a preterm birth or experience infant mortality compared to Black women who did not live in these neighborhoods. While low birth weight is not the focus of this current research study, these studies support my theoretical model that Black women in America can encounter structural racism which in turn impacts their maternal health outcomes regardless of their education and socioeconomic status. It is imperative to explore maternal impacts of institutional racism as through residential areas.

For instance, Grady (2006) explored the effect of racial disparities on low birth weight through residential segregation in New York City. The author states that residential segregation was driven by racism. It is described in the article as "a social manifestation of individual prejudices and institutional racism and discrimination" (Grady, 2006). Manifestations of

institutional racism can be seen in processes of segregating neighborhoods with a high percentage of Blacks or other minorities from opportunities, resources, employment, and favorable loans for housing in majority white neighborhoods (Glover & Miguel, 2020).

The study found that Black women in highly residential segregated neighborhoods had more low birthweight infants than women who did not reside in that area (Grady, 2006). The same association was true for Black women living in poverty (Grady, 2006). Similar to these findings, White & Borrell (2011) confirmed the negative impact of residential segregation on health disparities and that a person's residential area influences their health risk and contributes to health disparities for Blacks in general. These two studies suggest that institutional racism through residential segregation has a negative impact on maternal and child health.

The national rate of maternal mortality for Black women is higher than that for White women (Anachebe & Sutton, 2003; Creanga et al. 2014; Grobman et al. 2015; Howell et al. 2016). Multiple studies have been conducted to assess this racial disparity, but no known studies have examined the impact of institutional racism across various geographic scales (Anachebe & Sutton, 2003; Creanga et al. 2014; Grobman et al. 2015). Moreover, no known studies incorporate the role of environmental injustice on maternal health disparities at various geographic scales. For this reason, a key portion of my research will examine the Flint Water Crisis (FWC) and its effect on maternal health disparities. The next section summarizes the detrimental effects of one's environment on health.

2.6 Environmental Hazards and its Impact on Health

An environmental hazard is considered an event where material from the Earth alters human lives adversely (Liverman, 2001). Often times, this adverse effect is reflected in adverse health outcomes among humans. Place, one of the five pillars of the Geography discipline, is

extremely important and highly associated with one's health (Mennis & Yoo, 2018; Vaughan et al. 2014). Place can influence the amount of exposure one has to environmental hazards, poverty, neighborhood conditions, access to health facilities, quality of education, and occupation (Beatley et al. 1997). Many researchers have examined the disproportionality of environmental hazards among specific communities which are often minorities or people of color and low-income individuals (Ben Crump, n.d.; Mohai, 2018). This disparity is referred to as environmental injustice. There are many factors that contribute to environmental injustice but the most common are racism, residential segregation, low income, capitalism, and industrial land use (Ben Crump, n.d.; Groves et al. 2018; Mohai, 2018).

2.7 Historic Overview of the City of Flint

To understand the environmental injustice argument of my research, it is essential to provide background information about Flint and the FWC. According to the 2020 U.S. Census Bureau, Flint's current population is 81,252; 51.5% are female and 54% Black (Flint, MI, n.d.; United States Census Bureau, 2022). The poverty rate is 37.3% with a median household income of less than $30,383 (United States Census Bureau, 2022). Flint did not begin as a city of economic and population decline. In the mid-20th century, Flint was a booming industrial city with a fairly large population and flourishing economy due to production sites of automotive and manufacturing companies such as General Motors (Michigan Civil Rights Commission, 2017). After World War II, a large proportion of Blacks migrated from the Southern region of the U.S. to the North in search of jobs and better housing opportunities (Michigan Civil Rights Commission, 2017). Flint, specifically, was a city that many Blacks moved to due to the manual labor that was needed for production sites. The 1970 U.S. Bureau of Census reported a population of 193,317, with 28% being Black and just 7.5% of households below poverty. The

significant change in the population and economy of Flint began when General Motors (GM) relocated its production sites from the city to the suburbs in the 1970s and 1980s. The decentralization of GM along with white flight (e.g., White residents relocating from Flint to the suburbs) and institutional/systemic racist practices such as redlining and residential segregation contributed to the economic decline in Flint due to a large proportion of the city's tax being shifted to the suburbs (Michigan Civil Rights Commission, 2017). There was a plan proposed in 1957 to combine the governments of Flint's central city and surrounding suburbs called New Flint. This proposal suggested the combined areas would work under one government to "…preserve(d) the tax-break and direct(ed) it at common goals…" (Michigan Civil Rights Commission, 2017). This proposal failed within a year due to controversy among White residents and corporations and did not include the votes of Black residents (Michigan Civil Rights Commission, 2017). The change in economy observed when GM relocated left many inner-city residents, majority Black, without employment and a declining city (Michigan Civil Rights Commission, 2017). It is important to note that GM and other manufacturing companies contributed to the Flint River pollution due to years of dumping hazardous chemicals into the river. At the time, this was not a prominent issue as the city received its residential water supply from the Detroit water system (Michigan Civil Rights Commission, 2017).

In April of 2014, state appointed emergency officials decided to switch Flint's water source from Detroit's municipal water supply to the Flint River (Sadler & Highsmith, 2016; Masten et al. 2016). This decision to switch the residential water source without adequate water treatment led to a large number of Flint's residents being exposed to lead and other dangerous chemicals (Sadler & Highsmith, 2016; Hanna-Attisha et al. 2016; Danagoulian & Jenkins, 2020; Grossman & Slusky, 2019). Flint residents noticed a change in the water source and the spread of

sickness that occurred after the water switch (Danagoulian & Jenkins, 2020). However, their concerns were repeatedly ignored by government officials (Hanna-Attisha et al. 2016). It was not until national media attention covered the story of the water crisis that government officials took action. What is important to note about Flint in the aspect of environmental injustice other than the malicious decision of state appointed officials is its changing demographics from being a majority White city pre-World War II with a thriving economy to a majority, poor Black city by 2014. The FWC and the maternal health disparity in this country have one common component – underlying institutional/systemic racism. It is key to acknowledge that disparities and injustice may be driven by one's geographic place and space (e.g., place of residence). These factors significantly influence access to healthcare, type of care received, environmental exposures, and ultimately quality of life.

2.8 Conclusion

This chapter provides an overview of empirical evidence of the importance of the dissertation's research and the foundations of its conceptual model, Pathways of Institutional Discrimination on Maternal Health Disparities. It reviewed the current literature on maternal health disparities, the impact of environmental injustice on maternal health, and provided background knowledge on the city of Flint. From the literature review, I found that obstetric racism and systemic, structural, and institutional racism have a deep-rooted history of oppressing Black women in America. Often, the blame of maternal morbidity rates is placed on the mother and not the system that created these factors (Scott et al. 2019). This type of fault shaming and discrimination can change the dynamic of how Black and Brown mothers raise their children, especially their daughters, to avoid experiencing the same obstacles they once encountered

(Parks, 2001). Living in fear of being exposed to racism and other discriminatory practices is unethical and needs to be addressed and dismantled in order for health disparities to subside.

This dissertation developed a conceptual model, PID-MHD, to address maternal health disparities. This framework offers a holistic view of multiple factors (i.e., the influence of discrimination on individual, community, and healthcare services & quality received) on minority populations that directly and indirectly influences labor and delivery outcomes (e.g., SMM). The remaining chapters include three individual studies that applied a specific portion of the PID-MHD framework to its research objectives and hypotheses. Chapter 3 details the first study of this dissertation which focuses on the trend of maternal health disparities at the state geographic level. Chapter 4 addresses community level factors and the impact of the FWC on maternal health. Lastly, Chapter 5 focuses on individual experiences and perceptions of maternal health quality in Flint post-FWC.

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CHAPTER 3

COMMUNITY FACTORS ASSOCIATED WITH MATERNAL HEALTH DISPARITIES: A MICHIGAN CASE STUDY

3.1 Introduction

What costs trillions of dollars and has one of the worst return rates in America? The maternal health care system (Garber & Skinner, 2008; KFF, 2022; Papanicolas et al. 2018; Persaud-Sharma, 2020; Saluja and Bryant, 2021). For decades, the United States has experienced among the poorest maternal and child health care morbidity and mortality rates of all developed nations (Agrawal, 2015; Melillo, 2020; Persuad-Sharma, 2020; Tikkanen et al. 2020). The burden of the U.S. maternal morbidity and mortality falls disproportionately and consistently on Black women (Anachebe & Sutton, 2003; Johnson & Louis, 2020; Petersen et al. 2019; Lang & King, 2008; Orsl et al. 2010; Saluja & Bryant, 2021). Black women are four times more likely to experience maternal morbidity and/or mortality from childbirth than White women in America (Creanga et al. 2014; Guglielminotti et al. 2021; Howell et al. 2016; Lang & King, 2008). Researchers have attributed these disproportionalities to differences in socioeconomic status, income, education, occupation, and access to health, but even when controlling for these factors the disparities between Blacks and Whites are still evident (American Public Health Association, 2001; Anachebe & Sutton, 2003; Creanga et al. 2014; Grobman et al. 2015; Hasselle, 2018).

Previous research on maternal health disparities have examined its effects at several geographic scales including state, ZIP code, and neighborhood level (Janevic et al. 2020; Kozhimannil et al. 2020; Pickett et al. 2005). However, these scale-based investigations are usually conducted separately to determine the driving factors associated with this disproportionality, and the factors and relationships depend on the scale of analysis. In a national-level study examining SMM and mortality among Indigenous women in the U.S.,

Kozhimannil et al. (2020), found that, similar to Black women, Indigenous women experienced a higher rate of severe maternal morbidity and mortality than White women and that Indigenous women in rural areas experienced higher rates of SMM compared to urban areas (Kozhimannil et al. 2020).

At the neighborhood level, studies have found that the racial composition of a neighborhood can put a woman at an increased risk of SMM (Janevic et al. 2020; Pickett et al. 2005; White & Borrell, 2011). At the city level, a study by Benjamins et al. (2021) examined 30 cities on all-cause mortality and disparities among Black and White populations. The study supported the notion that it is possible to monitor and model the effect of health disparities across geographic levels (i.e., state, community, and neighborhood) by providing government personnel with essential information across those levels to support effective policy change.

The current study is first component of this dissertation to set the foundation to examine a continuum of effects of maternal health disparities across geographic scales (i.e., state, community, and neighborhood) in the presence of an environmental exposure, the Flint Water Crisis (FWC) from 2012 to 2017. Prior studies have found that the risk of SMM for Black women substantially increases in the presence of an environmental hazard (Benova et al. 2014). However, the impact of patient and community factors on maternal health disparities with environmental hazards has not been investigated. This chapter entails the first study to establish the impact of patient and community factors on maternal health disparity among Black and White women in Michigan two years prior to the onset of the FWC (January 1, 2012 through December 31, 2013). My research questions are 1) "What is the maternal health disparity between Black and White women in the state of Michigan between 2012 and 2013?", 2) "Which patient and community factors are associated with this disparity?", and 3) "Does living in ZIP codes with a higher proportion of Black population correlate to higher rates of SMM?"

This chapter has three hypotheses:

1) The maternal health disparity rate in Michigan is greater than the national rate.

For hypothesis one, I expect that Michigan has a greater maternal health disparity due to its distinctively racially segregated and minority dense communities such as Detroit, as areas with higher racial segregation have been linked to greater health disparities (Darden, 1990; McClure et al. 2019).

2) Patient and community factors do not explain the maternal health disparity rate observed in the state of Michigan.

For hypothesis two, I suspect that patient and community factors will have only modest influence on maternal health disparities. I believe the root cause of this disparity is more due to differential treatment within the medical field than to community or demographic factors.

3) ZIP codes with higher percentages of Blacks experience higher rates of SMM for both Black and White women.

For hypothesis three, I expect that as the percentage of Black residents within a ZIP code increases, overall SMM rates will increase due to the combined influence of poor-quality neighborhoods, hospitals, and presence of environmental hazard exposure that usually occurs in areas of concentrated minorities (Guglielminotti et al. 2019; Howell et al. 2016; Lee & Mohai, 2011).

3.2 Conceptual Framework

As mentioned in Chapter 2, the conceptual model combines theories from three models: 1) the Public Health Critical Race Theory (PHCRT) framework developed by Ford & Airhihenbuwa (2010) which applies the Critical Race Theory to explain disparities in health, income, and residential living spaces; 2) the maternal morbidity concept created by the World Health Organization (Filippi et al. 2018); and 3) the Pathways to Racial and Ethnic Disparities in

SMM & Mortality (Howell, 2018) model which examines the pathways of racial disparities on maternal health and the role of social determinants such as individual, neighborhood, and maternal health care factors. Drawing from these concepts and theories, I developed a conceptual framework, the Pathways of Institutional Discrimination on Maternal Health Disparities (**Figure 3.1**). This concept implies that societal discrimination (defined as differential treatment) among individual factors (e.g., race, ethnicity, and age), community factors (e.g., educational attainment and marital status), and healthcare & quality of health care services received jointly contribute to adverse labor & delivery outcomes such as maternal morbidity.

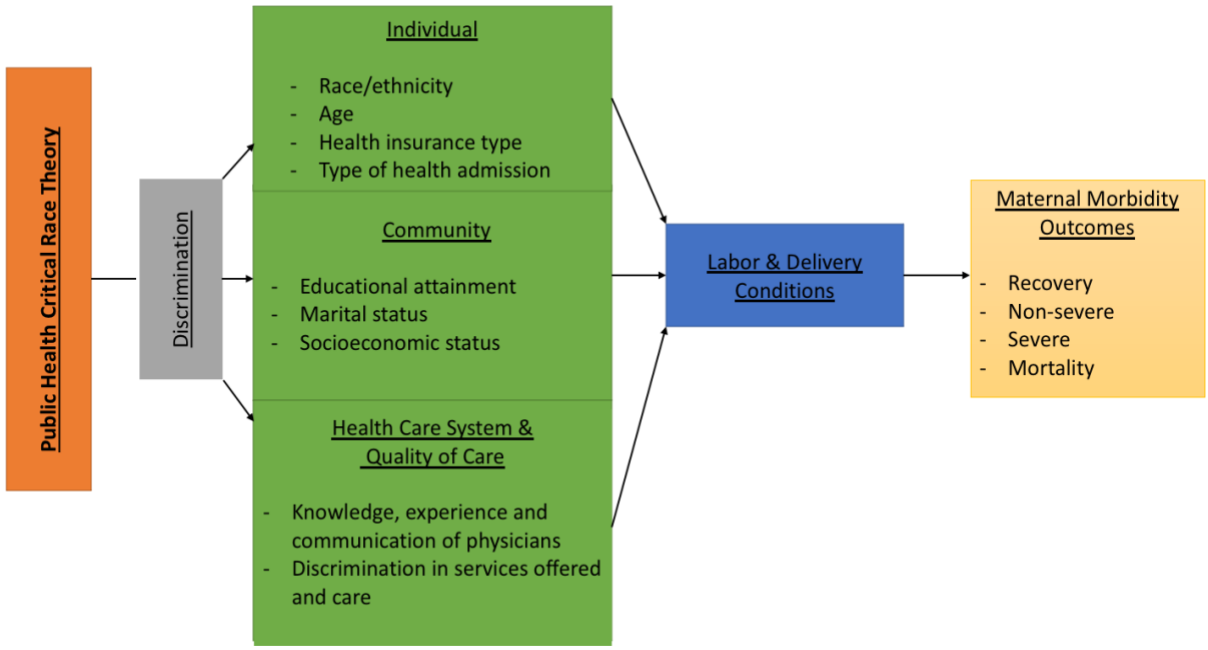

Figure 3.1: Pathways of institutional discrimination on maternal health disparities

3.3 Data

To test the study's hypotheses, I integrated two datasets: 2012 through 2013 maternal Michigan Inpatient Database (MIDB) patient records, and 2012 through 2016 5-Year American Community Survey (ACS)-Socioeconomic Status (SES) data from the National Historical Geographic Information System (NGIS) by ZIP code (National Historical GIS, 2021). Despite their shortcomings as geographic community proxies (Sadler, 2016), the approach of using ZIP code data to examine maternal health disparities is also used in recent studies on racial and economic polarization and COVID-19 disparities (Janevic et al. 2020; Long & Albert, 2021). Further, patient records in MIDB are only georeferenced by ZIP code, making finer geographic scale analysis impossible. Thus, ZIP code and patient level maternal health data was obtained from the Michigan Department of Health and Human Services (MDHHS) via the Michigan Inpatient Database System (MIDB), which houses all inpatient data for the state. The primary outcome was SMM which served as a proxy for maternal health disparities. The exposure variables were Michigan ZIP codes containing varying percentages of Black population ranging upward from 10%. I chose this cut off point to ensure adequate data as ZIP codes with < 10% of Black residents would have unreliable disparity rates (**Figure 3.2**). Patient level data from the MIDB consists of historic medical records that contains the demographic (e.g., race, ethnicity, and age), socioeconomic factors (e.g., health insurance payment method type), and SMM diagnosis for all women who delivered in a Michigan hospital during the two-year timeframe. All of the patient level covariates are considered social determinants of health (Artiga & Hinton, 2018). Patient data were aggregated by ZIP code of residence to evaluate at the community level of analysis. SMM rates for Black and White women were calculated for each ZIP code.

Key Definitions

SMM definitions

SMM is defined using the Centers for Disease Control and Prevention (CDC) 21 Severe Maternal Morbidity Indicators, as listed in **Table 3.1**. Blood products transfusion were excluded due to its ability to significantly increase the apparent rates of SMM (Centers for Disease Control and Prevention, 2021). This exclusion is consistent with the Centers for Disease Control & Prevention (CDC)'s information on SMM (Centers for Disease Control and Prevention, 2021).

Patient and Community Factors Definitions.

A patient is defined as a Michigan resident woman of reproductive age (15-54) who delivered a child in Michigan within the study's timeframe, 2012 through 2013. Community was defined as the ZIP code a Michigan resident woman of reproductive age resides in.

ACS, 5-Year SES Definition.

To understand the association between maternal health disparities and community factors (e.g., educational attainment and SES), I used 5-Year ACS data (Social Explorer, n.d.) at the ZIP code level for women within the reproductive age range, 15-54 (Reddy, 2003). The ACS variables in the data set, calculated as proportions, included Black and White women's marital status (*not married (i.e., separated, widowed, or divorced*) *or married*); educational attainment (*up to high school graduate or college (i.e., some college and bachelor's degree or higher*)); poverty status (*below poverty or above poverty*); and health insurance (*with health insurance coverage or no health insurance coverage*).

3.4 Methods

To test the study hypotheses, measure of association statistical tests and regression analyses were used. This section divides the statistical method used by the hypothesis tested.

Hypothesis 1

First, to gain an overview of the maternal health disparity rate in Michigan, I calculated the statewide SMM rate and mapped high risk areas of SMM per ZIP code in Michigan using ArcGIS software. SMM raw count cases by race were obtained from the MIDB database as csv files for each ZIP code in Michigan for each year. The files were cleaned and loaded into the R statistical software package (R Core Team, 2021). Odds ratios were used to calculate the statewide SMM rate which was expressed as the odds of Black women in the state of Michigan experiencing a SMM compared to White women in Michigan during the study's timeframe. Here the Odds ratio (OR) estimated the Relative Risk (RR) due to the rarity of SMM cases (Viera, 2008). **Equation 3.1** depicts how the OR and 95% confidence intervals were calculated.

Equation 3.1:

i. $$OR = \frac{\text{SMM Cases Black Women} * \text{SMM Non-Cases White Women}}{\text{SMM Cases White Women} * \text{SMM Non-Cases Black Women}}$$

ii. $$SE = \sqrt{\frac{1}{\text{SMM Cases}} + \frac{1}{\text{Non-SMM Cases}} + \frac{1}{\text{SMM Cases}} + \frac{1}{\text{Non-SMM Cases}}}$$

iii. $$95\%\ CI = \exp(\ln(OR) - 1.96 \times SE(\ln(OR)), \exp(\ln(OR) + 1.96 \times SE(\ln(OR))$$

Hypothesis 2

Patient Level Analysis.

RStudio statistical software was used to compute separate regression analyses for patient and community factors. At the patient level, I used logistic regression to identify the relationship between individual factors from the conceptual model (**Figure 3.1**) and whether a patient experienced SMM. **Model 3.1** suggests that SMM incidence is associated with the race (*White, Black, or Other),* ethnicity (*Hispanic, non-Hispanic, or Arabic*), patient's age (*continuous*

variable), admission type (*Emergency, Urgent, Trauma, or Other*), primary pay method (*Medicaid, Self-pay, Missing, or Other*).

Model 3.1:

SMM ~ race + ethnic + age + admission type + primary pay

Using R, I analyzed 2012 and 2013 patient level data that included each patient's ZIP code, race, ethnicity, age, admission type, primary pay method, county, and presence of SMM diagnosis or procedure codes. I cleaned the data to reflect only the study variables as factored variables: race (*White or Black*), ethnicity (*Hispanic, Arabic, or Other*), age (*continuous*), admission type (*Emergency, Urgent, Trauma, or Other*), and primary pay method (*Medicaid, Self-Pay, Missing, or Other*). SMM was factored by the presence of diagnosis (1) or no presence (0).

Community Level Analysis.

Next, I evaluated the role of community factors that could contribute to maternal health disparities using American Community Survey 5-year data for 2012 – 2017 using ZIP codes as the unit of analysis. I used this data as I do not suspect meaningful changes in ACS data within the 5-year period. These factors (**Model 2**) included educational attainment (*high school degree or less and some college experience or more*), socioeconomic status (*above or below poverty defined by the U. S. Bureau of Census*), presence of health insurance coverage (*insured or uninsured*), marital status (*married or not married*), and age by race. The survey data was confined to reflect only women of reproductive age, 15-54.

