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The Effects of Hurricane and Tornado Disasters on Pregnancy Outcomes

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This is to certify that the doctoral dissertation by

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Abstract

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by

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MPH, George Mason University, 2012

MA, Marymount University, 1994

MEd, University of West Florida, 1993

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Dissertation Submitted in Partial Fulfillment

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Abstract

Maternal prenatal exposure to hurricanes and tornadoes could contribute to an increased risk for adverse birth outcomes. Little is known about the effects of Hurricane Katrina of August 2005, on pregnancy outcomes in Mississippi. Additionally, little is known about the influence of the April 2011 Alabama tornado disaster on births in that state. The purpose of this study was to bridge this knowledge gap by examining the relationship between maternal prenatal exposure to these storms and adverse infant health outcomes. The theoretical framework guiding this retrospective, cross-sectional study was the life course approach. Data for this investigation included 2,000 records drawn from the Linked Infant Births and Deaths registers. Chi-square and logistic regression analyses were performed. Results indicated hurricane exposure was not a predictor of preterm birth (*OR* = .723, 95% *CI* = [.452, 1.16]; $p = 1.76$) or low birth weight (*OR* = .608, 95% *CI* = [.329-1.13]; $p = .113$). However, an association was observed between tornado exposure and preterm birth (*OR* = 1.68, 95% *CI* = [1.19-2.39]; $p = < 0.05$) and low birthweight (*OR* = 1.91, 95% *CI* = [1.27-2.87]; $p = < 0.05$). Findings suggest pregnant women are vulnerable to natural disaster storms, and are at risk for adverse pregnancy outcomes. The implications for social change include informing preparedness efforts to reduce vulnerability to increased pregnancy risk factors and adverse birth outcomes, consequential to hurricane and tornado disasters.

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Dedication

This dissertation is dedicated to my loving family. To the memory of my grandmother, Beatrice Athill Christopher; my father, Arthur Christopher; my aunt Elizabeth Krigger; my cousins, Cashena Benjamin; Maurice and Marion Sadio; Venetta Brathwaite; and Eric V. Krigger, Jr., who collectively, did more than just facilitate my intellectual development. Each provided an exemplary path for me to follow as a civic-minded individual; established high academic standards; challenged me to think critically; and ensured I had a good foundation to negotiate the challenges of this world. To the memory of my cousin Neville Sadio, who left us way too soon! To my Mother, Ernestine Christopher, who raised me to love, honor and obey my Creator, and to follow my dreams. To my brothers Arthur Viera; Charles, Athill, and Glen Christopher; my sisters, Jacinth Gilbert, Jackie Christopher, Karen McColley, Janet Lomax, and Dr. Juleen Christopher, who have always encouraged me. To my cousins, Denise Medley, and Hildred and Philip Mills, who have been a constant source of inspiration and has encouraged me to complete my doctorate degree. To my friend and mentor, Robert “Bob” Miller, who saw something in me and reminded me that I was born with a purpose and needed to find my focus, and fulfill my purpose. Finally, to all my friends, especially Kristine Cintron and Selgui Choi, and many others who were always there for me.

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Chapter 1: Introduction to the Study