Model 3.2:

SMM RR ~ education attainment + socioeconomic status + marital status + presence of health insurance

For the community level data analysis, the SMM rate was calculated for each ZIP code by race. Because small counts of SMM cases by race may lead to poor estimates of SMM risk, empirical Bayes estimation was used to smooth and estimate robust SMM rates for Black and White women in each ZIP code using the Ebest function in the spdep package in R (Bivand et al. 2018). The method of moments estimator is a widely employed empirical Bayes implementation described by studies such as Marshall (1991) and Clayton & Kaldor (1987) who used it for disease mapping. Then, I calculated the SMM disparity rate for each ZIP code by dividing the Black empirical Bayes estimate by the White empirical Bayes estimate. This disparity rate is referred to as the Relative Risk (RR), **Equation 3.2**. I used regression analyses to determine associations of ZIP code level RR against community level factors. Stepwise analysis was used to determine which variables were most associated with the standardized SMM RR rate. The final model for community factors is shown in **Model 3.2** below:

Equation 3.2:

$$RR = \frac{\frac{\text{Risk of SMM in Black Women}}{\text{Total number of Black women not at risk}}}{\frac{\text{Risk of SMM in White Women}}{\text{Total number of White women not at risk}}} = \frac{\text{Bayes estimation of Black SMM risk}}{\text{Bayes estimation of White SMM risk}}$$

Hypothesis 3

Racial Composition Analysis.

Finally, to test Hypothesis 3 on the impact of varying percentages of Blacks in ZIP code on SMM rates, I first grouped ZIP codes into categories based on the percentage of Blacks. I then used the following percentiles to depict increasing percentages of Blacks within each ZIP code: <10%, 10-20%, 20-30%, 30-40%, and >40%. Then, I calculated the ratio of Black and White maternal records and SMM cases in each of these categories. Third, I used a Kruskal-Wallis H test to determine the difference in means between the relative risk of Black and White SMM rates in R. Kruskal-Wallis is a one-way non-parametric ANOVA and was used due to the positive skewness of the SMM data (Kruskal-Wallis H test using SPSS Statistics, 2022). Finally, I developed a graph portraying SMM rates per 1,000 population for Blacks and Whites by category.

3.5 Results

There were 49,465 Black births and 171,119 White births from 2012 to 2013 in the state of Michigan (**Table 1**). Of these births, Black and White women experienced 824 and 773 severe maternal morbidities, respectively. As a result, Black women's risk of experiencing an SMM is 3.73 times greater than that for White women in Michigan (95% CI: 3.38 to 4.12, $P < 0.0001$). As a result, I observed significant associations beginning at a racial composition of <10% and as the percentages of Blacks within a ZIP code increased, the sample size decreased. From the logistic regression model of patient factors, race-Black, age, primary payer method-Medicaid, and primary payer method-Self Pay (p-value < 0.05) significantly increased SMM. There were significant reductions for the following patient variables: race-Other, race-White, admission type-Other, and admission type-Urgent (**Table 3.2**). The model did not explain much of the variation between

SMM and patient level factors based on the McFadden R^2 (0.04). Within the community level analysis, I did not observe any significant associations between SMM and the covariates. The only factor that had a marginally negative significance on SMM was White not married (p-value = 0.0841).

Table 3.1: Descriptive statistics of statewide raw counts of SMM among Black and White women, 2012 to 2013

	Black *N= 49,465 births*	White *N= 171,119 births*	SMM Odds Ratio**
Acute Myocardial Infarction	11	13	2.93
Adult Respiratory Disease	158	216	2.53
Acute Renal Failure	223	170	4.55
Air and Thrombotic	76	142	1.85
Amniotic Fluid Embolism	7	4	6.05
Aneurysm	4	4	3.46
Blood Transfusion*	1155	2183	1.81
CA/VF	11	12	3.17
Cardiac rhythm	13	16	2.81
Disseminated Intravascular Coagulation	177	555	1.10
Eclampsia	78	143	1.89
Heart Failure	17	16	3.68
Hysterectomy	0	0	NA
Puerperal Cerebrovascular Disorders	59	116	1.76
Pulmonary Edema Acute	180	170	3.67
Sepsis	218	355	2.13
Severe Anesthesia	16	14	3.95
Shock	69	137	1.74
Sickle Cell Disease	163	17	33.27
Temporary Tracheoscopy	8	5	5.54
Ventilation	37	39	3.28
Total Cases	1525	2144	2.50

*Blood transfusion diagnosis count was not included in the total or final analysis of this study.
** Odds ratios were based on raw counts of each diagnosis and may not be reliable estimates when the number of cases is small.

Table 3.2: Logistic regression model of patient level factor coefficients: race, ethnicity, age, admission type, and primary pay type (N=241,870)

Coefficients	**Estimate**	**Standard Error**	**Pr(>|z|)**
Intercept	-3.492	0.0794	< 2e-16 *
Race Black	0.259	0.041	1.58e-10 *
Race Other	-0.243	0.061	6.61e-05 *
Race White	-0.302	0.037	2.47e-16 *
Ethnic-Hispanic	0.031	0.084	0.719
Ethnic-Arabic	-0.231	0.231	0.318
Ethnic-Other	-0.018	0.037	0.632
Age	0.023	0.002	< 2e-16 *
Admission Type -Other	-1.117	0.038	< 2e-16 *
Admission Type-Trauma	0.591	0.501	0.238
Admission Type-Urgent	-1.095	0.029	< 2e-16 *
Primary Pay- Medicaid	0.347	0.033	< 2e-16 *
Primary Pay – Missing	0.012	0.708	0.987
Primary Pay – Other	0.027	0.036	0.450
Primary Pay – Self Pay	0.481	0.123	9.46e-05 *

**Significant at < 0.05 p-value*

The Kruskal-Wallis H test analysis was used to determine the difference in means among SMM RR and the racial composition of ZIP codes at varying percentages of Blacks. There were significant differences in SMM rate as the percentage of Blacks increase in a ZIP code (Chi-squared = 22.05, p-value = 0.0002, epsilon-squared = 5%). I used the Dunn's test for multiple comparisons with the Benjamini-Hochberg adjusted p-value method to determine which ZIP code percentage of Blacks was significant (Dunn, 1964). I found that < 10% compared to 11% to 20% (adjusted p-value = 0.01) and < 10 % compared to 21% to 30% (adjusted p-value = 0.01)

were both positively significant (**Table 3.3)**. A significant association beginning at a racial composition of <10% and as the percentages of Blacks within a ZIP code increased, the sample size decreased was also observed. ZIP codes that have < 30 % of Black residents have significantly elevated SMM disparities for Black women. However, **Figure 3.2**, illustrates the mean differences in SMM rates at each racial percentage, indicating a protective or negative effect of Black SMM rates in ZIP codes with < 10% Black residents. I also observed that SMM difference was consistent among ZIP codes with 10-40% of Black residents. I observed that the highest number of Michigan ZIP codes containing Black residents are at the 10% or less level (293 ZIP codes) while the lowest number of ZIP codes was observed at the >40% level. **Figure 3.2** shows the varying risk of SMM rates across the state of Michigan ranging from green (low risk) to red (high risk). Only ZIP codes with more than 10 were displayed in the map. There was a fairly high SMM rates (deep orange and red ranges with SMM rates > 3) in the eastern, southeastern, and southwestern regions of Michigan.

Table 3.3: Kruskal-Wallace test of SMM Relative Risk by varying ZIP code percentages of Black residents

Percent Black residents	Comparison	Adjusted P-value
<10%	10% to 20%	0.01*
<10%	20% to 30%	0.04*
<10%	30% to 40%	0.05
<10%	> 40%	0.07
10% to 20%	20% to 30%	0.94
10% to 20%	30% to 40%	0.89
20% to 30%	30% to 40%	0.96
>40%	10% to 20%	0.62
>40%	20% to 30%	0.62
>40%	30% to 40%	0.55

**Significant at < 0.05 p-value.*

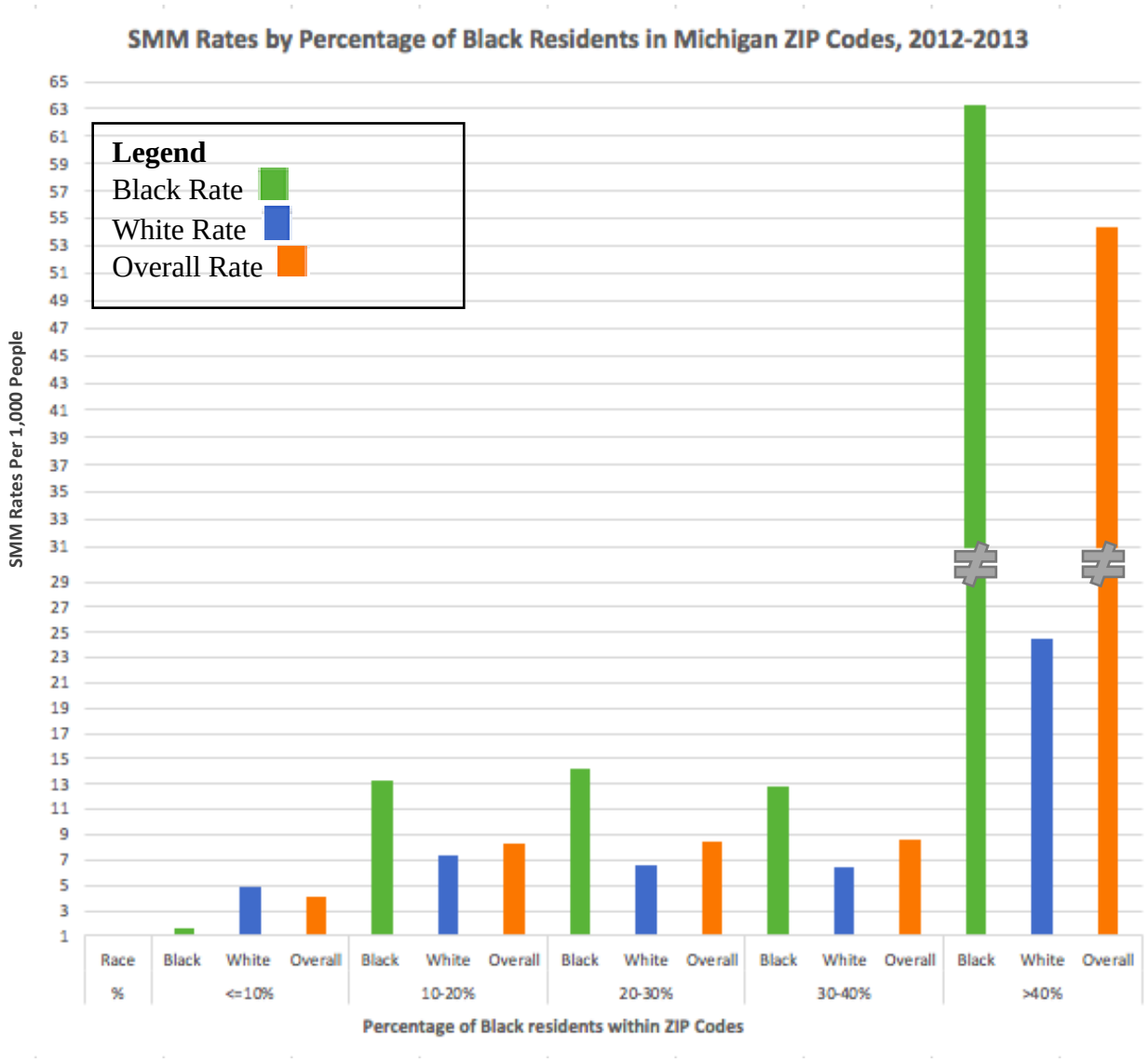

Figure 3.2: Differences in SMM rates per 1,000 people by varying percentages of Black residents in Michigan ZIP Codes, 2012 through 2013 (**dash* ≠ *indicates a break in data*)

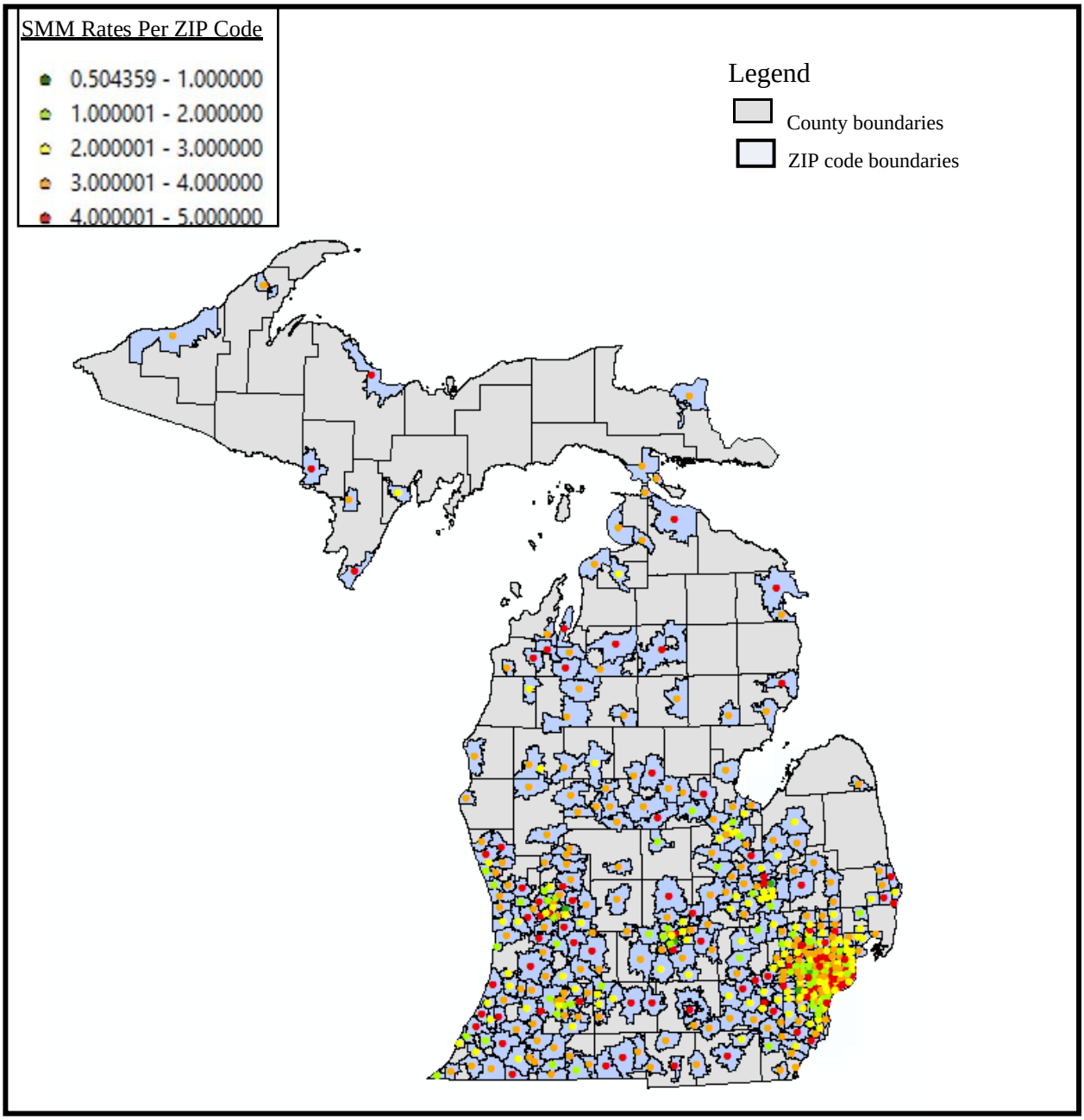

Figure 3.3: Severe Maternal Morbidity (SMM) Relative Risks rates by ZIP Code in Michigan, 2012 through 2013. Due to the criteria set for ZIP code inclusion, not all ZIP codes were displayed in the map

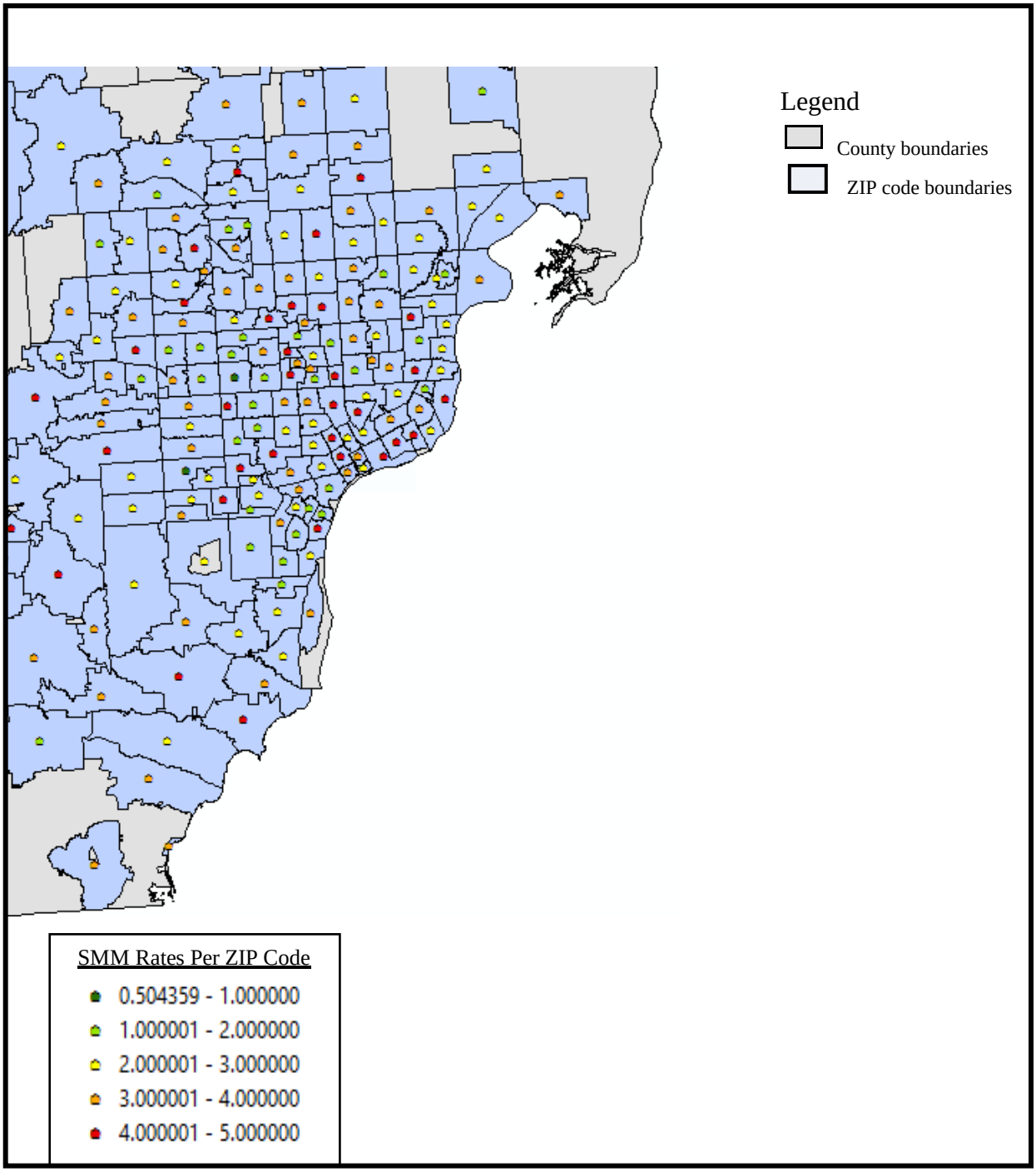

Figure 3.4: Inset of SMM Relative Risk in the Southeast Region of Michigan

3.6 Discussion

The overall maternal health morbidity disparity between Black and White women in the state of Michigan from 2012 to 2013 is 3.73, which is slightly higher than the national maternal

mortality ratio of 3.5 (MacDorman et al. 2021). This observation confirms study hypothesis one as I suspected a consist gap in maternal health outcomes among Black and White women. Patient and community factors did not solely influence SMM risk which confirms hypothesis two. Race was significant in the patient module with race-Black being positively associated with SMM while race-White was negatively associated. The difference in mean SMM rates for Black and White women were elevated in all groups; however, in ZIP codes with less than 30% of Black residents, the difference was significant. The ANOVA test confirmed a positive significance between both groups. In **Figure 3.2,** I did observe a lower rate of Black SMM cases in communities with less than 10% Black residents. However, I contribute the lower rate observed is due to either the smoothing of the Bayes estimation for ZIP codes with smaller numbers of Black SMM cases or to differences in the denominator from the Bayes estimated rate. For communities with 10 to > 40% Black populations, there appears to be relatively worse SMM outcomes for Black women were observed. This finding supports the third hypothesis that as the proportion of Black residents increase, SMM rates will increase overall. I encourage researchers to conduct similar studies at a finer geographic unit of analysis such as census tracts and examine maternal health disparities in ZIP codes that house less than 30% of Black residents. When examining **Figure 3.3**, I observed higher SMM rates throughout the state including both urban and rural areas. I did detect a concentration of high SMM rates in the southeast region of Michigan which houses cities such as Detroit, a substantially racially segregated city (Darden, 1990). While segregation is not a key aspect within this study, it is important to note the correlation of these cities that are highly concentrated with SMM and majority Black. Similar spatial concentrations were observed in the eastern region around Flint, a predominantly Black city, and the western region between Grand Rapids and Kalamazoo.

Limitations

First, the cross-sectional design of this study is a limitation as the study cannot determine causality from the results. Second, the unit of analysis, ZIP codes, is a major limitation to the study. The use of ZIP codes as a proxy for communities to determine health disparities is limitation that many health researchers face as ZIP codes may cover large and socially heterogeneous areas in which various neighborhoods are encapsulated. This issue makes it impossible to determine which neighborhoods are being overrepresented or underrepresented. While census tracts would be the ideal unit of analysis to determine the impact of neighborhood factors on health, patient residences were only referenced in the inpatient data with ZIP codes.

3.7 Conclusion

Embodying the social context of Black women and majority Black ZIP codes as well as the conceptual model for this study, the overarching conclusion is that discrimination in maternal health care services towards Black women plays a more prominent role in maternal health disparities for Black women, and this impact may be more important than their socioeconomic status. A recent study supports this notion of disparities arising geographically well beyond the neighborhood of maternal residence by identifying the relationship between lifetime exposure to discrimination and racism on social determinants of psychosis (Anglin et al. 2021). The ideal of geographic disparities is also observed in rural areas, as racially segregated communities were found to have limited access to health care and worse health outcomes (Caldwell et al. 2017). I believe the maternal health disparity observed in this study is driven by the marginalization of predominately Black communities. This phenomenon may contribute to factors that prohibit residents of those communities from health equity and a better quality of maternal health care which is supported by the increased rates in White SMM rates as well. Other studies have found that reducing discrimination and racial residential segregation can reduce health disparities and

birth rates among Black women (Beyer et al. 2016; Wallace et al. 2015; Williams et al. 2018). Based on the former findings and this study's results, policymakers should closely examine communities that have a higher risk of SMM and create interventions to improve health equity within high-risk areas. In order to identify keep areas and aspects in which intervention strategies should be incorporated, a finer geographic scale level of analysis is needed as the state-level of analysis only provides an overview of maternal health disparities. To reduce maternal health disparities, key driving factors of adverse maternal outcomes within high-risk communities must be examined. For this reason, the next chapter will investigate the impact of the FWC on maternal health disparities within Flint, Michigan using a quasi-experimental design to account for changes over time and the water crisis.

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CHAPTER 4

CONTRASTING THE IMPACT OF RACE AND AN ENVIRONMENTAL HAZARD ON MATERNAL HEALTH DISPARITIES: LESSONS FROM THE FLINT, MICHIGAN WATER CRISIS

4.1 Introduction

Racial injustices are increasingly in national discussions due to impacts from the COVID-19 pandemic, persistent violence perpetrated by police against Black civilians like George Floyd, the unlawful home invasions by police officers that resulted in the tragic death of Breonna Taylor's, and political movements such as Black Lives Matter (Mullin, 2020). Injustices towards minorities and people of color in the United States are longstanding with both social and environmental dimensions (Aalbers, 2014; Mullin, 2020). Environmental injustice is commonly referred to as the disproportionality of exposure to environmental hazard among minorities, in the US context especially Blacks compared to Whites (Patnaik et al. 2020). This exposure is not due to individual choice, but is rather systematically enforced by government, planners, and/or industries (Patnaik et. al 2020).

An ongoing environmental injustice that began in 2014 is the Flint Water Crisis (FWC). This engineered water crisis resulted from Michigan state appointed officials changing the drinking water source for Flint, Michigan, a majority Black city, from its original water source to a water supply that was not properly treated. Inadequate treatment of the water source corroded water pipelines and resulted in Flint residents being exposed to hazardous chemicals and elements such as lead. Lead-related childhood developmental concerns generated scholarship on the impacts of the FWC on children (Hanna-Attisha et al. 2016). Surprisingly, no studies have examined the impact of the FWC on maternal health; however, Benova et al. (2014) found national evidence

that, when pregnant women are exposed to unsafe drinking water, the risk of maternal mortality and morbidity significantly increases.

Purpose & Hypothesis

The purpose of this study is to conduct a quasi-experimental research design to compare Flint to a demographically similar city within the state of Michigan and determine what effect, if any, the FWC had on maternal health from 2012-2017. This effect is referred to as the Flint Effect represents the chances of Flint experiencing a certain impact because of the water crisis and its current demographic and economic state. The term Flint Effect has been used by other authors to encapsulate the effects of the water crisis (Grossman & Slutsky, 2017; Bryant, 2016). In this paper, the Flint Effect is defined as the change in maternal health disparities in Flint due to the interaction of the water crisis with other limiting factors that are common in high minority communities. Due to the gap in the literature on the effects of the FWC on maternal health and maternal health disparities, this study's objectives are to 1) investigate if there is a Flint Effect that impacts maternal health disparities at the city level using the difference-in-difference (DID) method; 2) examine the maternal health disparity patterns between Black and White women in Flint from 2012 through 2017 in three phases of the FWC: pre-FWC (2012 through 2013), during-FWC (2014 through 2015), and post-FWC (2016 through 2017). The research questions addressed are 1) "Are Black women in Flint, MI more likely to bear the burden of maternal morbidity post-FWC and during-FWC compared to pre-FWC than White women?" and 2) "What was the effect of the FWC on maternal health disparities in Flint?".

I hypothesize that Flint will have a higher maternal health disparity during the FWC due to the water crisis as well as years of environmental injustice and institutional discrimination compared to a city of similar sociodemographic factors. I suggest that the maternal health

disparity observed in Flint is influenced by the FWC as well as years of urban neglect and economic and population decline. In order to grasp the reasoning for suggesting there is a Flint Effect on maternal health disparities, it is essential to understand the study area and how it became a place for environmental hazards and injustice.

Environmental History of the Flint Water Crisis

The Flint Water Crisis began on April 10, 2014 when state appointed officers made a decision to switch the water source from the Detroit municipal water supply to the Flint River to save money. This decision was initially made to address the economic crisis within the city of Flint (Butler et al. 2016; Masten et al. 2016; Sadler & Highsmith, 2016). The roots of the FWC matriculated from the booming automobile industry in the 1930s-1970s, particularly by General Motors. During this period, the car industry in Flint and surrounding cities continuously poured lead, batteries, paints, lacquers, gasoline, and other similar elements into the Flint River and the surrounding air, and soil for years (Butler et al. 2016; Rosener, 2016).

The Flint River has not been used as a domestic water source by Flint residents since 1967 when the city of Flint switched its water supply to the Detroit Municipal water source (Wiitala et al. 1964); that is until April 2014 (Hanna-Attisha et al. 2016). This switch the water source without adequate water treatment led to thousands of Flint residents being exposed to lead and other dangerous chemicals through corroded water pipes (Danagoulian & Jenkins, 2019; Grossman & Slusky, 2019; Hanna-Attisha et al. 2016; Sadler & Highsmith, 2016).

Similarly, devasting as the actual exposure to contaminated water was the dismissal of complaints from Flint residents to government officials about the negative health effects observed once the water source was changed (Dolan et al. 2016; Felton, 2014; Morckel & Terzano, 2019). Flint residents did not receive the attention or assistance needed from the

government for almost two years after the initial water source was switched. Research highlights the impacts of lead on child-development and biological processes of children by Hanna-Attisha et al. (2016) and major media outputs shining a light on the FWC played a major role in the responsiveness of the government to address the effects of the water crisis. A map of resident lead testing kits that were dispersed a few months after the news broke about the water crisis showed lead ranges from 0 to 150 or above parts-per-billion (ppb) within the city of Flint, with higher ranges (50 ppb and above) mostly concentrated within the central city and lower lead ranges mostly on the outskirts of Flint (Brush, 2016). These lead ranges surpassed the maximum Centers for Disease Control and Prevention (CDC)'s safe blood lead levels in children's blood of 5 uq/dl or 50 ppb, and the United States Environment Protection Agency (EPA)'s level for action to treat lead in water of 15 ppb (Brush, 2016; United States Environment Protection Agency, n.d.).

Demographic History of Flint

In the mid-twentieth century, Flint consisted of a majority White population. For example, Genesee County, which contains the city of Flint, housed 374,313 residents of which 90.1% were White and 9.8% Black in 1960 (Social Explorer & U.S. Census Bureau, 2022). Almost all of the Black population at this time resided in the city of Flint. As the second Great Migration progressed, more Black citizens migrated to the north in search of jobs and opportunities that were not readily available in the southern US; however, these migrants were still subject to racial segregation in residences, education, and other social factors. In 1960, few relatively small neighborhoods had dense minority populations. As the Great Migration continued, more and more Flint census tracts or neighborhoods consisted of Black communities. These trends reflected regional shifts in manufacturing employment. Around the 1950s,

manufacturing jobs such as the Big Three automotive companies in Michigan (i.e., Ford, General Motors, and Chrysler) migrated to the suburbs resulting in decentralization of major companies, suburbanization, metropolitan fragmentation, and economic decline in cities such as Flint (Darden, 1990; Highsmith, 2014; Scorsone & Bateson, 2011). People living in inner cities who were able and could afford to move closer to jobs in the suburbs relocated. Most of these people were Whites while most Blacks remained in the central cities due to social and political constraints leading to metropolitan-scale segregation (Lee & Mohai, 2011). Urban access to suburban manufacturing job locations was limited by the lack of transportation from the inner city to the suburbs which led to the economic decline of most inner cities in America in the second half of the 20th century (Downey, 2005; Massey & Denton, 1993). Thus, Flint, along with many other predominately Black inner cities, experienced economic hardship and decades of economic decline (Frey, 1979).

Currently, according to the 2020 U. S. Census Bureau, Flint has an estimated population of roughly 81,252 (**Figure 4.1**) with 54% of its residents being Black (United States Census Bureau, 2022). A little over 85% of Flint residents have a high school diploma or higher, but only 12.3% have a bachelor's degree or higher (United States Census Bureau, 2022). Women account for 51.5% of the labor force in Flint (United States Census Bureau, 2022). The median household income is $30,383 and 37.3% of Flint residents are considered in poverty. Additionally, 20% of individuals under the age of 65 are living with a disability (United States Census Bureau, 2022). Because of its demographic make-up and persistent economic decline coupled with the disregard for the well-being of Flint residents by state-appointed officials that led to the FWC, there is an empirical case to examine if there is an underlying racial component in the resulting health impacts due to the environmental exposures to lead and hazardous

chemicals. For the purpose of this paper, I will focus specifically on the maternal health impacts of women within the reproductive age range (15-54).

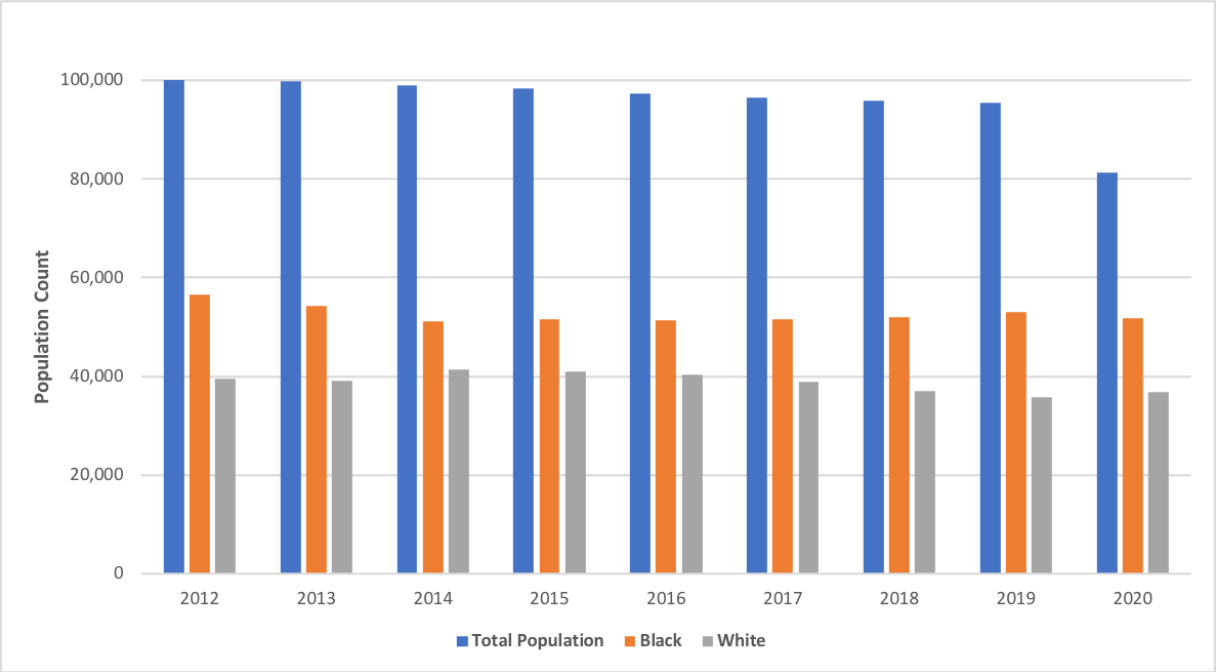

Figure 4.1: Total counts of Flint residents from 2012-2020 (United States Census Bureau (2022, June 3)

Impact of Environmental Hazardous Effects on Health

To further unpack the effects of the FWC on the well-being of Flint residents, it is important to understand the effect of environmental hazards on health. What does this impact look like for a majority minority community such as the city of Flint? This section will define environmental hazards and explore the impact of the hazards on maternal health.

An individual's environment such as their residence, job, or place where they spend their leisure time can affect their health. According to the Institute of Medicine (US) Committee on

Enhancing Environmental Health Content in Nursing Practice, an environmental hazard occurs with the exposure of "contaminated air, soil, water, and (or) food" through various pathways such as "inhalation...ingestion…and dermal absorption..." (Pope et al. 1995). The 1995 article from the Surgeon General states that there are "…no major chronic disease to which environmental factors do not contribute, either directly or indirectly" (Pope et al. 1995; Services, 1979). Thus, the safety and sustainability of an environment is a critical component in influencing health.

Many studies have found that constant interaction with a hazardous environment substantially impact the well-being of an individual and result in adverse outcomes such as cancer (adult and childhood cancer), cardiovascular disease, or negative pregnancy outcomes (Vrijheid, 2000; Brender et al. 2011). A relevant finding in the review of 49 studies by Brender et al. (2011) was the impact of a pregnant woman's residential environment on her birth outcome. This review found that the effects of exposure to environmental hazards included raised incidences of congenital malformations, chromosomal abnormalities, preterm birth, low birth weight, and perinatal mortality, among other negative outcomes (Brender et al. 2011).

As stated previously in this article, Black women tend to experience more adverse pregnancy outcomes compared to White women. Consistent with the previous study, a literature review by Morello-Frosch and Shenassa (2006) further identified the relationships between environmental hazards and maternal and child health disparities (Morello-Frosch & Shenassa, 2006). This study examined the impact of environmental hazards with psychosocial stressors on the increasing maternal health disparity gap between Black and White women in the United States. Morello-Frosch and Shenassa (2006) explore prior evidence that states that Black

communities of poor, urban status such as Flint are confronted with an increased risk of hazardous environmental exposure as well as psychosocial stressors.

Examining the relationship between environment and psychosocial stressors on maternal health disparities, one study found that the "combination and potential interaction of elevated environmental hazard exposures…and socioeconomic stressors…have been described as a form of 'double jeopardy' (IOM, 1999). Previous research has shown that for women of childbearing age who reside within in communities of poor, urban, and dense minority population status, the maternal and child heath outcome could be detrimental.

Other studies such as Grady (2006) investigated the underlying reason that minorities live in these high-risk environmental hazard areas and the impact on maternal and child health. The study determined that residential segregation due to racial disparities negatively affects maternal and child health disparities (Grady, 2006). The negative outcomes of maternal and child health due to residential racism and segregation include, but are not limited to all-cause mortality, cancer, infant mortality, and low birth weight (Collins & Williams, 1999; Grady, 2006; LaViest, 1989). All of these studies have three common themes: discrimination and/or racism (socially, politically, or environmentally), maternal health disparities, and the impact of a hazardous environment.

4.2 Conceptual Framework

This study's conceptual framework, Pathways of Institutional Discrimination on Maternal Health Disparities, combines three models: 1) the Public Health Critical Race Theory (PHCRT) framework developed by Ford & Airhihenbuwa (2010) which applies the Critical Race Theory to explain disparities in health, income, and residential living spaces; 2) the maternal morbidity concept created by the World Health Organization (Filippi et al. 2018); and 3) the Pathways to

Racial and Ethnic Disparities in Severe Maternal Morbidity (SMM) & Mortality (Howell, 2018) model which examines the pathways of racial disparities on maternal health and the role of social determinants. The dissertation's conceptual framework encompasses certain portions of the above concepts titled the Pathways of Institutional Discrimination on Maternal Health Disparities (**Figure 4.2**). This theory implies that societal discrimination (defined as differential treatment) among individual factors community factors, and health care & quality of health care services received contributes to adverse labor & delivery outcomes such as maternal morbidity. This paper will focus within the community level of the conceptual framework while controlling for patient-level factors, including race.

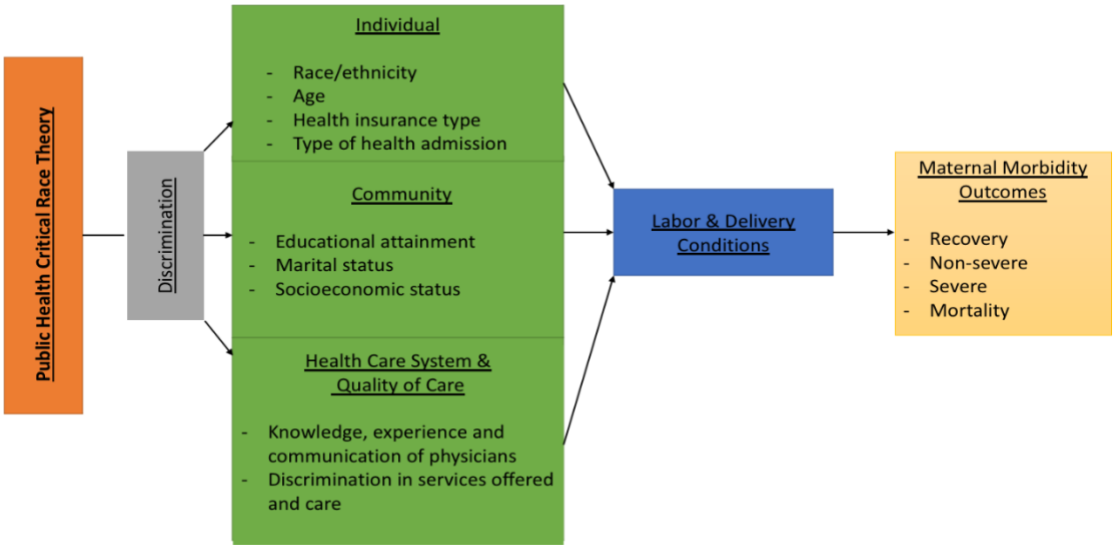

Figure 4.2: Pathways of Institutional Discrimination on Maternal Health Disparities

4.3 Data

Michigan Inpatient Database system (MIDB) data—which contains all health data from the Michigan Department of Health and Human Services (MDHHS) —was used to test the study's hypothesis. The study's timeframe is broken down in three phases: pre-FWC (2012

through 2013), during (2014 through 2015), and post-FWC (2016 through 2017). Some researchers might state that the FWC is ongoing, and the outlined timeframe is considered "during the FWC". I agree that the FWC is still present; however, the timeframes identified includes the closest period before the start of the FWC (2012-2013), the affects during the FWC (2014-2015) and the potential lingering affects post-FWC when the water source was replaced. The outcome of interest is maternal health disparities defined by the presence of a severe maternal morbidity (SMM) diagnosis during childbirth, pre-, during-, and-post-FWC. Due to my study design, there are two main sources of variables to consider over time: treatment and control groups. The treatment group consist of women who listed her home address as Flint before, during, and/or after the FWC. The control group is women who gave birth in a comparison city that is similar to Flint, but that did not experience the FWC. Patient level factors (i.e., race, ethnicity, age) and socioeconomic factors (i.e., health insurance payment type and hospital admission type) were determined for both groups.

Defining the outcome of interest

SMM was defined using the Centers for Disease Control and Prevention (CDC) 21 Severe Maternal Morbidity Indicators. These diagnosis codes include: acute myocardial infarction, adult respiratory disease, acute renal failure, air and thrombotic, amniotic fluid embolism, aneurysm, cardiac arrest/ventricular fibrillation (CA/VF), cardiac rhythm, disseminated intravascular coagulation, eclampsia, heart failure, hysterectomy, puerperal cerebrovascular disorder, pulmonary edema acute, sepsis, severe anesthesia, shock, sickle cell disease, temporary tracheoscopy, and ventilation (Centers for Disease Control and Prevention, 2021). I excluded blood products transfusion in my analysis as its inclusion can significantly influence the effect size (Centers for Disease Control and Prevention, 2021).

Patient Level Factors

I defined patient as a Michigan resident who identify as a woman of reproductive age (15-54) who delivered a child in Michigan within the study's timeframe, 2012 through 2017. The patient level variables used in this study were race, ethnicity, hospital admission type, and primary insurance payer method. Each of the patient records associated a woman who gave birth during the study's timeframe to a five-digit ZIP code in Michigan. ZIP codes or Zone Improvement Plans were created as a method for U.S. government to deliver mail (Terrell, 2013). Today, theses ZIP codes are commonly used for researchers, policy makers, and other governmental/non-governmental organizations to extract data for research on health, city planning, financial disbursement, and other factors. Shapefiles of Michigan Minor Civil Divisions that served as city boundaries and Michigan ZIP Code shapefiles were downloaded from the IPUMS NHGIS -2012 through 2016 American Community Survey data (Manson et al. 2022).

Comparison City Identification

Michigan's census tracts and minor civil divisions from the U.S. Bureau of Census - TIGER/Line (United States Census Bureau, 2022) were downloaded to identify a comparison city. To determine which city was the most similar to Flint in the aspect of race, demographics, and socioeconomics, I used civil division level socioeconomic position variables from the modified Darden-Kamel Composite index (Darden et al. 2010). While this index is used for examining socioeconomic position (SEP) of neighborhoods at the census tract level, this is the first study to use the same variables of this index to determine the similarity of cities. The socioeconomic variables used for this analysis are: 1) percentage of residents with university degrees, 2) median household income, 3) percentage managerial and professional positions, 4)

median gross value of dwelling, 5) median gross rent of dwelling, 6) percent of homeownership, 7) percentage below poverty, 8) unemployment rate, and 9) percent of residents with one vehicle (Darden et al. 2010). The identification of a comparison or control group is an important step in my quasi-experimental design as the study design requires a control group to assess the effects of the FWC. The DID assumptions require that the control group be similar to treatment group (Flint) such that if the treatment (FWC) had not occurred, the projected outcome would be similar (Kolak & Anselin, 2020).

4.4 Methods

I used analytical methodology and statistical software to test my study hypothesis that Flint will have a higher maternal health disparity due to factors other than the water crisis that contribute to years of environmental injustice and institutional discrimination. Once the control city was determined, I conducted fitted generalized linear regression (GLR) and difference-in-difference (DID) regression to test the study hypothesis.