Introduction

Women with prenatal exposure to natural disasters like hurricanes and tornadoes, may have an increased risk of unhealthy pregnancies and adverse birth outcomes (Antipova & Curtis, 2015; Currie & Rossin-Slater, 2013; Simeonova, 2011; Zahran et al., 2014; Zahran, Peek, Snodgrass, Weiler, & Hempel, 2013). Hurricanes and tornadoes are naturally occurring weather phenomena with portentous destructive winds. These cyclonic storms are a common occurrence in the United States, and can devastate entire regions and their populations, producing high rates of morbidity and mortality, and extensive property damages (Klein & Shih, 2010; Wallace, 2010). The United States has experienced an increase in natural disasters potentiated by extreme weather incidents, resulting in damages equal to or exceeding billions of dollars (Lindsay & McCarthy, 2012; National Oceanic and Atmospheric Association National Climatic Data Center [NOAA NCDC], n.d.a). Over the last several years, experiences from natural disaster storms like Hurricanes Katrina and Sandy and the Joplin, Missouri and Tuscaloosa, Alabama tornadoes have resulted in homelessness, economic impairment, and the disruption of healthcare, and social and public services leading to considerable stress for those exposed (Abramson & Redlener, 2012; Colten, Kates, & Laska, 2008; Cutter et al., 2006; Kates, Colten, Laska, & Leatherman, 2006; Miller et al., 2013; Paul & Stimers, 2012; Prevatt et al., 2013; Shen, DeMaria, Li, & Cheung, 2013). As pregnancy is a significant life event inherent with enormous stress, pregnant women and the developing fetus are particularly susceptible to the direct and indirect damaging effects elicited by experiences from natural disasters (Dunkel Schetter, 2011; Dunkel Schetter & Glynn, 2011; Dunkel Schetter & Lobel, 2012; Dunkel Schetter & Tanner, 2012; King & Laplante, 2015; Xiong et al., 2010; Zotti, Tong, Kieltyka, & Brown-Bryant, 2012).

Unhealthy pregnancies and adverse birth outcomes such as eclampsia, premature rupture of membranes, spontaneous abortions and premature labor; low birth weight (less than 2500g), preterm birth (defined as less than 37 weeks gestation), and intrauterine growth retardation or small for gestational age (birth weight $\geq$ 2 standard deviations below the mean for gestational age), are sensitive indicators for adverse maternal and infant health outcomes resulting from prenatal exposure to natural disasters (Antipova & Curtis, 2015; Harville, Xiong, & Buekens, 2009; King & Laplante, 2015; Oyarzo et al., 2012; Simeonova, 2011; Torche & Kleinhaus, 2012; Zahran et al., 2014; Zahran et al., 2013). Gestational age and birth weight are two significant indicators of infant health (Gibbs, Wendt, Peters, & Hogue, 2012; McCormick, Litt, Smith, & Zupancic, 2011). In calendar year 2013, 11.4% of births in the United States were preterm and the low birth weight rate was 8% (Martin, Hamilton, Osterman, Curtin, & Mathews, 2015). Preterm birth and low birth weight are known contributing factors to severe infant morbidity and mortality (King, Gazmararian, & Shapiro-Mendoza, 2014; Mathews & MacDorman, 2013). Moreover, preterm and low birth weight infants are known to have an increased risk of morbidity and longer-term health and social complications, including: hypoglycemia, respiratory distress issues, low blood platelet count, jaundice, cerebral palsy, autism, neurodevelopmental disorders, chronic respiratory conditions, lower educational attainment and developmental challenges, and cardiovascular and metabolic disorders (Behrman & Butler, 2007; Boulet, Schieve, & Boyle, 2011; Kajantie & Hovi, 2014; Fuller, 2014; McCormick et al., 2011; Moster, Lie, & Markestad, 2008; Norris et al., 2012; Saigal & Doyle, 2008). These adverse outcomes demand significant research consideration and attention as they represent a substantial financial and emotional cost to affected families and an economic burden on communities due to increasing healthcare costs and long-term treatment requirements (Behrman & Butler, 2007; Johnson, Patel, Jegier, Engstrom, & Meier, 2013; Owen, Goldstein, Clayton, & Segars, 2013; Russell et al., 2007; Soilly, Lejeune, Quantin, Bejean, & Gouyon, 2014; Zhang et al., 2013).

Although there is evidence suggesting an increased risk of maternal prenatal exposure to natural disasters and adverse birth outcomes, more information is needed to enhance understanding of the association between maternal prenatal exposure to natural disasters like hurricanes and tornadoes and birth outcomes, and the prospective risk factors which may promote infant mortality (Buekens, Xiong, & Harville, 2006; Callaghan et al., 2007; Kanter, 2010; Zahran, Snodgrass, Peek, & Weiler, 2010). In this study, county-level linked birth and infant death data was utilized to examine the influence of hurricane and tornado disasters on pregnancy outcomes; including birth weight, preterm birth, infant mortality, and mode of delivery. To facilitate identification of potentially exposed pregnant populations and the most austere hurricane and tornado storms for the period of 2002 through 2012, disaster impact data were examined with the following observable thresholds: fatalities (>10 victims) and property damage (> $10 million); and detailed by affected states and counties with the highest fatalities and property damage (see Table 1).