Identifying a comparison city

Using this file, I identified a control city within Michigan to compare to Flint using Michigan census tract and minor civil division data for the study's timeframe. This city was chosen based on the similarities of socioeconomic factors outlined in Data (Section III): Comparison City. To determine the similar city, I categorized the socioeconomic factors as follows: aggregating the total counts of people per city in two age groups (under 18 and over 64); educational attainment was defined as 'no degree considered less than high school or high school', 'high school diploma and some college', and 'college educated' which included bachelor's degree, master's degree, professional degree, or doctoral degree.; and median household income (calculate as an average for each minor civil division).

Then, I grouped the census tracts by minor civil division for each city. I transformed the socioeconomic variable rates into counts by dividing the rate by the total population. I used two types of clustering analysis to identify a similar city based on key variables: race-Black, age under 18, age over 65, less than high school education, median household income, and unemployment. The data was then scaled to contribute equally to the data distance calculations. The first clustering method used was hierarchical clustering. Hierarchical clustering was performed to calculate the distance between all tracts in a scaled data space using the Euclidean method. This method calculates the greatest common divisor between two factors and determines their similarity based on the distance (freeCodeCamp, 2019). From here, I calculated and plotted a hierarchical cluster tree in RStudio using the hclust function to determine dissimilarities among the cities in Michigan compared to Flint (Murtagh et al. 2014; Legendre, 2012; Murtagh, 1985).

Due to the fact that Michigan houses just under 10 million residents, across 276 cities, and 83 counties, I reduced the hierarchical clustering plot to reflect only the closest 10 cities that are socio-demographically similar to Flint (**Table 4.1**). The second type of clustering analysis used was K-means. This method is used to identify non-overlapping groups within a dataset and determine which city is the most similar to Flint. K-means identifies cluster centers that minimize within-cluster distances (Dabbura, 2018; Garbade, 2018). The resulting number suggests how close or similar a city is based on the K-mean value. From this analysis, I chose Saginaw as the comparison city.

Computing General Linear Regression Analysis

Linear regression was used to control for patient level factors (race, ethnicity, age, admission type, and primary payer method for health care) on the MIDB data for Flint and Saginaw. Race (*Black, White, or Other*), ethnicity (*Hispanic or Non-Hispanic*), admission type (*Emergency,*

Trauma, Urgent, or Other) and primary payer method (*BlueCross, Medicaid, Self-Pay, or Other*) were characterized and factored. Age remained as a continuous variable. It is important to note that patient records in the MIDB are associated with a ZIP code. Unfortunately, ZIP codes cover a wide range of areas and often have overlapping properties across city boundaries (Sadler, 2016). In Flint, this resulted in the state attempting to discredit researchers at the start of the water crisis by stating the data was not adequate and encouraging residents to continue to use the water source (Smith, 2015).

To combat the possible inadequacy of ZIP codes, weighted linear regression was used for each ZIP code within the treatment (Flint) and control groups (Saginaw), where the weight was the proportion of the ZIP code within the municipal boundary. While a weighted analysis does not completely address the issue of ZIP codes, it serves as a proxy for complex data that is not readily available at a finer geographic scale. To determine the weights of each ZIP code, I overlapped Michigan Minor Civil Division/City Limit shapefile with Michigan ZIP code boundary shapefiles in ArcMap (**Figures 4.3 & 4.4**). I joined the overlain boundaries with the patient level factors and added a new field titled "Area ZIP". This field characterized the proportion of Flint and Saginaw ZIP codes within the municipal boundaries and was used to assign a weight to each ZIP code for the regression. The weight was calculated by dividing the area of the ZIP code within the city limit by the total area of the ZIP code for both Flint and Saginaw. I confirmed the proportions using the identifier tool in ArcMap to find each ZIP code to determine if the assigned weight matches the section of the ZIP code within the city limits.

Next, I downloaded the modified patient level factor data from ArcMap and uploaded it to RStudio for weighted logistic regression analysis. SMM was categorized as either absent (0) or present (1). Two models were evaluated on this variable. **Model 4.1** depicts the logistic

regression model used to determine the predictability of SMM while controlling for patient level factors (**Table 4.2**).

Model 4.1:

SMM ~ race + ethnicity + age + hospital admission type + primary pay method

Weights = proportion of ZIP code within city limits

While community level factors are not the primary focus of this chapter, I also conducted a general linear regression analysis on the community (ZIP code) level to determine if I observed a similar outcome as patient level factors. SMM in this case was determined using relative risk for the pre-and-post-FWC period only for each city. Similar to Chapter 3, for analysis purposes, I used Bayes Estimation to calculate the risk of SMM among Black women in both the treatment and control group (Meza, 2003). The regression model used to determine the association of community level factors on SMM is outlined in **Model 4.2**.

Model 4.2:

SMM Relative Risk (RR) ~ below poverty + health insurance + no-health insurance + married + not-married + high school education or less + college education or higher

Computing Difference-in-Difference Analyses

The difference-in-difference method was used to determine if the Flint Effect on maternal health disparities over the study time periods, pre-, during-, and post-FWC. As mentioned previously, DID is best used to determine the difference between two similar variables in which one received treatment or exposure to a new policy, law, or event and the other one did not (Kolak & Anselin, 2020; Stuart et al. 2014; Wing et al. 2018). This method assumes that in the

event that the treatment (FWC) did not occur, the two variables would have similar outcomes. The standard DID equation is defined below in **Equation 4.1**.

Equation 4.1: *A standard equation for a Difference-In-Difference model.*

$Y=\beta_0+\beta_1*T + \beta_2*I + \beta_3*[T*I] +\beta_4*C$

Y = outcome of interest
β_0 = intercept/baseline
β_1= time trend
β_2 = difference between groups (treatment/no treatment)
β_3 = difference in change over time between groups
β_4 = covariates

For this study, I modified the standard DID equation to fit my study variables. The outcome of interest is presence (1) or absence (0) of SMM for Flint and Saginaw for both the pre-, during-, and-post-FWC periods. I created the DID variable by merging pre-FWC (2012 through 2013), during-FWC (2014 though 2015), and post-FWC (2016 through 2017) patient level data in RStudio and creating a field to determine the timeframe. This field was titled "Year" and coded as pre-FWC (0), during-FWC (1), and post-FWC (1). Then, I created a "Treatment" variable that represented the city of Flint. Next, I created the DID variable by calculating the interaction of the Year (1) *Treatment variable. I computed two DID analyses using both unweighted and weighted linear regression analysis for the pre-during and pre-post-FWC timeframes (**Table 4.3:4.5**). If the DID variable is significantly different from 0, a Flint Effect will be indicated. **Model 4.3** and **Model 4.4** below reflect the unweighted and weighted models for both DID analyses, the first a very basic model with no additional variables, and the second with a range of patient-level control variables.

Model 4.3:

SMM ~ Treatment + Year + DID

Model 4.4:

SMM ~ Treatment + Year + DID + race + ethnicity + age + admission type + primary payer method

4.5 Results

The study total number of patient observations across eight ZIP codes (i.e., five Flint ZIP codes and three Saginaw ZIP codes) in each time period are as follows: pre-FWC n=8,127; during-FWC n=7,664; and post-FWC n=7,473 (**Table 4.2**). The top three cities that were statistically similar to Flint by sociodemographic factors according to the hierarchical cluster and K-means analyses are River Rouge, Ecorse, and Saginaw. The comparison city (control group) chosen for the DID analysis was Saginaw due to its' close proximity and similarity in total population size to Flint (**Table 4.1**). **Figures 4.3 & 4.4** depict both Flint and Saginaw's city limits and the issue of overlapping ZIP codes.

Table 4.1: Top 10 cities in Michigan that are the most demographically similar to Flint in Michigan

Location	**Total Population**	**Similarity Distance from Flint**
Flint	**97,645**	**0.00**
River Rouge	7,559	0.73
Ecorse	9,321	1.44
Saginaw	49,168	1.89
Benton Township	7,485	2.28
Detroit	679,600	2.64
Pontiac	63,378	2.85
Royal Oak Township	4,453	2.92
Mt Morris Township	20,698	3.00
Muskegon Heights	10,743	3.00
Inkster	24,670	3.33

Note: Flint (in red) is considered the baseline value in which other cities are being compared to. The higher the value is from the Flint (0.00), the farther away the city is in similarity.

Table 4.2: Descriptive statistics of Flint and Saginaw population demographics

	Pre-FWC		**During-FWC**		**Post-FWC**	
Flint	**N=5135**	**SMM (*count*)**	**N=4912**	**SMM (*count*)**	**N=4688**	**SMM (*count*)**
Black	2662	127	2624	100	2539	60
White	1996	74	2097	67	1950	44
Other	30	0	191	5	142	2
Saginaw	**N=2992**	**SMM (*count*)**	**N=2752**	**SMM (*count*)**	**N=2785**	**SMM (*count*)**
Black	1375	59	1198	61	1289	63
White	1190	22	1075	27	1032	18
Other	35	1	479	20	464	16

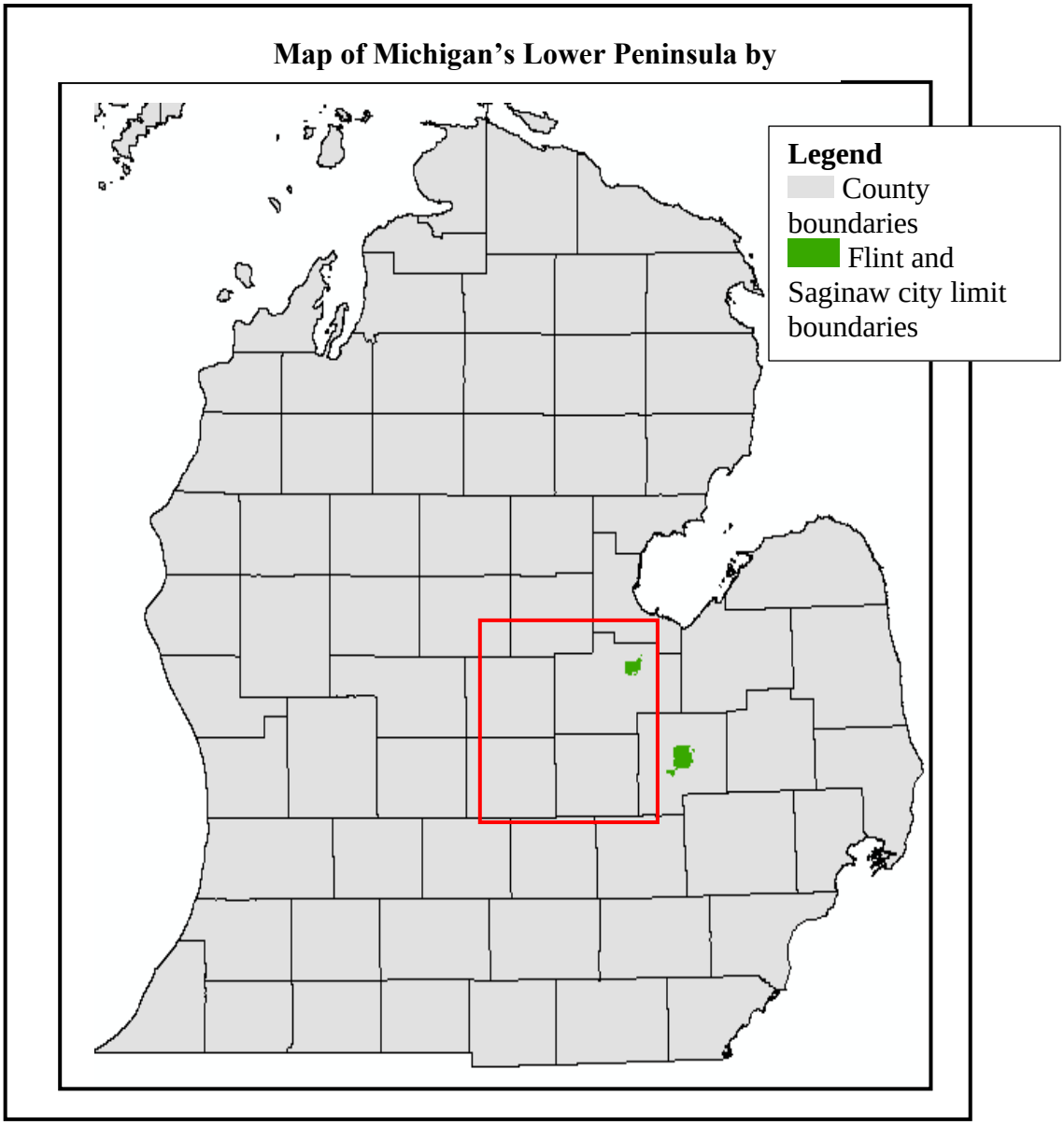

Figure 4.3: A map of Michigan counties highlighting Flint and Saginaw

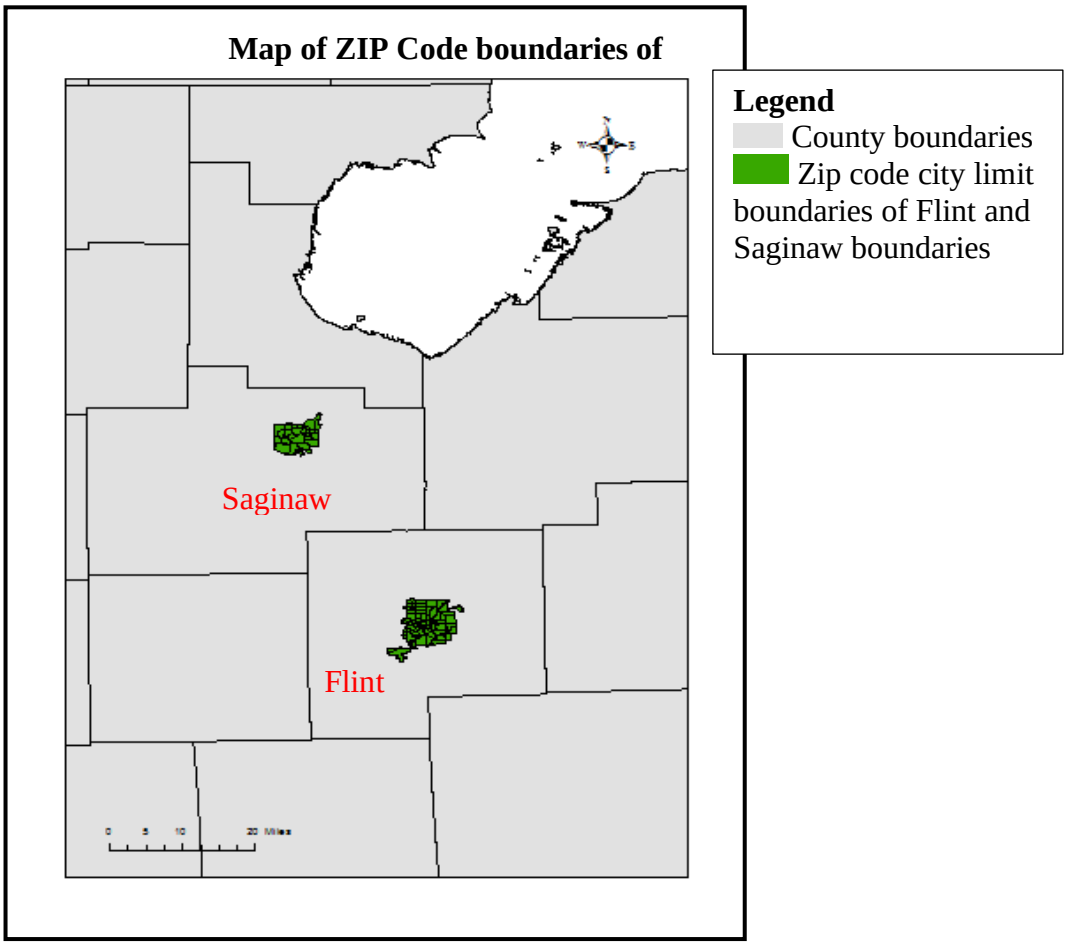

Figure 4.4: Map Inset of Flint and Saginaw city limits using ZIP codes

Weighted Regression Analyses

Model 4.1 (Tables 4.3:4.5) outlined the weighted regression formula used to determine if patient level factors (i.e., race, ethnicity, age, admission type, and primary pay method) influenced the odds of SMM in the pre-during-and-post-FWC timeframes. In the pre-FWC analysis, I found that age (0.001, p-value: 0.009) and primary pay method-Other (0.023, p-value: 0.018) significantly increased the likelihood of a patient experiencing a SMM. Admission type Other (-0.108, p-value: <2e-16) and admission type-Urgent (-0.122, p-value: <2e-16) significantly reduced the odds of SMM. Ethnic-Other was marginally significant in reducing the odds of SMM as well (-0.008, p-value: 0.095).

Controlling for patient factors during the FWC, I found that race-Black (0.017, p-value: 0.032) was the only variable that significantly increased the odds of experiencing a SMM (**Table 4.4**). The following covariates significantly reduced the chances of SMM: admission type-Other (-0.159, p-value: <2e-16), admission type-Trauma (-0.167, p-value: 0.016), admission type-Urgent (-0.156, p-value: <2e-16), primary payer method-Other (-0.014, p-value: 0.047), and primary payer-Self Pay (-0.052, p-value: 0.028). Primary payer method-Medicaid (-0.008, p-value: 0.099) was marginally significantly in reducing SMM. The findings for the post-FWC period were slightly similar to the pre-FWC time period as age (0.001, p-value: 0.0004) significantly increased the odds of SMM (**Table 4.5**). However, race-White (-0.016, p-value: 0.049), admission type-Other (-0.175, p-value: <2e-16) and admission type-Urgent (-0.178, p-value: <2e-16) significantly reduced the chances of SMM.

Within the pre-and-post-FWC period, age significantly increased the odds of a woman experiencing a SMM (**Tables 4.3 & 4.5**). Additionally, in the pre-FWC timeframe, primary pay method- Other significantly increased SMM while ethnicity-Other, admission type-Other, and admission type-Urgent significantly reduces the likelihood of a women experiencing a SMM. During the FWC, race-Black and primary pay method-Other significantly increased the chance of SMM. Admission type-Other, admission type-Trauma, admission type-Urgent, and primary payer method–Self Pay significantly reduced the odds of SMM. For the post-FWC analysis, race-White, admission type-Other, and admission type-Urgent significantly reduced the chance of SMM. The pre-FWC RR for Flint and Saginaw are as follows: 1.84 and 1.58. The post-FWC RR in Flint dropped from 1.83-pre-FWC to 1.06-post-FWC. Within Saginaw, the post-FWC RR increased from 1.58 to 3.24. There were no significant community factors in either the weighted

or unweighted linear regression. The results for the community analysis or computation of RR are not shown.

Table 4.3: Weighted linear regression controlling for patient factors, pre-FWC (2012 through 2013)

Variable	Estimate	Standard Error	P-value
Intercept	0.106	0.019	2.84e-08*
Race Black	0.016	0.012	0.206
Race White	0.003	0.013	0.978
Ethnicity Hispanic	0.009	0.014	0.496
Ethnicity Other	-0.008	0.005	<2e-16*
Age	0.001	0.000	0.009*
Admission type -Other	-0.108	0.009	<2e-16*
Admission type-Trauma	-0.128	0.081	0.115
Admission type-Urgent	-0.122	0.008	<2e-16*
Pay method-Medicaid	0.011	0.007	0.102
Pay method-Other	0.023	0.010	0.018*
Pay method-Self Pay	-0.020	0.024	0.387

**P-value is significant at the 0.05 level.*

Table 4.4: Weighted linear regression model controlling for patient factors, during-FWC (2014 through 2015)

Variable	Estimate	Standard Error	P-value
Intercept	0.150	0.013	<2e-16*
Race Black	0.017	0.008	0.032*
Race White	0.012	0.008	0.118
Ethnicity Hispanic	-0.004	0.009	0.616
Age	<0.000	0.000	0.106
Admission type -Other	-0.159	0.009	<2e-16*
Admission type-Trauma	-0.167	0.069	0.016*
Admission type-Urgent	-0.156	0.007	<2e-16*
Pay method-Medicaid	-0.009	0.005	0.099
Pay method-Other	0.015	0.007	0.047*
Pay method-Self Pay	-0.052	0.023	0.028*

** P-value is significant at the 0.05 level.*

Table 4.5: Weighted linear regression model controlling for patient level factors in the post-FWC period (2016 through 2017)

Variable	Estimate	Standard Error	P-value
Intercept	0.019	0.127	0.883
Race Black	0.000	0.008	0.964
Race White	-0.016	0.008	0.049*
Ethnicity Hispanic	-0.005	0.011	0.646
Age	0.001	0.000	4e-4*
Admission type -Other	-0.175	0.010	<2e-16*
Admission type-Trauma	-0.005	0.100	0.582
Admission type-Urgent	-0.178	0.008	<2e-16*
Pay method-Blue Cross	0.136	0.127	0.282
Pay method-Medicaid	0.157	0.126	0.215
Pay method-Other	0.147	0.127	0.247
Pay method-Self Pay	0.092	0.131	0.485

**P-value is significant at the 0.05 level.*

Difference-in-Difference Analyses

In the unweighted DID logistic regression **Model 4.3**, the treatment variable for the pre-during-FWC period (0.003, p-value: 0.3184) was not significant; however, the interaction term, DID, significantly reduced SMM (-0.006, p-value: 0.0322), and the time variable (Year) significantly reduced the odds of SMM (-0.017, p-value: 4.2e-10). The weighted DID regression analysis resulted in race-Black (0.016, p-value:0.026) and age (0.0006, p-value:0.005) significantly increasing the odds of SMM while the interaction term (-0.009, p-value: 0.001), ethnicity-Other (0.014, p-value: 2.76e-05), admission type-Other (-0.013, p-value: <2e-16), admission type-Trauma (0.015, p-value: 0.005), and admission type-Urgent (0-.14, p-value: <2e-16) significantly reduced the chance of experiencing a SMM during childbirth (**Table 4.6**).

Within the unweighted DID logistic regression analysis **Model 4.3** for the pre-post-FWC period, I observed a similar trend as pre-during period as the treatment variable was not significant (-0.002, p-value: 0.548), however; the interaction term (-0.010, p-value: 0.004) and time variable (-0.008, p-value: 0.0065) significantly reduced the odds of SMM. In the weighted

DID regression analysis controlling for patient level factors, the treatment variable (-0.11, p-value: 0.002), interaction term (-0.015, p-value: 0.002), admission type-other (-0.136, p-value: <2e-16), and admission type-urgent (-0.147, p-value: <2e-16) had a significant reduction in SMM while age (0.001, p-value: 1.00e-05) significantly increased SMM odds post-FWC (**Table 4.7**). The adjusted R^2 value is 0.04 which implies that the variables within this model explain 4% of the variation. A slightly different pattern was observed in the unweighted DID regression analysis controlling for patient level factors as the interaction term (-0.012, p-value: 7.40e-05), ethnicity- other (-0.011, p-value: 0.002), admission type-other (-0.107, p-value: <2e-16), and admission type-urgent (-0.116, p-value: <2e-16) significantly reduced SMM while age (0.001, p-value: 1.44e-05) significantly increased the probability of SMM.

Table 4.6: Weighted DID model controlling for patient level factors in the pre-during-FWC period (2012 through 2015)

Variable	Estimate	Standard Error	P-value
Intercept	0.144	0.011	<2x-16*
Treatment	-0.003	0.003	0.35
DID	-0.009	0.003	<0.00*
Race Black	0.016	0.007	0.03*
Race White	0.005	0.007	0.44
Ethnicity Hispanic	-0.005	0.008	0.55
Ethnicity other	-0.014	0.003	2.76e-05*
Age	0.001	0.000	<0.00*
Admission type-Other	-0.127	0.006	<2e-16*
Admission type-Trauma	-0.149	0.054	0.00*
Admission type-Urgent	-0.138	0.005	<2e-16*
Pay method-Medicaid	0.002	0.004	0.67
Pay method-Other	0.004	0.006	0.47
Pay method-Self Pay	-0.032	0.017	0.05*

**P-value is significant at the 0.05 level*

Table 4.7: Weighted DID model controlling for patient level factors in the pre-post-FWC period (2012 through 2017; excluding 2014 -2015)

Variable	Estimate	Standard Error	P-value
Intercept	0.079	0.115	0.49
Treatment	-0.011	0.004	0.00
DID	-0.015	0.003	1.33e-05*
Race Black	-0.007	0.007	0.26
Race White	-0.007	0.007	0.33
Ethnic- Hispanic	-0.003	0.009	0.72
Ethnicity Other	-0.006	0.003	0.07
Age	0.001	0.000	1.00e-05*
Admission type-Other	-0.136	0.063	<2e-16*
Admission type-Trauma	-0.099	0.006	0.11
Admission type-Urgent	-0.147	0115	<2e-16*
Pay method-BlueCross	0.061	0.115	0.59
Pay method-Medicaid	0.079	0.115	0.49
Pay method-Other	0.080	0115	0.48
Pay method-Self Pay	0.030	.115	0.79

**P-value is significant at the 0.05 level.*

4.6 Discussion

The data analysis supports the hypothesis that maternal health disparities increased during the timeframe of the FWC. In both the during-and-post-FWC weighted linear regression analyses, race had a significant effect on SMM. The probability of a Black women experiencing a SMM during the Flint Water Crisis significantly increased while the chances significantly decreased for White women post-FWC. Exploring the post-FWC period in more depth is essential as, White women, while considered the minority in a majority Black community still have a lower chance of experiencing a SMM than Black women. This finding is important as nationwide, there is a maternal health disparity gap; however, in Flint where women who give birth are suspected to be living in similar conditions with access to similar services and quality of care, the disparities still exist. The results further support the Flint Effect notion that there are indeed other factors in addition to the FWC that affects the maternal health disparity rate.

Controlling for patient factors during-FWC, I found that depending on what race a woman identifies as significantly influenced the odds of SMM, especially if this woman is Black. The difference-in-difference analyses shows that during the timeframe of the FWC, probability of an SMM was significantly reduced. In the pre-during-FWC DID analysis, race-Black was a significant factor that increased SMM. However, in the pre-post-FWC, only age significantly increased SMM. Statistically, the patient data examined during the timeframe of the FWC did not play an influential part in increasing SMM as much as race and age. While this finding slightly differs from my original hypothesis of factors associated directly/indirectly with the FWC significantly increasing SMM, it does attest to the possibility of the results being negatively skewed due to population decline. Another interesting finding is that primary payer method-Self Pay was significant in the weighted patient and DID analyses. This suggests that women whose primary method of pay is "Self-Pay" had a lower odd of experiencing a SMM. More research at a granular level and biological level are essential to explore the root cause of maternal disparities in Flint during the FWC.

Limitations

First, the study design itself is a limitation as cross-sectional data cannot determine causality or temporality between the study outcome and exposure variables. While it is evident that lead poisoning occurred after the corrosion of the water pipes, the study cannot determine if SMM was directly or indirectly caused by FWC. However, using the DID methodology to determine changes in maternal health disparity with and without the FWC improves the efficacy of this study as it serves as a quasi-experimental research design. Prospective randomized control trials (RCT) are the optimal research design as one can control for selection bias, determine temporality, and control for limiting factors. Using the DID quasi-experimental research design,

this study's results are as close to a RCT as possible without exposing individuals to hazardous conditions (Wing et al. 2018). Second, use of ZIP code level data to determine health disparities is a potential limitation. This data, while the finest-scale spatial reference present, may increase bias in this study and a chance of ecological fallacy. From the dataset, I was unable to identify if a woman lived within the city of Flint or suburbs which could bias the data. The available patient location data was only at the ZIP code level which poses a chance of ecological fallacy, underestimation, and overestimation of the effect of the FWC. To address the possibility of ecological fallacy, I am aware of biases in this data set and used a quasi-experimental design since a randomized control trial or individual data was not readily available. It is important to note that there should be more health data available at finer geographic scales. To better understand the effect of the FWC on maternal health disparities at various geographic scales, location health data should be provided the census tract level for more fine-scale urban neighborhood analysis. Without neighborhood level conditions such as median household income, occupation, and homeownership, the maternal health disparity among Black and White women can only be assumed at a coarse- scale while the driving factors cannot be observed.

The study consisted of ZIP code patient level data from the MIDB. ZIP codes cross city boundaries which can over-or-underestimate the true effect of the FWC on maternal health disparities. To address this issue, I mapped the city boundaries of both Flint and Saginaw and calculated the proportion that each ZIP code that falls within the city. I then calculated the proportions of ZIP codes and used this percentage as a weight. Because the data was adjusted to reflect only the ZIP codes within the city boundaries of Flint and Saginaw, there is a possibility of marginal error in the proportion. MIDB data is collected when a patient checks into a hospital. Using this data presents misinformation bias as the patient may or may not complete the hospital

information form completely or accurately as well as misclassification bias as there is a possibility of missed SMM cases or undiagnosed cases. Also, it is important to note that examining health data at this geographic scale can over-or-underestimate the true effect of health outcomes as subpopulations are grouped together across neighborhoods and city boundaries (Sadler, 2016).

Lastly, using the difference-in-difference method presumes that the comparison cities would follow similar trends in maternal health disparities if the event, the FWC, did not happen. While this is a risk, I computed multiple statistical analyses (i.e., K-means and hierarchical clustering) to identify a strongly parallel city to Flint based on independent socioeconomic and demographic factors for each city during the study's timeframe.

4.7 Conclusion

Maternal health outcomes observed in Flint during the FWC are significantly influenced by race, with especially adverse associations for Black maternal patients. The above study showed that regardless of a woman giving birth in a predominantly Black city, an environmental hazard, and her age range, maternal health disparities are still present if that woman identifies as Black. Based on this finding, I recommend more research studies to examine other factors such as the declining population rate, increasing suburbanization, urban irrelevancy/neglect, environmental injustice, and the healthcare system to determine the role each factor plays on maternal health disparities during-FWC. This paper is essential as its findings can be used to examine the role of race in environmental hazards and maternal health disparities in future situations such as the brewing water crisis in Jackson, Mississippi (Rojas, 2022). This is the first known study to use both the Darden-Kamel Composite Index as a reference to testing comparison levels of cities and the difference-in-difference method to determine the effect of the

FWC on maternal health disparities. More research should be conducted at the individual level to finely examine key contributing aspects that aid in the role of race within the maternal healthcare system. For this reason, the next chapter, Chapter 5, will examine the perceptions of the FWC on maternal health disparities from participants of an ongoing RCT in Flint, the SPARRK study.

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CHAPTER 5

THE VOICE UNHEARD: WOMEN'S PERCEPTION OF MATERNAL HEALTH CARE POST-FLINT WATER CRISIS

5.1 Introduction

Eight years have passed since the public outcry of the Flint Water Crisis (FWC) and yet, many voices are still unheard. While the Michigan Civil Rights Commission wrote a letter to Flint residents empathizing with their suffering from the FWC while referencing the lack of trust in the government and decades of systemic racism and discrimination, actions and strategic plans are still needed to support and care for the needs of residents of Flint who are majority Black and female (Michigan Civil Rights Commission, 2017). Studies have investigated the effects of lead ingestion from the FWC on child development; however, there has not been research on the impact of the water crisis on the women who gave birth in Flint (Danagoulian & Jenkins, 2007; Grossman & Slusky, 2019; Hanna-Attisha et al. 2016; Sadler & Highsmith, 2016). Exposure to an environmental hazard such as drinking water contamination can increase overall maternal morbidity significantly (IOM, 1999). Moreover, Morello-Frosch & Shenessa (2006) suggested that there is a doubled risk of severe maternal morbidities (SMM) among Black women due to the everyday stressors combined with an environmental hazard (Morello-Frosch & Shenessa, 2006). SMM serves as an indicator for maternal morbidity and can result in mortality.

Another study supports Morello-Frosh & Shenessa (2006) findings by stating that Black women in an environmentally disadvantaged area will likely experience higher risk of maternal mortality and morbidity (Benova et al. 2014). Reviewing the published literary work on the FWC, I found that there were no qualitative studies that obtained the perceptions of maternal health from women who delivered in Flint post-FWC. Health can be defined both subjectively

and objectively; with perception playing a vital role in health status (Condello et al. 2016; Lee et al. 2021). For this reason, the aim of this study was to examine the perceptions of the FWC, and quality of maternal healthcare services received among Black and White women who delivered a child in Flint post-FWC and post-national attention on injustices within this community. My research questions are 1) "Did women in Flint perceive their overall health improved after the FWC?" and 2) "Did women's perceptions on maternal health services and quality improve after the Flint Water Crisis?". Based on the findings of studies that have found significant linkage between perception and health such as Lee et al. (2021) couple with the PID-MHD conceptual model for this dissertation, I suspect the perceptions and experiences of maternal health care quality and services received will negatively impact Black women more than White women in Flint despite the mothers residing in similar neighborhoods and delivering at the same hospital.

The City of Flint

Flint's demographic and economic make up suggest that its maternal population is at an increased risk of SMM among its population. According to the 2020 U.S. Bureau Census, Flint houses approximately 81,252 residents of which 54% are considered Black (Flint, MI, n.d.; United States Census Bureau, 2022). Women account for 51.5% of Flint's population (United States Census Bureau, 2022). 20% of Flint residents are considered disabled, 8.1% of residents under the age of 65 are without health insurance, and 37.3% of the residents live in poverty (United States Census Bureau, 2022). Historically, communities of color are more prone to receive the "short-end of the stick" in health care quality and care services due to redlining, segregation, and discrimination in environment hazard exposure (Bullard, 1999; Duque, 2021; Mays et al. 2021). The FWC and the maternal and child health disparity in this country has one

common component – the indication of systemic discrimination among a majority minority community.

Maternal Health Disparities

The condition of maternal and child health in the United States is a major and rapidly growing public health challenge as the mortality rate is substantially higher compared to other developed countries, **Figure 5.1** (OCED, 2022; Statista, 2020). One might ask, why does the amount of money the U.S. spends on healthcare not reflect in the overall health of its citizens? One way to figure out why there is a disproportionality between healthcare spending and healthcare quality is to assess the burdens of impact. The burden of many factors related maternal and child health such as infant mortality, low birth weight, maternal morbidity and mortality falls upon Black women and their infants (Anachebe & Sutton, 2003; Lang & King, 2008). This disparity is often attributed to socioeconomic status, occupation, education, and limited access to healthcare (American Public Health Association, 2001; Anachebe & Sutton, 2003; Creanga et al. 2014; Grobman et al. 2015; Hasselle, 2018). However, recent studies have shown that a health gap still exists independently of these aspects (Bauer et al. 2013; Grobman et al. 2015).

There has been a great deal of research on the importance of improving maternal and child health in the aspect of quality of care and health care services to reduce mortality and morbidity (Hasselle, 2018; Lang & King, 2008; Maternal, Infant, and Child Health, 2020). A significant amount of the United States' Healthy People 2020 focuses on the importance of improving maternal and child health (Maternal, Infant, and Child Health, 2020). Across the world, maternal and child health care ultimately falls short in the quality health services, accessibility, assistance, and necessities needed to achieve longevity and quality of life (Amnesty

International, 2011). What sets the U.S. apart from other OCED countries in quality health services and care aside from socioeconomic status is race and embedded discrimination. Howell et al. (2016) found that, in New York City, despite delivering at a similarly rated hospital as White women, Black women still had the higher risk of negative maternal health outcomes. Thus, if Black and White women deliver at the same hospital, have a similar socioeconomic status, and education, the quality of maternal health care services received typically varies.

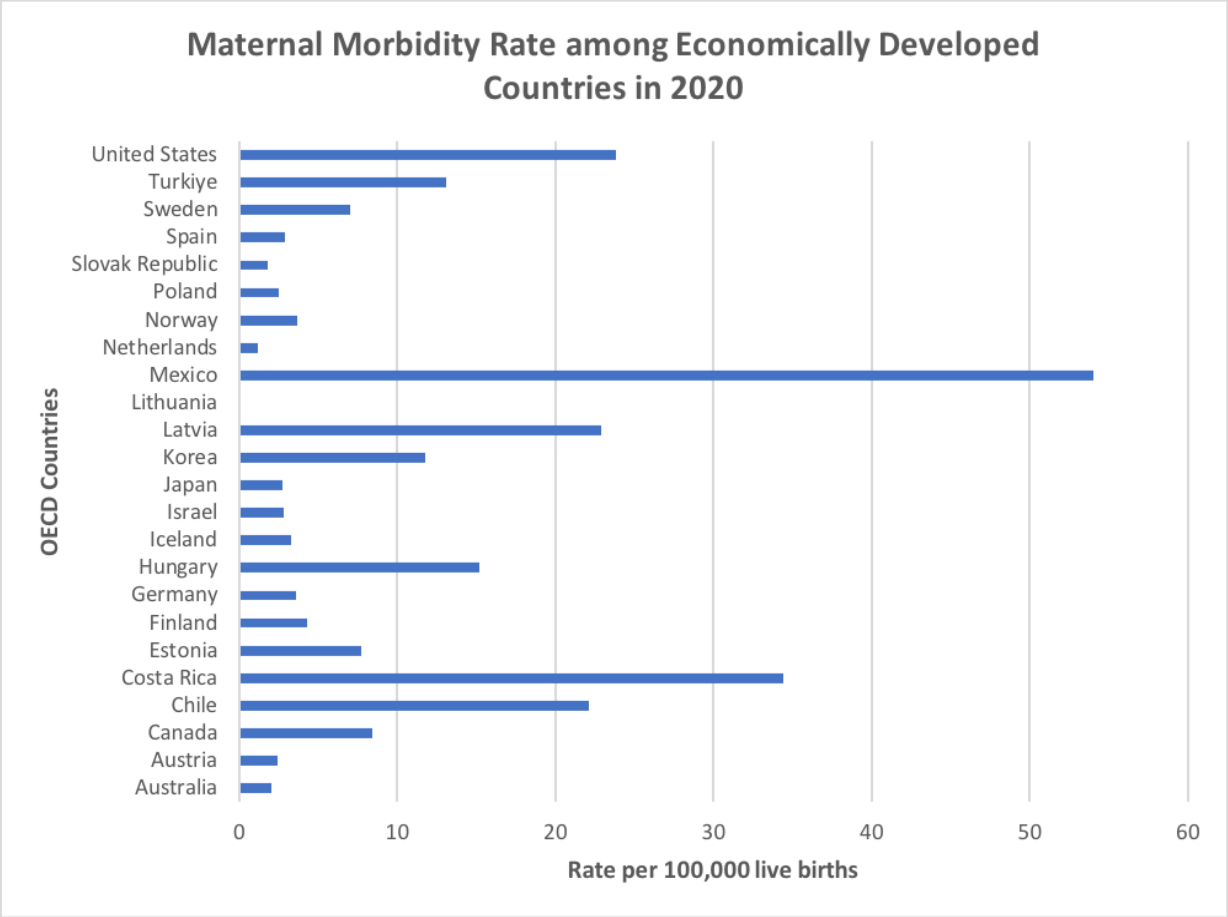

Figure 5.1: Maternal mortality rates per 100,000 live births for all Organization for Economic Cooperation and Development (OECD) countries. Colombia and Belgium were excluded due to the lack of available data (OECD, 2020)

5.2 Conceptual Framework

The conceptual framework, Pathways of Institutional Discrimination on Maternal Health Disparities (**Figure 5.2**), combines three concepts derived from the Public Health Critical Race Theory (PHCRT), the World Health Organization, and the maternal morbidity concept (Filippi et al. 2018; Ford & Airhihenbuwa, 2010; Howell, 2018). The proposed framework suggests that discrimination or difference of treatment across sociodemographic factors (i.e., individual and community) and within the healthcare system contributes to adverse labor & delivery outcomes. This paper will focus on the portion of the framework related to the perceived impact of maternal health care system and quality of care received post-FWC.

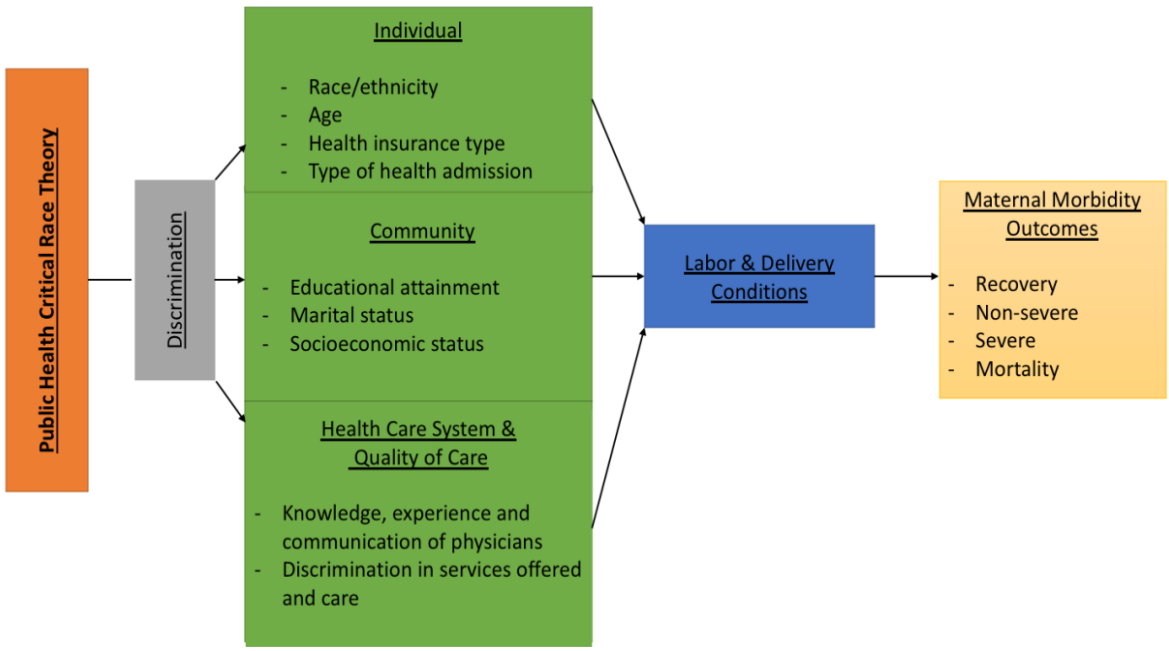

Figure 5.2: Pathways of Institutional Discrimination on Maternal Health Disparities

5.3 Data

A cross-sectional study design was used to conduct the analysis at the census-tract-level. The study area is Flint, Michigan. I collaborated with an ongoing randomized control trial

(RCT), Supporting Parents and Raising Resilient Kids (SPARRK) study, to obtain primary responses from women who delivered a child at Hurley Medical Center in 2022. The parent study's overall goal is to determine the role of universal strengths-based parenting support in preventing adverse outcomes among young children in the aftermath of the FWC. SPARRK found that health disasters disproportionately affect poorer communities for an extended period of time. Thus, the study's goal was to randomize 486 families to two groups: Video Interaction Project (VIP) or a control group. The treatment group is exposed to VIP which supports and encourages ideal parenting through the aftermath of FWC and COVID, and to assess the success of this project while the control group is not. By partnering with this study, I contributed to Aim 1 (**Appendix A**) of the parent study and gained access to a group of women enrolled in the SPARRK study who recently had children and could attest to the healthcare services that they received post-FWC. These women were surveyed concerning their perceptions on three themes: 1) maternal health experience, 2) Flint Water Crisis experience, and 3) healthcare services received. The target population is all women who gave birth after the FWC. These participants were not physically interviewed but responded to a baseline survey received from trained research assistants picked by the SPARRK study.