Through greater understanding of the association between maternal prenatal exposure to hurricane and tornado natural disasters and adverse maternal and infant health outcomes, social change could reduce risk factors and advance preparedness efforts. Potential implications for social change as a result of this study include the provision of evidence-based data regarding the threat posed by hurricane and tornado natural disasters to pregnant women and the developing fetus. These data could be utilized by the scientific and public health and medical communities to prevent future negative impact to this vulnerable population.

Table 1

Hurricanes & Tornadoes Fatalities and Property Damage: 2002 – 2012

Date	Disaster incident	State	County	Fatalities	Date	Disaster incident	State	County	Damages (2013 estimate)
Hurricanes									
8/29/05	Katrina	LA	Orleans	510	10/29/12	Sandy	NJ	Monmouth	$11.9 billion
8/29/05	Katrina	LA	St. Bernard	99	10/29/12	Sandy	NJ	Ocean	$11.2 billion
8/29/05	Katrina	MS	Harrison	79	8/29/05	Katrina	LA	Jefferson	$7.1 billion
8/29/05	Katrina	LA	Jefferson	50	8/29/05	Katrina	LA	Lafourche	$7.1 billion
8/29/05	Katrina	MS	Hancock	43	8/29/05	Katrina	LA	Orleans	$7.1 billion
10/29/12	Sandy	NY	Richmond	24	8/29/05	Katrina	LA	Plaquemines	$7.1 billion
8/29/05	Katrina	AL	Mobile	14	8/29/05	Katrina	LA	St. Bernard	$7.1 billion
8/29/05	Katrina	AL	Baldwin	13	8/29/005	Katrina	LA	St. Tammy	$7.1 billion
10/29/12	Sandy	NY	Queens	11	8/29/2005	Katrina	MS	Jackson	$5.5 billion
8/29/05	Katrina	MS	Jackson	10	8/29/2005	Katrina	MS	Hancock	$5.5 billion
8/29/05	Katrina	MS	Jones	10	8/29/2005	Katrina	MS	Harrison	$5.5 billion
Tornadoes									
5/22/2011	Tornado	MO	Jasper	158	5/22/2011	Tornado	MO	Jasper	$2.8 billion
4/27/2011	Tornado	AL	Tuscaloosa	44	4/27/2011	Tornado	AL	Tuscaloosa	$1.5 billion
4/27/2011	Tornado	AL	DeKalb	28	4/27/2011	Tornado	AL	Limestone	$1 billion
4/27/2011	Tornado	AL	Franklin	27	4/27/2011	Tornado	AL	Jefferson	$749 million
4/27/2011	Tornado	AL	Marion	25	04/04/2011	Tornado	MS	Lawrence	$517 million
5/4/2003	Tornado	TN	Madison	22	04/14/2012	Tornado	KS	Sedgwick	$507 million
2/2/2007	Tornado	FL	Lake	21	5/11/2005	Tornado	KS	Grant	$417 million
11/6/2005	Tornado	IN	Vanderburgh	20	04/03/2012	Tornado	TX	Dallas	$406 million
4/27/2011	Tornado	AL	Jefferson	20	3/1/2007	Tornado	AL	Coffee	$280 million

Note: Data from "The Spatial Hazard Events and Losses Database for the United States (SHELDUS), Version 13.1 [Online database]" by Hazards and Vulnerability Research Institute, 2014, June 21. Retrieved from http://hvri.geog.sc.edu/SHELDUS/.

Informed by their professional experience and the findings of this investigation, public health practitioners and healthcare providers could help educate policymakers and communities about the specter of these hazards. In doing so, they could build support for, and shape preparedness policies and programs to meet the needs of maternal and neonatal populations, to potentially prepare for and respond to future hurricane and tornado natural disasters.