The outcome variables concerned the following themes: 1) perceived quality of maternal healthcare received post-FWC (*e.g., During your pregnancy and the birth of your child, did you feel like the physicians, nurses and/or hospital personnel treated you with less respect or differently due to your race, culture, ethnicity, or age?)*, 2) overall health pre-and-post FWC (*e.g., How would you rate your overall health before the Flint Water Crisis (before 2014)?),* and 3) experience of SMM (*e.g., During your most recent pregnancy, has a doctor, nurse, or other health care professional ever told you that you had one of the following severe maternal*

morbidity conditions?) (**Appendix B**). The independent count variables obtained from the SPARRK survey respondents were race (*Black, White, or Other*), ethnicity (*Hispanic or Non-Hispanic*), marital status (*single, married, or separated*), education (*less than a 12th grade education, some college including associate degree, college degree considered as bachelor's degree, and professional degree*), income (*estimated income*), employment (*currently employed or not currently employed*), Medicaid (*served as health insurance indicator*), median income (*continuous*), and pre-pregnancy comorbidities (*high blood pressure, hypertension, depression, gestational diabetes, Type 2- diabetes).* All of these factors have been shown to be associated with severe maternal morbidity (Guglielminotti et al. 2019). Additionally, neighborhood factors for study participants' residences were obtained at the census tract level from the 2020 American Community Survey (ACS) – U.S. Bureau of Census. The neighborhood covariates controlled for as count variables include race (*White and Black*), means of transportation to work (*car, truck or van; public transportation, or other*), marital status (*married or separated*), education (*less than high school diploma, some college, and college degree or higher*), median household income (*continuous*), poverty status (*below or above poverty*), employment status (*employed or unemployed*), house type (*owner or renter occupied*), health insurance presence by age (*under 18, 19 to 54, and 54 and over*). The Centers for Disease Control and Prevention (CDC) (2019) defines SMM using 21 indicators (Centers for Disease Control and Prevention, 2019). For this study, I selected common SMM indicators and adjusted the diagnosis code to provide a more comprehensive procedure list to study participants (**Table 5.1**).

Table 5.1: List of common Severe Maternal Morbidity (SMM) indicator diagnosis codes and the adjusted term used in the Parent Baseline Survey of the SPARRK RCT study

SMM Indicator Term	**Adjusted Survey Term**
Acute Renal Failure	Kidney Failure
Adult Respiratory Distress Syndrome	Fluid in lungs
Cardia Arrest, Fibrillation or Conversion of Cardiac Rhythm	Heart failure/stroke/heart arrest
Shock	Shock
Acute Myocardial Infraction or Aneurysm	Heart Attack
Sepsis	Severe bacterial infections during or shortly after pregnancy
Hysterectomy	Removal of cervix
Disseminated Intravascular Coagulation	Blood clots/anormal bleeding
Acute Congestive Heart Failure	Heart failure/fluid around heart
Eclampsia	Seizures/coma/toxic pregnancy
Blood transfusion	Blood transfusion
Ventilation/temporary tracheostomy	Ventilation/temporary tracheostomy to assist with breathing

5.4 Methods

To conduct this analysis, I submitted a Michigan State University Institution Review Board (IRB) application for an exempt-human data request as there is no risk of harm among

study participants and there is a limited possibility of identifying participants as the data received is unidentifiable. Once the study was approved, I submitted maternal healthcare services and quality of care survey questions to the SPARRK study to be add to the Baseline Parent Survey (**Appendix B**). These additional questions were modifications of the Everyday Discrimination scale. For instance, one of the questions is, *"How would you rate your overall health before the Flint Water Crisis (before 2014)?".* The possible responses are: **"Excellent"**, **"Very Good"**, **"Good"**, **"Fair"**, or **"Poor"**. Similar questions were asked about experiences of an SMM and perceived maternal health care. To determine if perceived maternal health care predicts SMM among women who reside within Flint city boundaries, logistic regression analyses were performed while controlling for race and residing within Flint (**Model 5.1**). The respondent rankings for perceived health are as follows: **"Never"**, **"Often"**, **"Sometimes"**, **"Rarely"**, **"Unsure"**, and **"No Answer"**. I conducted a separate analysis grouping **"Often"** and **"Sometimes"** responses to reflect a binary outcome, 1 = "Often" or "Sometimes" and 0 = "Never", "Rarely", "Unsure", or "No Answer". Lastly, a Wilcoxon's rank sum test was computed to determine the statistical difference in perceptions of health between Black and White women (Boston University School of Public Health, n.d.)

Model 5.1:

SMM ~ perceived health care quality + race + lives in Flint

Descriptive statistics were performed using RStudio to obtain an overview of the study population (e.g., total number of participants, race categories, SMM counts). Contingency tables were used to show the perceptions of women's health pre-and-post-FWC and perceived health care services received. The difference in health was calculated to observe the change in overall

health post-FWC. Additionally, logistic regression analyses were performed to determine if perceived health predicted the likelihood of a woman experiencing a SMM. An odds ratio was computed to determine the maternal health disparity gap among the study sample with Black women as the exposure group, White women as the unexposed group, SMM as the outcome variable coded as 1 = "Experienced SMM" or 0= "Did not experience a SMM." To determine the fit of the logistic regression model of participant factors, I computed the area under the curve (AUC) test.

Logistic regression analyses were used to determine the predictability of SMM among the study sample and associated neighborhood level factors. First, statistical analysis was conducted on respondent data. The survey participant covariates controlled for were race (*Black, White, Other*), ethnicity (*Hispanic or Non-Hispanic*), marital status (*single, married, or separated*), education level (*less than high school diploma or high school diploma, some college, college degree, or professional degree*), income (*counted as a continuous variable*), employment status (*job or no job*), and presence of Medicaid (*served as a health insurance indicator*). **Model 5.2** shows the logistic regression model used for this analysis.

Model 5.2:

SMM ~ race + ethnicity + marital status + education + income + employment + Medicaid

Next, logistical analysis were conducted on neighborhood factors. The ACS covariates controlled for at the census tract level include proportion of race within each census tract (*White and Black*), means of transportation to work (car, truck or van; public transportation, or other), marital status(*married or separated*), education (*less than high school diploma, some college, and college degree or higher*), median household income (MHI), poverty status (*below or above*

poverty), employment status (*employed or unemployed*), house type (*owner or renter occupied*), health insurance presence by age (*under 19, 19 to 34, 35 to 64, and 54 and over*). Using RStudio and QGIS, these variables were spatially merged with respondent survey data to match each participant's address with the associated census tract. The final file was used for logistic regression analyses. **Model 5.3** shows the neighborhood logistic regression model. Stepwise regression was performed on the **Model 5.4** to identify key variables associated with SMM to reduce the model size. The following covariates remained: proportion-Black, transportation-Public, marital status-Separated, education-Some College, education-Degree or higher, MHI, employment status-Employed, health insurance by age 19 to 34 and no health insurance by age 65 and over.

Model 5.3:

SMM ~ race + transportation + marital status + education + MHI + poverty status + employment status + house type + health insurance

Model 5.4:

SMM ~ race-Black + transportation-Public + marital status-Separated + education-Some College + education-Degree or higher + MHI + employment status-Employed + with health insurance-19 to 54 + without health insurance-55 and over

Finally, I obtained the geocoded addresses of all women in the study sample and uploaded the shapefile into RStudio. This shapefile was then reduced to reflect only complete addresses and their associated census tracts. This step was done by geocoding each address in RStudio and spatially joining the resulting coordinates to a nationwide 2020 U.S. Bureau of

Census tract shapefile from IPUMS USA using ArcMap (Ruggles et al. 2022). The remaining shapefile containing the geocoded address of survey participants was then overlaid with a map of lead level ranges from the FWC. The purpose of this step was to provide a visual representation of where SPARRK participants currently live and the lead levels of the FWC. To provide additional knowledge to the study, I created a field to determine if there was an interaction between race and living within Flint city limits (**Model 5.5-Model 5.6**). Using QGIS software, the binary field computed a "1" if a participant lives within Flint census tracts and a "0" if not. Then, I conducted logistic regression analyses with interaction terms for both Black and White women who live in Flint (e.g., race = 'Black' * Flint census tract = 1) to identify if there is a race-specific Flint Effect.

Model 5.5:

SMM ~ race + ethnicity + marital status + education + income + employment + Medicaid + Race-Black (1) * Flint (1)

Model 5.6:

SMM ~ race + ethnicity + marital status + education + income + employment + Medicaid + Race-White (1) * Flint (1)

5.5 Results

The study sample consisted of 152 survey respondents in which 60.53% were Black, 34.21% were White, and 5.26% were considered Other (Native America, Pacific Islander, no response, and other). One respondent was excluded due to the inability to obtain an address, leaving 151 participants. There were 14 cases of SMM with Black women accounting for

57.14% of the observed cases. White women accounted for 42.85% of SMM cases in this sample. The overall odds ratio of SMM with Black women being the exposure variable is 0.70 (95% CI: 0.23-2.16) which implies that identifying as Black within this population reduces in the likelihood of experiencing SMM.

Overall perceived health post-FWC rating decreased health for both Black and White mothers (**Table 5.2**). In the pre-FWC period, 59 participants rated their health as **"Excellent"** while only 30 respondents rated their health as **"Excellent"** in the post-FWC period (⍙Black = 23; ⍙White = 5; ⍙Other = 1). Additionally, 19 mothers rated their health as **"Fair"** in the pre- while 35 rated their health as **"Fair"** in the post-FWC (⍙Black = 17; ⍙White = 2; ⍙Other = 1). A similar increase in lower health rates was observed in the **"Poor"** health ratings as the 3 respondents rated their health as **"Poor"** in the pre-FWC period while 10 selected this category in the post-FWC (⍙Black = 6; ⍙White = 1; ⍙Other = 0). **Table 5.3** shows the concordance of health ratings among participants in the pre-and-post-FWC. There were 23 participants who rated their health as **"Excellent"** in the pre-period also rated their health as **"Excellent"** in the post-period; 52 respondents rated their pre-and-post-FWC health as **"Good"** in the pre-period rated it the same in the post-period; 16 individuals rated their pre-and-post-FWC health as **"Fair"**; 1 participant rated their pre-and-post-FWC health as **"Poor"**; and 2 respondents did not rate their pre-and-post-FWC health.

Table 5.2: Difference in overall health rating pre-FWC compared to post-FWC

	Pre-FWC			**Post-FWC**			
Health Ratings	**Black**	**White**	**Other**	**Black**	**White**	**Other**	**Overall Difference in Rating (⍙)**
Excellent	41	15	3	18	10	2	- 29
Good	36	28	3	40	30	3	+6
Fair	13	7	0	25	9	1	+16
Poor	2	1	0	8	2	0	+7
No Answer	0	1	1	1	1	1	-1

Table 5.3: Concordance in overall health rating pre-FWC compared to post-FWC

		Post- FWC				
Pre-FWC	**Health Ratings**	**Excellent**	**Good**	**Fair**	**Poor**	**No Answer**
	Excellent	23	21	11	3	1
	Good	4	52	6	5	0
	Fair	3	0	16	1	0
	Poor	0	0	2	1	0
	No Answer	0	0	0	0	2

Among the perceived health care questions that referred to whether or not the mother received advice or was shown respect and understanding during the prenatal period (**Appendix B**), the majority of both Black (92.3%) and White (93.3%) women answered “Yes” while 7.70%

of the Black moms and 7.14% of White moms answered "No". Similar findings were found among participates that were asked if "…understanding and respect…" was shown during the birthing process, the majority answered "Yes" (94.9% Black and 93.3% White) while only 5.13 % of Black moms and 7.14% of White moms answered "No" (**Appendix B**). When women were asked if they felt "…the physician, nurses, and/or hospital personnel listened [to them]…" about their feelings of pain and discomfort during childbirth, 31% responded that they were **"Often"** to listened (74% Black; 26% White), 15% responded as **"Sometimes"** (66% Black; 33% White), and 5% responded as **"Never" or "Unsure" (Figure 5.3)**. Participants were asked if "…the physicians, nurses, and/or hospital personnel treated…" them with "…less respect or differently due to…[their] race, culture, ethnicity, or age?" (**Figure 5.4**). Of the respondents, 86% stated **"Never"** (58.6% Black; 41.4% White), 4.48% stated **"Rarely"** (33.3% Black; 66.7% White), 4.48% responded **"Sometimes"** (50% Black; 50% White), and 3.73% responded **"Often"**. (100% Black), felt they were treated differently by physicians, nurses, and/or hospital personnel.

Furthermore, when asked about the quality of services during childbirth (**Figure 5.5**), 80% of participants stated that they **"Never"** received poorer services dues to their race, culture, ethnicity, or age with Black survey participants accounting for majority of this response, 54.1%. Of the remaining respondents, 7.41% stated that they **"Sometimes"** received lower quality services (33.3% Black; 66.7% White), 1.48% stated responded **"Often"** (100% Black) or **"Rarely"** (50% Black; 50% White), and 0.74% were "Unsure" or did not respond (100% Black). Within the logistic regression analysis of perceived maternal health care quality (**Model 5.1: Table 5.4**), answer **"Often"** or **"Sometimes"** on Question 2 (**Figure 5.4**) significantly increased the likelihood of experiencing an SMM (0.184, p-value: 0.037). However, perceived health, race, and residing in within Flint did not have an effect on SMM for Questions 1 & 3 (**Figure 5.3 &**

Figure 5.5). The Wilcoxon rank sum test performed confirmed the logistic regression results as there was only significant differences between Black and White women in response to Question 2.

Question 1: "Whether or not you experienced one or more of the previous maternal diagnosis or procedures during the delivery of your child, do you feel as if the physicians, nurses and/or hospital personnel listened to you about your feelings such as pain, discomfort, or overall birthing experience?"

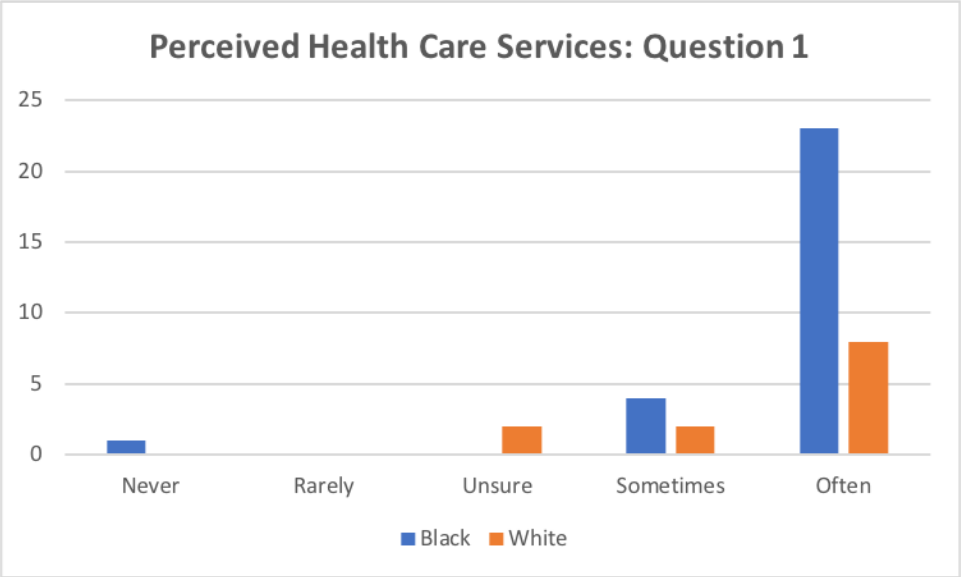

Figure 5.3: Perceived health care services questionnaire Question 1

Question 2: "During your pregnancy and the birth of your child, did you feel like the physicians, nurses and/or hospital personnel treated you with less respect or differently due to your race, culture, ethnicity, or age?"

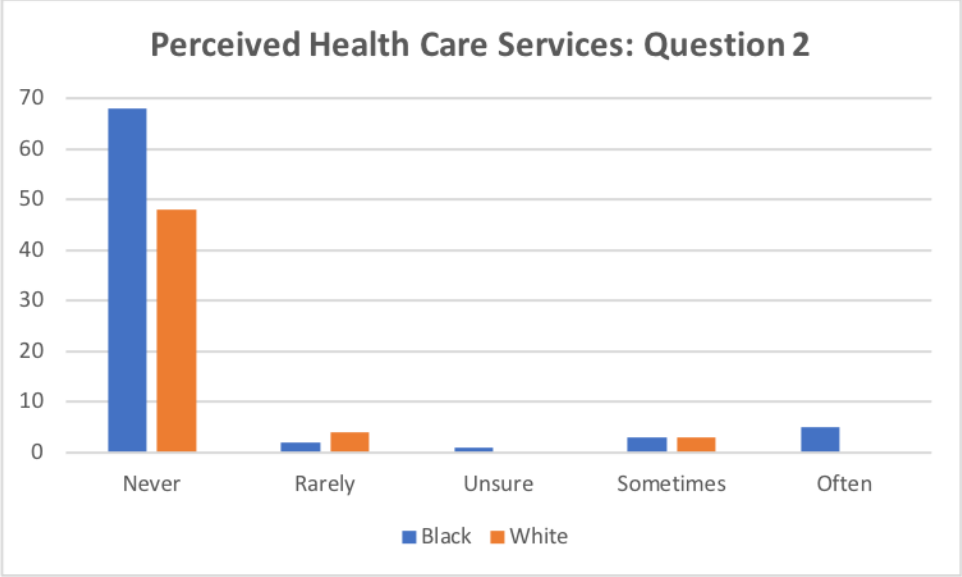

Figure 5.4: Perceived health care services questionnaire Question 2

Question 3: "During your pregnancy and the birth of your child, did you feel as if you received poorer service than other expecting mothers due to your race, ethnicity, culture, or age?"

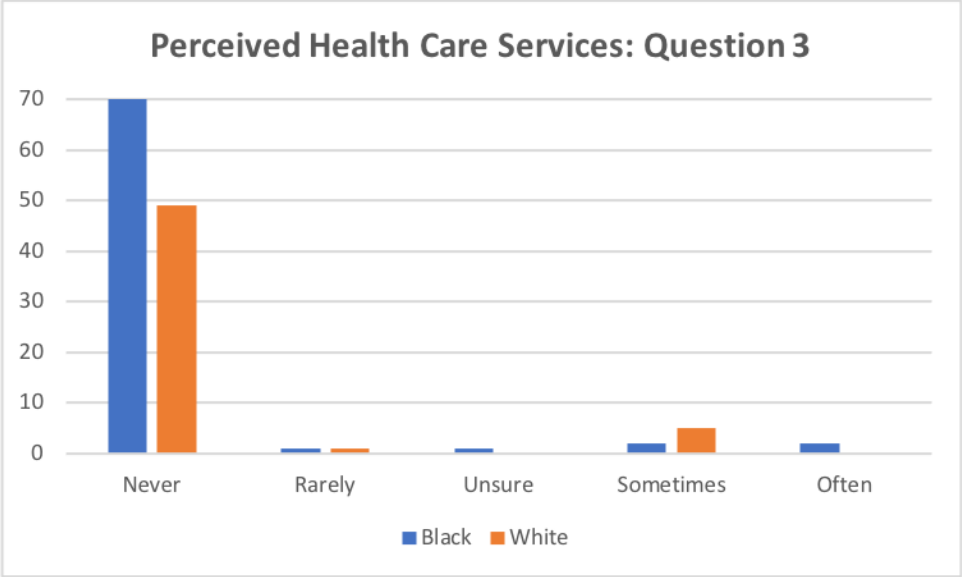

Figure 5.5: Perceived health care services questionnaire Question 3

Table 5.4: Perceived Maternal Health logistic regression analysis predicting SMM

Variable	Estimate	Standard Error	P-value
Intercept	-0.051	0.116	0.658
Perceived Health: Q3	0.185	0.088	0.037*
Race White	0.135	0.117	0.249
Race Black	0.102	0.114	0.369
Lives within Flint=True	0.035	0.048	0.469

*Significant at the p-value of 0.05**

Within the logistic regression analysis controlling for participant factors (**Model 5.2)**, ethnicity-Hispanic (3.232e-0, p-value: 0.012) was the only variable that significantly increased the odds of SMM (**Table 5.5**). The odds of experiencing an SMM is 1.381 for women who identify as Hispanic compared to non-Hispanic women (**Table 5.6**). Race, marital status, education attainment level, income, employment status, or Medicaid were not significant in influencing the odds of SMM among the survey participants. The AUC for this analysis was 0.9167 which suggests the model is good at predicting SMM (Zach, 2021). Similar results as Model 5.2 were observed for **Models 5.5 & 5.6** which contained the interaction term for race*living within the city of Flint census tracts. Ethnicity-Hispanic was the only variable that increased the likelihood of experiencing SMM regardless of the participant residing in Flint or not. The results for these models are not shown. Within the neighborhood level of analysis, the proportion of Blacks within a census tract (3.516e-01, p-value: 0.001), being employed (6.232e-04, p-value: 3.15e-05), and no health insurance among the 55 and over age group significantly increase the likelihood of SMM. Education (i.e., some college and college degree or higher) and having health insurance within the 19 to 54 age group significantly reduced the odds of experiencing SMM among the study population (**Table 5.7**).