This chapter introduces the research topic and provides an overview of the investigation. In the background segment of the chapter, current literature related to hurricane and tornado disasters and their effect on pregnancy outcomes are summarized, and gaps in the literature and a rationale describing the need for the investigation are presented. Next, a problem statement is provided to describe and define the research problem. This is then followed by a research statement of purpose, research questions, and hypotheses. An elucidation of the theoretical framework grounding the study is then offered, followed by a brief narrative describing the nature of the study; a listing of definitions of essential terms and key concepts; and a statement enumerating and explicating the study's assumptions, limitations, scope and delimitations. The significance of the study within the context of implications for social change is then provided, followed by a summary of the chapter, and a primer and transition statement to introduce Chapter 2.

Background

Hurricanes and tornadoes are natural storms containing life threatening and harsh winds which adversely impact the United States annually. Hurricane and tornado disasters often engender billions of dollars in property damage, disturbances in communities, mass casualties, which can overwhelm the healthcare system, loss of life and substantial challenges to public health (Klein & Shih, 2010; Sastry & Gregory, 2013; Wallace, 2010; Zotti et al., 2012). These natural disaster storms also induce stress and other negative psychological outcomes like fear and collective anxiety and post-traumatic stress disorder (PTSD). Other depressive symptoms such as diminished self-efficacy, decreased work performance, increased vulnerability, and despondency are also possible (Klein & Shih, 2010; Reissman, Schreiber, Shultz, & Ursano, 2010; Sastry & Gregory, 2013; Wallace, 2010; Xiong et al., 2008; Xiong et al., 2010). Moreover, natural disaster storms are known to impinge healthcare services and community infrastructure, triggering a multitude of adverse impacts and issues to vulnerable populations such as pregnant women and the unborn child (Sastry & Gregory, 2013; Xiong et al., 2008; Xiong et al., 2010; Zotti et al., 2012; Zotti, Williams, Robertson, Horney, & Hsia, 2013). These detrimental effects include psychosocial stress, inadequate or lack of prenatal care, and the interruption of essential human services like nutritious sustenance, social support, and housing (Sastry & Gregory, 2013; Xiong et al., 2010; Zotti et al., 2012).

Natural disasters induced by weather cyclones like hurricanes, have been implicated in adverse maternal and infant health consequences. Inferences between hurricanes and adverse pregnancy outcomes like preterm births and low birth weight were reported by Antipova and Curtis (2015); Hamilton, Sutton, Mathews, Martin, and Ventura (2009); Harville, Xiong, and Buekens (2009); Simeonova (2011); and Xiong, Harville, Mattison, Elkind-Hirsch, Pridjian, and Buekens (2008). Similarly, Currie and

Rossin-Slater (2013); Zahran, Breunig, Link, Snodgrass, Weiler, and Mielke (2014); and Zahran, Peek, Snodgrass, Weiler, and Hempel (2013) found adverse pregnancy outcomes to include fetal deaths, spontaneous abortions, premature labor, high rates of cesarean deliveries, and fetal distress among pregnant women exposed to the effects of a hurricane natural disaster. Moreover, researchers exploring the impacts of Hurricane Katrina on pregnant women, found a much greater incidence of maternal distress and PTSD among pregnant women exposed to this disastrous incident (Harville, Xiong, Pridjian, Elkind-Hirsch, & Buekens, 2009; Harville, Xiong, Buekens, Pridjian, & Elkind-Hirsch, 2010; Xiong et al., 2008).