Table 5.5: Logistic regression analysis predicting SMM among participant level factors

Variable	Estimate	Standard Error	P-value
Intercept	-7.189-02	1.493e-01	0.631
Race White	2.488e-01	1.337e-01	0.066
Race Black	2.011e-01	1.377e-01	0.148
Ethnicity- Hispanic	3.232e-01	1.260e-01	0.012*
Marital Status-Single	-6.893e-02	8.580e-02	0.424
Education-Less than High School	-2.018e-02	6.972e-02	0.772
Education- Some College	1.805e-02	8.132e-02	0.824
Education- Professional	-7.212e-02	2.882e-01	0.803
Income	-5.764e-07	1.088e-06	0.597
Employment Status- No	3.270e-02	6.955e-02	0.716
Employment Status-Yes	-1.252e-02	7.000e-02	0.842
Medicaid- No	-6.154e-02	8.504e-02	0.471

*Significant at the p-value of 0.05**

Table 5.6: Odds ratio and confidence intervals of participant level factors predicting SMM

Variable	Odds Ratio	2.5%	97.5%
Intercept	0.931	0.694	1.247
Race White	1.282	0.987	1.666
Race Black	1.222	0.933	1.601
Ethnicity- Hispanic	1.381	1.079	1.768*
Marital Status-Single	0.933	0.789	1.104
Education-Less than High School	0.980	0.855	1.123
Education- Some College	1.018	0.868	1.194
Education- Professional	0.930	0.529	1.637
Income	0.999	0.999	1.000
Employment Status- No	1.033	0.883	1.209
Employment Status-Yes	0.986	0.860	1.130

*Significant at the 95% Confidence interval level**

Table 5.7: Logistic regression analysis predicting SMM among ACS neighborhood factors

Variable	Estimate	Standard Error	P-value
Intercept	-2.435 e-01	1.320e-01	0.0674
Proportion Black	3.516e-01	1.084e-01	0.001*
Transportation-Public	7.576e-04	4.144e-04	0.069
Marital Status-Separated	4.436e-04	2.382e-04	0.064
Education- Some College	-8.420e-04	2.402e-04	6.23e-04*
Education-College Degree or higher	-3.551e-04	1.243e-04	0.004*
Median Household Income	5.868e-06	2.812e-06	0.039*
Employed	6.232e-04	1.446e-04	3.15e-05*
Health Insurance- 19 to 34	-3.193e-04	1.834e-04	0.084
Without Health Insurance- 65 and over	3.179e-03	1.444e-03	0.029*

*Significant at the p-value of 0.05**

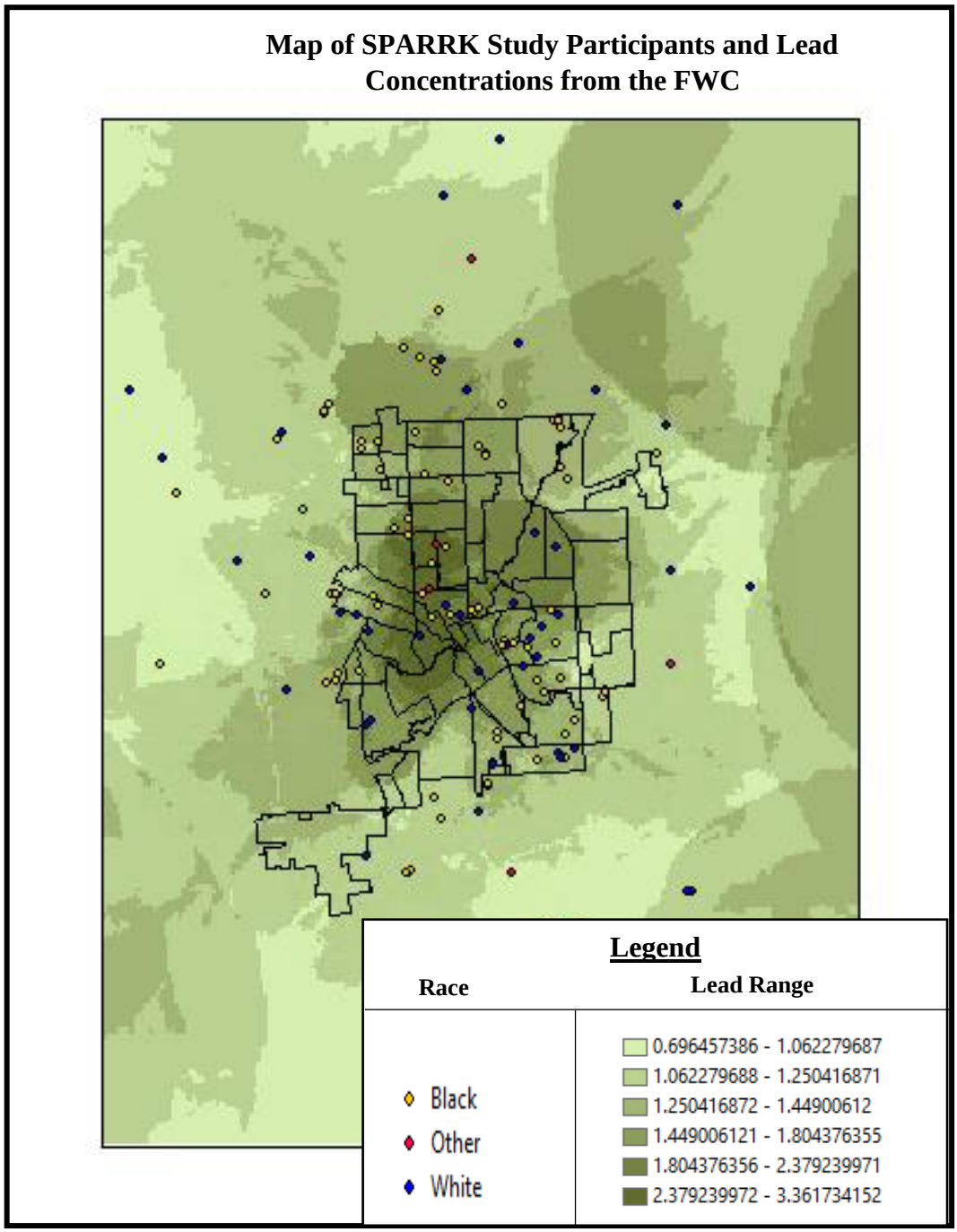

Figure 5.6: Cartographic map depicting SPARRK study participants by race and lead range levels in Flint

5.6 Discussion

The goal of this study was to examine the perceptions of the FWC, and quality of maternal healthcare services received among Black and White women enrolled in the SPARRK study after the Flint Water Crisis. On average, women in Flint believe they receive a significantly poorer maternal health care service due to either their race, ethnicity, culture, or age. The study provided evidence that overall perceived health decreased post-FWC for all women which addresses my first research question, (i.e., *Do women in Flint perceive their overall health improved after the FWC?).* I also found that there was a significant difference in between Black and White women in responses to feeling as if the physician, nurses, and hospital personnel treated them with less respect due to their race, ethnicity, culture, or age with Black women stating **"Often"** more than White women.

While many women had similar responses about maternal health care and services received, Hispanic women were 1.381 times more likely to experience an SMM at the participant level than non-Hispanic women. This result confirms my hypothesis of the maternal healthcare quality and services negatively impacting minorities more than White women despite delivering at the same hospital. From the perceived health and logistic regression results, it appears that minority woman living within a predominately Black city, within the same neighborhood and deliver at the same hospital as a White woman still receive differential treatment based on race, ethnicity, culture, or age. Furthermore, I found that the chance of an SMM significantly increases based on the proportion of Black residents within a neighborhood. The following sections provide more detail on the maternal disparity observed within perceived maternal health and socioeconomic & neighborhood factor results.

Perceived Maternal Health

Study participants experienced similar maternal health care quality which address my second research question (i.e., *Did women's perceptions on maternal health services and quality improve after the Flint Water Crisis?*). However, a greater number of Black respondents experienced more negative experiences than White respondents. In **Figure 5.3A**, Question 1, I found that majority of participants **"Often"** felt like the physicians, nurses, and/or hospital personnel listened to them about their feelings of pain or discomfort during the birthing process. It is important to note that more Black women responded to being listened to as **"Sometimes"** or **"Never"** than White women in this sample which suggest that there could be a possibility of differential treatment in healthcare services provided.

In Questions 2, **Figure 5.4**, most women responded **"Never"** to being treated with less respect due to their race, culture, ethnicity, or age. More White respondents indicated they **"Rarely"** felt like they were not listened to by physicians, nurses, and hospital personnel while more Black participants indicated that they were **"Often"** not treated with respect. Similar to Question 2, most women stated **"Never"** to receiving poorer treatment due to their race, ethnicity, culture, or age in Question 3 (**Figure 5.5**). More White women than Black women stated **"Sometimes"** to receiving poorer services while more Black women than White women perceived that they **"Often"** received poorer services.

Due to the demographic makeup of Flint and close residential proximity of these women, one would expect to have similar perceptions of healthcare services received. Assessing the perceived health care services received post-FWC, I found that the majority of the views of discrimination in services provided follow a similar positive trend towards less discrimination. However, even in a majority Black city, there are still more Black women that perceive they are

given differential treatment in services provided, respect, and being listened to during childbirth. The logistic regression analysis (**Table 5.6**) of neighborhood factors predicting SMM confirms that the proportion of Black residents within a neighborhood can significantly increase the odds of SMM.

Controlling for Socioeconomic and Neighborhood Factors

From the survey respondent logistic regression analyses (**Table 5.5**), ethnicity-non-Hispanic was the only factor that significantly increased the odds of SMM (OR: 1.381, p-value = 0.012, 95% CI: 0.003-0.681). Race, marital status, education attainment, employment status, and presence of health insurance did not influence the odds of a women in this study experiencing an SMM (**Table 5.6**) neither did place (i.e., living in Flint or not) influence SMM. The logistic analysis of the survey respondents suggests that race, age, education, income, and employment status are not statistically different among the study sample. However, examining the effect of neighborhood factors on SMM (**Table 5.7**), I found that the proportion of Black residents within the study participant's census tract and age significantly increased the odds of SMM.

Additionally, having a higher education (e.g., some college or a college degree or higher) and health insurance for ages 19 to 54 significantly reduced the chances of SMM. The difference in the survey logistic regression analysis and the neighborhood factors analysis suggest that survey data might be better represented to conceptual difference in treatment among participants while the ACS is better used to show the statistical difference within the neighborhood. **Figure 5.6** shows a high concentration of SPARRK participants who identify as Black residing within the inner city of Flint which also had the highest lead level ranges (1.44 or higher) in 2016. Most participants that identify as White were concentrated mostly closer to the outer edge of the city in which the lead level ranges were 1.44 or less. The map also shows that many SPARRK study

families live in surrounding areas not directly exposed to the FWC at this time. By representing the survey participants spatially, it is easier to see the potential difference in exposure had the women resided in these neighborhoods during the FWC.

Limitations

The study design of this paper is cross-sectional which limits the ability to determine causality. However, the data is deducted from an ongoing RCT and is a primary data source which helps control potential biases. Another limitation is the inability to generalize the study results to other cities as Flint might be a special case due to it being a post-war industrial city, years of economic decline, and the FWC. Presently in 2022, there are five cities that are widely reported as experiencing a water crisis: Benton Harbor, MI; Baltimore, MD; Jackson, MS; Rio Grande Valley, TX; and Honolulu, HI (ABC New, 2022). Additionally, there is a potential information bias as respondents might misinterpret the survey question and answer incorrectly. Another limitation is the inability of to directly determine the effects of the FWC; this study can only determine the indirect effects (e.g., years of urban and economic decline). Lastly, **Figure 5.6** shows lead level ranges in drinking water within Flint in 2016. With the available data, there is no way to determine if the participant lived in this exact location and neighborhood during the FWC. For this reason, the overlay map of SPARRK participants and lead level ranges from the FWC was not statistically computed but merely shown as a reference to the current residential situation of respondents within and around Flint.

5.7 Conclusion

Based on the study's findings and previous literature discussed in this dissertation, it is conclusive to state that the chance of experiencing maternal health disparities is significantly associated with the proportion of Black residents within a neighborhood. I found that education,

income, health insurance status, marital status, and employment status do not significantly influence the odds of an SMM; however, a woman of minority status (i.e., Hispanic) and the proportion of Blacks within a neighborhood significantly increases the risk of an SMM. Examining the maternal health perceptions of women who delivered in Flint, the overall perceived health has declined post-FWC for all women. Surprisingly, delivering a child within a predominately Black city, the perception of maternal health care services received differs between Black and White women. More Black women felt that they were not listened to about feeling of pains and discomfort, were treated with less respect due to their race, ethnicity, age, or culture, and received poorer services. Controlling for maternal health care services as outline in the conceptual framework for this study, the most inconsistencies observed are due to women of color receiving poorer maternal health care services.

The purpose of this study was to shine a light on the issues within Flint's health care systems and possibly evoke policy change among hospital directors, staff, and key personnel to create an intervention strategy that promotes maternal health equity and services provided to all women within the city of Flint. With such a life-threatening topic, health professionals should take on the challenge of identifying disproportionalities in the healthcare system and environment. Every woman regardless of race, age, socioeconomic status, and education should have the right to have an equitable, successful birth and a quality birthing environment. It is my hope that this research will provoke conversations among policy makers to understand and work towards eliminating negative maternal health outcomes associated with harmful environmental exposures and addressing systemic racism in the healthcare field. A few practices hospital personnel can incorporate to address perceived differential treatment within the maternal healthcare system are:

A) Partner with the National Birth Equity Collaboration (NBEC) to conduct a hospital/birthing facility evaluation and training to encourage equitable birthing experiences for all women. NBEC's purpose is to promote birth equity and aid in reducing the maternal health disparity gap.

B) Provide incentives to physicians, nurses, and hospital personnel for patient satisfaction. Granting incentives might encourage birthing facilities to adhere to the NBEC training and promote health equity and prevent maternal morbidities/mortalities.

C) Depict hospital and physician ratings to provide patients and their families with an overview of each physicians, patient satisfaction ranking, and specialty. Displaying these ratings grants families with the opportunity to choose and review physicians that are a best fit for them.

The final chapter of this dissertation summarizes the overall findings from each study and proposes recommendations on interventions and best practices among health professionals and researchers.

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CHAPTER 6

CONCLUSION

6.1 Dissertation Summary

This dissertation investigated the impact of maternal health disparities across three geographic scales (i.e., state, community, and individual), identified community factors that contribute to the impact of an environmental hazard on maternal health disparities, and considered the perception of systemic discrimination post-environmental injustice on maternal health outcomes as outlined in Chapter 1. There were three independent research studies with appropriate objectives created to examine issues at that specific geographic level. Overall, the following steps were taken to address the dissertation's study objectives and goals 1) I defined and provided background literature on maternal health disparities, 2) I discussed the impact of environmental hazards on maternal health, 3) I explored the history and significance of the city of Flint, MI, 4) I developed and applied a new conceptual framework that explains the pathways of discrimination on maternal heath disparities from a Public Health Critical Race Theory lens across all three geographic scales, and 5) I conducted three separate studies that examine maternal health disparities using new and innovative techniques within each study.

This dissertation's research supports the interdisciplinary nature of the Geography discipline as a whole by examining the influence and intersectionality of health, race, and place. Additionally, this dissertation contributes to the current maternal health literature by being the first study to 1) describe multiscale factors that affect maternal health disparities within one literary framework to display congruent contributing elements such as race and age at the state and metropolitan scale and race at the individual scale that drive differences in health outcomes, 2) develop a new conceptual model, Pathways of Institutional Discrimination on Maternal Health

Disparities, to name the pathways in which discrimination affects maternal health disparities and offer this framework for future researchers to examine maternal health disparities, 3) deploy census variables adapted from the Modified Darden-Kamel Composite Socioeconomic Index to identify socioeconomic and demographic similarities among cities within the same state, 4) use difference in difference (DID) models to determine the Flint Effect on maternal health disparities while controlling for changes in maternal health during the timeframe of the FWC, and 5) examine the perceptions of maternal healthcare quality post-FWC among Flint women.

The remaining sections identify the importance of the newly developed conceptual model when researching adverse maternal health outcomes, provide a summary of each study's findings and contributions conducted in this dissertation, discusses next steps for the city of Flint and similar urban areas and makes recommendations for addressing maternal health disparities.

6.2 Pathways of Institutional Discrimination on Maternal Health Disparities

The ideology used to develop the conceptual model of this dissertation was explained in Chapter 2. In summary, the Pathways of Institutional Discrimination on Maternal Health Disparities conceptual model details the routes in which discrimination impacts individual, community, and healthcare quality and services factors. Similarly, the stated factors can further influence labor and delivery outcomes which substantially contribute to the severity of maternal morbidities. Many conceptual models explain similar pathways of race/racism on maternal health disparities, such as the three frameworks used to create the dissertation's conceptual model: Public Health Critical Race Theory (PHCRT) (Ford & Airhihenbuwa, 2010), the World Health Organization's maternal morbidity framework (Filippi et al. 2018), and the Pathways to Racial and Ethnic Disparities in SMM & Mortality (Howell, 2018). However, to my knowledge, no model has explicated viewed the pathways of discrimination through a public health CRT lens to

identify individual, community, and systemic factors that contribute to labor and delivery outcomes thus influencing maternal health outcomes such as SMM. Viewing the conceptual model through a PHCRT lens across geographic scales can inspire future researchers to further maternal health disparity knowledge by creating more substantial empirical evidence of cross-geographical factors such as race that contribute to differential treatment and health outcomes. The PIDMHD concept is implicates race and the discriminatory action of individuals in places of power as major contributing factors in healthcare quality and health outcomes.

The chapter then provided a literature review defining maternal health disparities, describing medical racism and how it disproportionately affects Black women, the role of systemic, structural and institution racism on health, the impact of environmental hazards on maternal health, and a historic overview of the city of Flint. The overarching result from this chapter is that Black women and their associated health are continuously oppressed through racism/discriminatory practices within the obstetric, systemic, structural, and institutional racism/discrimination systems in America. The literature review finding along with the conceptual model for this dissertation and the historic and present systemic and environmental injustice within Flint, provided empirical evidence to conduct a multi-scale analyses on the impact of the FWC on maternal health disparities.

Furthermore, it is essential for future researchers and health policy/program makers to examine maternal health across geographic scales. The maternal data provided at each scale can identify key factors that can encourage policy change across the various branches of political power. For instance, at the state geographical level in Chapter 2, I found that race and age are two prominent contributing factors to maternal health disparities in Michigan. This information can encourage state elected officials to create statewide programs and initiatives to aid in

reducing maternal health disparities to 1) allocate funds to researchers to create intervention strategies, 2) lobby for more funding to support birthing facilities and 3) provide hospitals with modern medical equipment and training that are located in areas with high maternal morbidity rates across the state.

Similarly, at the metropolitan scale, community leaders and local organizations can use these states allocated finding to further pinpoint high risk areas of maternal morbidity as well as create local programs to reduce maternal health disparities by ensuring a healthy built environment, access to healthy foods and, and transportation to birthing facilities. The functionality and efficacy of political power exerted at each geographical scale to reduce maternal health disparities can be measured at the individual geographic scale by analyzing the SMM rates at the census tract or census block group or obtaining the perceptions of women who delivered a child within these areas. Thus, the use of a multi-scale analysis to examine maternal health disparities can investigate key contributing factors and ensure that invention strategies are correctly addressing the target population and reducing further disparities.

6.3 Multi-scale impacts on maternal health disparities

The following subsections summarize the purpose, data, key methods, results, and conclusions of each study conducted in this dissertation (i.e., Chapters 3:5). Based off these findings, the next section will detail the overall contributions of this research and provide policy recommendations for state, local, political, and key stake holders of health facilities.

Chapter 3: State-level Summary

The broadest geographic scale of analyzed for this dissertation occurred at the state level of Michigan. This chapter lays the foundation for the remaining papers as it sets the baseline maternal health disparities within the state of Michigan. The chapter establishes the impact of

patient and community factors on maternal health disparity among Black and White women in Michigan during the two years prior to the onset of the FWC (January 1, 2012, through December 31, 2013). The CDC's 21 SMM indicators served as a proxy for maternal health disparities, the outcome variable, for all maternal inpatient health records in Michigan during the study's timeframe.

This chapter set out to answer three research questions: "What is the maternal health disparity between Black and White women in the state of Michigan between 2012 and 2013?"; "Which patient and community factors are associated with this disparity?"; and "Does living in ZIP codes with a higher proportion of Black population correlate to higher rates of SMM?". Based on these research objectives, I hypothesized that 1) the maternal health disparity rate in Michigan is greater than the national rate, 2) patient and community factors do not explain the maternal health disparity rate observed in the state of Michigan, and 3) ZIP codes with higher percentages of Blacks experience higher rates of SMM for both Black and White women. MIDB was used to obtain the following patient level covariates: race, ethnicity, hospital admission type, and primary insurance payer method. The following community level covariates were obtained from the 2012 through 2017 American Community Survey: educational attainment, socio-economic status, presence of health insurance coverage, marital status, and age by race. The methodology used to test the first hypothesis was odds ratio, logistic regression was used to predict the likelihood of SMM among patient and community factors, and Kruskal-Wallis one-way non-parametric ANOVA was used to address the third hypothesis.

I found that, within Michigan, Black women's odds of experiencing an SMM is 3.73 times greater than that for White women. Thus, the maternal health disparity suggests that across the state, Black women were almost 4 times more likely to experience an adverse maternal

outcome during childbirth in the two years just prior to the FWC. This result answers my first research question by showing that the maternal health disparity rate in Michigan is higher than the national maternal mortality ratio of 3.5 (MacDorman et al. 2021). From the logistic regression model of patient level factors, race-Black, age, primary payer method-Medicaid, and primary payer method-Self Pay significantly increased the odds of a patient experiencing an SMM while race-Other, race-White, admission type-Other, and admission type-Urgent significantly decreased the odds of SMM. Within the community level analysis, I did not observe any significant associations between SMM and the covariates. These findings answer the second research question as community factors did not explain the maternal health disparities from the data used; however, among the patient level factors, race, age, and type of hospital payment significantly increased the likelihood of SMM. Lastly, from the Kruskal-Wallis test, I found that ZIP codes with < 30 % of Black residents have significantly elevated SMM disparities for Black women compared to White women. In ZIP codes > 30%, the SMM rates per 1,000 were not significant but remained higher than White women. The previous finding addresses research question three and confirms that as the proportion of Black residents increased within ZIP codes, the SMM rate increases for all women. It is important to note that within ZIP codes with < 30% of Black residents, this SMM rate for Black women was significantly different than that for White women.

In summary, the state level analysis on maternal health disparities in Michigan supports the need for future research to more deeply explore the factors outlined in the Pathways of Institutional Discrimination on Maternal Health Disparities (i.e., individual, community, and healthcare quality). This chapter makes several major contributions to the Health Geography literature including: 1) Black women were nearly 4 times more likely to experience a SMM in

Michigan which is higher than the national rate and highlights the need for more research on the driving factors specific to Michigan that contribute to this rate; and 2) controlling for patient level factors suggests that SMM likelihood was associated with differences in race, age, and method of payment thus warranting further research on the pathways in how these patient factors increase SMM. The major contributions of this study to the Health Geography literature are 1) community factors at the ZIP code level did not show significant associations with SMM which merits finer-geographic scale research; 2) SMM rates were significantly different in ZIP codes that housed less than 30% of Black residents compared to those with > 30%; and 3) as the proportion of Black residents increased, overall SMM rate for all women increased. The findings from this study, encourages the exploration of maternal health disparities at a granular scale to determine driving factors.

Chapter 4: Community-level Summary

At a narrower geographic scale, a community level study was conducted on maternal records for women residing within the city boundaries of Flint and a comparison city. This chapter incorporated factors that could manifest at the state or individual level. The goal of this chapter was to conduct a quasi-experimental research design to compare Flint to a demographically similar city within the state of Michigan and determine the Flint Effect on maternal health from 2012-2017. The Flint Effect for this study was referred to as the change in maternal health disparities in Flint due to the interaction of the water crisis with other contributing factors influenced by discrimination at the community level as outlined in the conceptual framework of this study. The study's timeframe was divided into three phases of the FWC: pre-FWC (2012 through 2013), during-FWC (2014 through 2015), and post-FWC (2016 through 2017).

The primary aims of this chapter were to investigate the impact of the Flint Effect on maternal health disparities using an innovative method and examine the difference in SMM between Black and White women in Flint. SMM served as an indicator for maternal health disparities, the outcome variable. The research questions addressed were 1) "Are Black women in Flint, MI more likely to bear the burden of maternal morbidity post-FWC and during-FWC compared to pre-FWC than White women?"; and 2) "What was the effect of the FWC on maternal health disparities in Flint?". I hypothesized that Flint had a higher maternal health disparity during the FWC due to the water crisis as well as years of environmental injustice and institutional discrimination compared to a city of similar sociodemographic factors.

Data was obtained from the MIDB at the patient level. Covariates for this study included race, ethnicity, hospital admission type, and primary insurance payer method. Each of the patient records associated a woman who gave birth during the study's timeframe to a five-digit ZIP code in Michigan. To test my study hypothesis, I first identified a comparison city using the K-means and hierarchical clustering analysis using the U.S. Bureau of Census variables outlined in the Modified Darden-Kamel Composite Socioeconomic Index. Saginaw was the resulting control city chosen based on total population size and distance similarity to Flint. Next, I conducted weighted linear regression tests of patient factors predicting the likelihood of SMM for each time period (i.e., pre-, during-, and-post-FWC). ZIP code weights were based on the proportion of the ZIP code within the city boundaries of both Flint and Saginaw. Lastly, I used a quasi-experimental research design, DID, to determine if the FWC influenced SMM in Flint. The DID methodology compares a treatment group to a control group that did not experience a specific event to determine if the treatment group would have experienced similar outcomes if an event had not occurred. A key aspect of the DID method for this chapter is its ability to control for two

time periods (pre-event and post-event). The variables used in the DID analyses include Flint (treatment group), Saginaw (control group), years (pre-during-FWC and pre-post-FWC), and an interaction term (year*Flint).

Weighted linear regression models used in the pre-FWC time period determined that age and primary pay method- Other significantly increased the likelihood of a patient experiencing an SMM while admission type–Other and admission type-Urgent significantly reduced the odds of an SMM. In the during-FWC phase, race-Black was the only variable that significantly increased the odds of an SMM, and the following covariates substantially reduced SMM: admission type-Other, admission type-Trauma, admission type-Urgent, primary payer method-Other, and primary payer-Self Pay. The post-FWC analysis resulted in age being the only variable to significantly increase the odds of SMM while race-White, admission type-Other, and admission type-Urgent significantly reduced the chances of an SMM. The pre-during-FWC DID analysis revealed that race-Black and age significantly increased the likelihood of experiencing an SMM while controlling for the FWC interaction term, significantly reduced the odds of SMM. The following covariates also significantly reduced the chances of SMM: ethnicity-Other, admission type-Other, admission type-Trauma, and admission type-Urgent. However, the pre-post-DID computation resulted in age being the only variable to substantially increase SMM while the FWC interaction term, admission type-Other, and admission type-Urgent significantly reduced the likelihood.

This chapter provided evidence that the Flint Effect did occur in the city of Flint, Michigan as living in Flint during the timeframe of the FWC (i.e., 2014-2015) played a significant role in reducing the likelihood of SMM. The interpretation of the DID analysis suggests that if the coefficient is different from zero (positive or negative) and significant, the

event of interest changed the outcome of the treatment group, Flint (DS4PS, n.d.). Note that the biological influence of the FWC on maternal health was not identified in this study. Moreover, the results of this chapter concluded in a negative yet significant DID interaction term thus, the interaction of living within Flint during the FWC significantly reduced the chance of SMM among the city of Flint; however, one's age and identifying as Black significantly increased the likelihood. The results of the DID analyses supported Flint Effect theory as the probability of an SMM was indirectly affected by the FWC as well as other variables such as population decline and patient level factors. This chapter fills the gap in the current literature on the FWC and environmental hazards on maternal health by being the first study to examine the impact of patient level factors pre-, during-, and-post-FWC on maternal health outcomes. To my knowledge, this study is the first to use the DID methodology to examine maternal health disparities and the U.S. Bureau of Census variables used in the Modified Darden-Kamel Composite Index to identify a comparable city to Flint based on demographic and economic variables.

Chapter 5: Individual-level Summary

This chapter worked at the finest geographic scale of this dissertation, the individual level of analysis. Its purpose was to investigate the perceptions of the FWC, and quality of maternal healthcare services received among women who delivered a child in Flint post-FWC. I hypothesized that the maternal health care quality and services received will negatively impact Black women more than White women in Flint despite the mothers residing in similar neighborhoods and delivering at the same hospital. The chapter's research questions are: 1) "How do women in Flint perceive their overall health improved after the FWC?", and 2) "Did

women's perceptions on maternal health services and quality improve after the Flint Water Crisis?".

To address the research questions, qualitative survey data was obtained through a collaboration with the SPARRK program which is an ongoing RCT. The parent study randomly assigned families who gave birth at Hurley Medical Center in Flint, MI to a VIP to determine if improving parenting skills post-FWC has a positive effect on child development. 2020 U.S. Bureau of Census tract data was used to match the geocoded addresses of the survey respondents to the associated census tract in Flint. I controlled for the following census tract variables using 2016-2020 ACS 5-year data: race, mode of transportation, marital status, educational attainment, MHI, employment status, and presence of health insurance by age group.

A variety of methods were used: descriptive statistics (e.g., frequency counts and totals), logistic regression analysis to predict the likelihood of SMM among survey respondent demographic data, logistic regression analysis to determine the odds of SMM using neighborhood level factors obtained from the ACS, and geocoding addresses to depict the spatial context of survey respondents compared to the lead ranges of the FWC were used in this chapter. In summary, 151 surveys were used for all analyses conducted in this chapter. The majority of the participants identified as Black. The odds of a Black woman within this sample experiencing a SMM was less than 1 (i.e., 0.70) that of a White participant in this study. Women who identify as Hispanic were 1.381 times more likely to experience an SMM compared to non-Hispanic women. This finding suggests that race, marital status, educational attainment, MHI, employment status, and presence of health insurance among the study sample was not significant in influencing the odds of an SMM. Furthermore, more Black women within this study believed they received a poorer maternal health care service and was not listened to due to either their

race, ethnicity, culture, or age than White women. In aspect of the FWC, overall perceived health decreased for all women post-FWC. At the neighborhood level, I found that the proportion of Black residents within a neighborhood significantly increased the odds of an SMM.

This chapter provided an overview of the perceptions of women who delivered in Flint post-FWC and characterized their views on the quality of maternal healthcare services received. The findings suggest that the perceptions of health among women who delivered a child post-FWC is considerably lower than before the water crisis. An important outcome of this study is the stark probability of a Black woman who resides within a predominately Black city, lives within the same neighborhood and gives birth at the same hospital as a White woman yet still receive differential treatment based on her race, ethnicity, culture, or age. This study is the first study to obtain the perceptions of maternal healthcare quality and services received among women who delivered a child in Flint post-FWC.

6.4 Importance of research

Examining the chapters of this dissertation through the Pathways of Institutional Discrimination on Maternal Health (PIDMH) conceptual model, it is evident that across multiple geographic scales and in the presence of an environmental hazard, age and identifying as Black significantly increase the odds of maternal health disparities. For instance, in Chapter 3, I found that at the state geographic scale, race plays a more pronounced role in differential maternal health outcomes for Black women than their socioeconomic status. By examining the proportion of Black residents within a ZIP codes to SMM rates, I contributed to health geography and maternal health knowledge by statistically highlighting high risk target areas for health professionals and intervention strategies. This research also can encourage future researchers to explore the same relationships within other states and at a finer geographical scale

such as census tracts or census block groups. Additionally, the findings from this study can provide the foundation for researchers and healthcare policy makers to design experiments to test for issues around race and maternal outcomes to further identify key points of intervention and reduce differential treatment across racial and ethnic groups. Governments at the state level can use the findings from this study to create a task force or program that targets areas that are statistically prone to disparities and address major issues that contribute to maternal health disparities such as the built environmental of these areas and healthcare treatment and accessibility.

Furthermore, in Chapter 4 I discovered that maternal health outcomes observed in Flint during the FWC are significantly influenced by race. This is the first study to my knowledge to explore maternal health outcomes post-FWC and use the DID analysis to compare Flint to a socioeconomically and demographically similar city as well as control for a change in time pre-and-post-FWC. The chapter's findings demonstrated that, regardless of a woman giving birth in a predominantly Black city and the event of an environmental hazard, the FWC, maternal health disparities are still present if that woman identifies as Black. This study contributes to the maternal health literature by controlling for major contributing factors (e.g., socioeconomic variables and environmental hazard) and identifying its effect on maternal health disparities. From a policy standpoint, key personnel and decision makers can use this information and methodology in areas that are consistently affected by environmental hazards such as hurricanes in New Orleans to create intervention tactics and programs aimed at reducing adverse maternal health outcomes and disparities.

Lastly, in Chapter 5 which surveyed 152 women, I observed that the likelihood of a woman experiencing a maternal health disparity is significantly associated with the proportion of

Black residents within a neighborhood. This chapter's findings support the results of Chapter 3 which implies that as the proportion of Black residents within a ZIP code increases so does the SMM rate. They reinforce an issue brief by the Commission on Health that states, "the neighborhoods we live in shape our behaviors and influences our health…" (Cubbin et al. 2008). As mentioned in the Chapter 2 of this dissertation, place significantly influences health outcomes as shown in the perceptions of women who delivered in Flint post-FWC. This study is the first study to my knowledge to obtain the perceptions of women who delivered in Flint post-FWC and determine the association of perception and maternal health disparities. The research conducted for this study can serve as a starting point for collaboration between community leaders and healthcare personnel to break information and communication barriers, address stereotypes, and create a sense of rapport between physicians and the communities they serve which could possibly aid in reducing maternal health disparities as noted and observed by several research studies (Meade et al. 2007; McElfish et al. 2015; Morgan & Lifshay, 2006).

Each of the studies conducted in this dissertation contribute to both the current literature on maternal health disparities and health geography discipline by geographically investigating maternal health disparities while controlling for common contributing factors across geographic scales. The two factors that were associated with differential outcomes regardless of geographic scale are age and race. While both factors, age and race, impact maternal health disparities across the geographical boundaries examined in this dissertation, race is the most prominent. Confirming findings in the previous literature on the importance of age on reproductive health outcomes, I found that aging is a homogeneous variable that affects everyone regardless of race, culture, ethnicity, and gender identification (Haghighi, 2021; Swamy et al. 2012). However, no study including this dissertation has found any biological or socioeconomic factor that explicitly

implies a statistical or substantial reason as to why identifying as Black should increase SMM. Race, then, has been statistically proven by this dissertation as well as Bower et al. (2018) and other researchers to act more as a social construct that influences individual, community, healthcare quality and services received, and maternal health outcomes as opposed to a representation of biological characteristics (Gravlee, 2009; Hilmert et al. 2014; Taylor, 2020; Wallace et al. 2015).

Future researchers should use the methodology and empirical evidence of this dissertation as a tool to identify and examine high-risk areas of SMM in other geographic regions and across geographic scales. Additionally, future maternal health researchers should also examine race through the PIDMHD framework to pinpoint the pathway in which discrimination has directly influenced the health outcome of women of minority status. While the focus of this dissertation was on Black women, who are a high-risk population for maternal health disparities, the methods and conceptual framework can be applied to all marginalized women of color.

6.5 Future of Flint

President Joe Biden pledged to uproot corroded pipes in Flint and across America to prevent future water crises (Wilson, 2022). The progress of this act has yet to be determined nationwide; however, in Flint, many suspected hazardous waterlines have been removed. Flint residents are still awaiting the approved $626.25 million dollar settlement from the injustices of water crisis (Bellamy, 2021). Currently, there is a literary debate between Morckel (2020) and Sadler et al. (2021) on rightsizing the city of Flint. Rightsizing refers to an attempt to condense a shrinking city's resources to fit the "new" size of that city. Morckel (2020) argues that rightsizing Flint can reduce other potential water contamination that can be caused by using a "…larger-than-necessary water system".

However, Sadler et al. (2021) argues that while rightsizing is logical from an urban/city planner perspective, this type of infrastructure can disproportionately affect communities of color by threatening the action of displacement of residents. Sadler et al. (2021) also states that rightsizing tends to be conducted without the involvement of residents and is not cost effective. While I understand the viewpoints of both authors, I agree with Sadler et al. (2021) that rightsizing is not the appropriate proactive method to prevent further water contamination exposure. I argue that state and local governments or organizations should work with Flint community leaders to redevelop the urban infrastructure of Flint to make it more sustainable for current residents and create a ten-year fiscal plan to steadily increase the economic flow within the city of Flint to raise its capital without initiating gentrification within the inner city.

6.6 Health Implications and Policy Recommendations

In conclusion, this dissertation has examined multi-scale impacts of the FWC on maternal health disparities. It is evident that discrimination operates across geographic scales and is embedded in multiple systems that impact individual factors, community factors, and maternal healthcare quality and services received which disproportionately affects Black women and leads to maternal health outcomes (Bower et al. 2018; Hilmert et al. 2014; Howell, 2018; Taylor, 2020). The following suggestions are my recommendations to aid in the fight to close the maternal health disparity gap. These items range from critical view standpoints (i.e., recommendation 1) to healthcare intervention strategies (i.e., recommendations 2-4) and governmental practices (i.e., recommendation 5).

1. Address maternal health disparities through the public health critical race theory lens. Thus, understand and admit that systemic, structural, and institutional racism are the root causes for disparity.

2. Rebrand the current and upcoming healthcare field and professionals with modern medical theories that are inclusive and dismiss theories that are embedded in racism/discrimination and promote stereotypes such as the “strong Black woman” embedded within the framework.
3. Require mandatory equity training among hospital personnel, physicians, and nurses yearly with updated inclusivity modules to ensure that everyone is aware of what racism/discrimination is and how to actively prevent it.
4. Enforce internal investigations and discipline among hospital personnel, physicians, and nurses that are accused of racist or discriminatory actions.
5. Change the federal and state government systems and policies that were created to oppress subpopulations that identify as Black to a more equitable policy. For example, new policies should encourage similar access to resources, and opportunities such as grocery stores with healthy foods, adequate educational systems, and employment opportunities in deprived neighborhoods with a majority Black population.

Drawing from the empirical evidence observed in this dissertation as well as the numerous studies cited that have found a correlation between race and health outcomes, it is imperative that public health professionals and health geographers start with identifying and understanding the influence and power of race. While race is a social construct, acts of discrimination and racism aimed at communities of color has transformed a societal factor into a biological process that has inherently affected the maternal health outcomes of women of color, especially Black women in America, for centuries. Because of this well-known yet vaguely addressed issue, the first recommendation is to view maternal health disparities in public health

through a critical race theory lens. Furthermore, it is essential to use conceptual models such as the Pathways of Institutional Discrimination on Maternal Health Disparities to identify and focus on routes of discrimination to reduce these inequalities and inequities.

From here, health professionals can begin to implement training strategies such as the ideas outlined in recommendations 2 through 4 to ensure every hospital personnel are aware of the signs and biases associated with maternal health disparities. Beginning these changes within the community can aid in reducing disparities as noticed by other researchers such as McElfish et al. 2015. This initiation of reducing maternal health disparities at the community level can also influence state and federal governments to use its power to create more equitable environments for Black communities to further reduce health disparities overall.

Malcolm X, a Lansing, Michigan native, stated in 1962 that "The most disrespected person in America is the Black woman…" (Jones, 2020). While this quote is decades old and occurred during the Civil Rights Movement, the statement holds true today and is exhibited in maternal health outcomes as well as the perceptions of women studied in this dissertation. In order to change this phenomenon, we as public health professionals and humans in general should change our individual thought process and that the approaches of state and federal governments as well as initiate mandatory healthcare policies and interventions to ensure equality and equity for all women.

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APPENDIX A:
SPARRK STUDY AIMS

I. Study Aims and Hypotheses:

Aim 1. Characterize participants' experience of the Flint Water Crisis (FWC) using ecological (neighborhood- level), geocoded Speak to Your Health (STYH) survey data, ecological indicators of water quality and parent self-report measures.
H1a. Spatial data analysis and cluster analysis of longitudinal profiles, examined separately and jointly, will reveal distinct groups suggesting specific patterns of family experience of the FWC.

H1b. Race and socioeconomic characteristics will be associated with experience of the FWC.
Aim 2. Assess impacts of strengths-based parenting support (Video Interaction Project; VIP) after a disaster compounding chronic poverty.
H2a. VIP will result in enhanced parenting practices/parent-child relationship and child development.
H2b. Parenting compensatory assets/vulnerabilities and practices/relationships will mediate child outcomes. **Aim 3.** Assess variation in VIP impacts in relation to FWC experience.
H3a. Family experience of the FWC as characterized in Aim 1 will moderate VIP impacts.
H3b. Exploration of mechanisms of FWC moderation of VIP impact through analyses of VIP engagement.

II. Statistical Design and Power for Aim 1: *(Characterize variability in FWC experiences for families in the randomized controlled trial [RCT])*

A. Aim 1 preparatory analyses
1. Data reduction: Factor analyses will be performed within neighborhood-level (community cohesion, institutional mistrust) and family-level (anxiety, depression, post-traumatic stress symptoms, discrimination) variables. Principal axis factoring will be used for extraction (robust to non-normality in the data) and rotation applied (e.g., varimax). This preprocessing will identify constructs that capture approximately the same information as in the larger set of variables, but more precisely via aggregation; they also reduce multicollinearity in subsequent analyses. We use standard approaches for choosing the number of factors: Kaiser criterion, scree plots proportion of variance explained. Composite factors will be used in analyses.
2. Areal interpolation on respondent scores for each of the derived factors: By geocoding every survey to the respondent's home address, we can create a series of surfaces representing the general characteristics of the neighborhood related to the constructs above. We will perform ordinary Kriging, with individual respondents' scores (co-Kriging may also be used[201]) and create an estimate of the presumed score for every location in the city. Each surface will be normalized to a 0-1 scale and used in latent class and cluster analyses (see below).

APPENDIX B:
MATERNAL HEALTH INTERVIEW QUESTIONS FROM SPARRK BASELINE SURVEY

MATERNAL HEALTH

1.Before you got pregnant, would you say that, in general, your health was-

A) Excellent B) Good C) Fair D) Poor

2.How would you rate your overall health before the Flint Water Crisis (before 2014):

A) Excellent B) Good C) Fair D) Poor

3.How would you rate your overall health after the water system was switched in Flint (2014-present)?

A) Excellent. B) Good C) Fair. D) Poor

4.During your most recent pregnancy, has a doctor, nurse, or other health care professional ever told you that you had one of the following severe maternal morbidity conditions?

Diagnosis Name:	Yes	No
Kidney failure (aka Acute renal failure)		
Fluid in lungs (aka Adult Respiratory distress syndrome)		
Heart failure/stroke/heart arrest (aka Cardiac a arrest, fibrillation, or conversion of cardiac rhythm)		
Shock		
Heart attack (aka Acute myocardial infarction or aneurysm)		
Severe bacterial infections during or shortly after pregnancy (aka Sepsis)		
Removal of cervix (aka Hysterectomy)		
Blood clots/abnormal bleeding (aka Disseminated intravascular coagulation)		
Heart failure/fluid around heart (aka Acute congestive heart failure		
Seizures/coma/toxic pregnancy (aka Eclampsia)		

5.During your most recent pregnancy, did you have one of the following serious medical procedures?

Procedure

Name: Yes No

A. Blood transfusion
B. Ventilation/temporary tracheostomy to assist with breathing

6. If you experienced one or more of the above diagnosis or procedures during the delivery of your child, do you feel as if the physicians, nurses and/or hospital personnel listened to you about your feelings with the pain, discomfort, or overall birthing experience?

A) Your voice was heard and included in how the physicians and nurses responded to your needs.
B) Your felt that your voice was included slightly in how the physicians and nurses responded to your needs.
C) You felt that you did not see a difference in how you were treated.
D) You feel like you were not heard but your needs were responded to.
E) You felt ignored and your needs were not responded to.

Prenatal:

7. How did you feel about the prenatal care you got during your most recent pregnancy? If you went to more than one place for prenatal care, answer for the place where you got most of your care. You can answer 'yes' if you were satisfied or 'no' if you were not satisfied with each of the following:

No Yes
a. The advice you got on how to take care of yourself
b. The understanding and respect shown toward you as a person

Discrimination during pregnancy:

8. Whether or not you experienced one or more of the previous maternal diagnosis or procedures during the delivery of your child, do you feel as if the physicians, nurses and/or hospital personnel listened to you about your feelings such as pain, discomfort, or overall birthing experience?

A) Never
B) Rarely
C) Unsure
D) Sometimes
E) Often

9. During your pregnancy and the birth of your child, did you feel like the physicians, nurses and/or hospital personnel treated you with less respect or differently due to your race, culture, ethnicity, or age?

A) Never
B) Rarely
C) Unsure
D) Sometimes
E) Often

10. During your pregnancy and the birth of your child, did you feel as if you received poorer service than other expecting mothers due to your race, ethnicity, culture, or age?
A) Never
B) Rarely
C) Unsure
D) Sometimes
E) Often