Although evidence exists to suggest prenatal disaster exposure is linked with adverse maternal and infant health consequences, including deleterious effects on the quality of life and across the lifespan (Beydoun & Saftlas, 2008; Shonkoff, Boyce, & McEwen, 2009), there is limited research on the relationship between maternal prenatal exposure to natural disasters and infant mortality (Kanter, 2010; Zahran et al., 2014; Zahran et al., 2013). Researchers have provided evidence demonstrating low birth weight and preterm birth intensifies the risk of infant mortality and morbidity (Shapiro-Mendoza et al., 2008; Stoll et al., 2010). However, none of these relationships have been observed within the context of a hurricane or tornado natural disaster. Intrauterine growth retardation and preterm births are also known to heighten cardiovascular and metabolic disease risk, contributing to morbidity and premature mortality across the life course (Gluckman, Hanson, & Beedle, 2007; Godfrey, Gluckman, & Hanson, 2010). The belief prenatal stress influences the developing fetus, with enduring implications into adulthood, has received extensive consideration and validation (Barker, 2004; Ben-Shlomo & Kuh, 2002; Class, Lichtenstein, Långström, & D'Onofrio, 2011; Dunkel Schetter & Lobel, 2012; Dunkel Schetter & Tanner, 2012; Henrichs et al., 2010; Khashan et al., 2008; Wadhwa, 2005; Wadhwa, Entringer, Buss, & Lu, 2011). Furthermore, maternal prenatal exposure to natural disasters like ice storms, hurricanes, and tropical storms has been concomitant with unfavorable pregnancy outcomes and adverse neurological and cognitive development in children exposed in-utero (King et al., 2009; Kinney, Miller, Crowley, Huang, & Gerber, 2008; Laplante, Brunet, Schmitz, Ciampi, & King, 2008).

Problem Statement

Research investigators have provided a constellation of an emerging body of evidence showing that prenatal stress induced by exposure to man-made and natural disasters, detrimentally affects pregnancy outcomes. While the causes of unfavorable pregnancy outcomes during natural disasters are not clearly understood, emerging evidence implicates prenatal stress exposure as having a significant role to play (Antipova & Curtis, 2015; Currie & Rossin-Slater, 2013; Harville et al., 2009; Harville, Xiong et al., 2010; Simeonova, 2011; Zahran et al., 2013). This prenatal stress induced by natural disasters is associated with adverse maternal and infant health consequences, which include maternal PTSD (Harville et al., 2009; Harville et al., 2010; Lipkind, Curry, Huynh, Thorpe, & Matte, 2010; Xiong et al., 2008; Xiong et al., 2010); eclampsia (Tong, Zotti, & Hsia, 2011); premature rupture of membranes (Oyarzo et al., 2012; Sekizuka et al., 2010); spontaneous abortions and premature labor (Zahran et al., 2010; Zahran et al. , 2013); low birth weight (Harville et al., 2009; Oyarzo et al., 2012; Sherrieb & Norris, 2013; Simeonova, 2011; Tong et al., 2011; Torche, 2011); preterm birth (Antipova & Curtis, 2015; Harville et al., 2009; Oyarzo et al., 2012; Sherrieb & Norris, 2013; Torche & Kleinhaus, 2012; Xiong et al., 2008); and intrauterine growth retardation or small for gestational age (Oyarzo et al., 2012; Simeonova, 2011; Torche & Kleinhaus, 2012).

Though research among pregnant women has associated weather disasters to unfavorable pregnancy outcomes, there is a dearth of evidence on the influence of hurricanes on infant mortality (Kanter, 2010; Zahran et al., 2014; Zahran et al., 2013), leaving a gap in the literature. In addition, to the best of my awareness, systematic knowledge on the impact of tornado disasters on pregnancy outcomes is lacking as evidenced by a recent review of available research. As the frequency and intensity of hurricane and tornado disasters increase along coastal and inland segments of the United States, pregnancy places women at higher risk-levels for maternal and infant health complications from these disasters (Zahran et al., 2010; Zotti et al., 2013). Correspondingly, low birth weight and preterm birth are substantial indicators of a community's health (Hamilton, Sutton, Mathews, Martin, & Ventura, 2009; Hillemeier, Weisman, Chase, & Dyer, 2007; Nkansah-Amankra, Luchok, Hussey, Watkins, & Liu, 2010). Therefore a retrospective, cross-sectional cohort study utilizing county-level linked birth and infant death data in the United States is needed to capture variations in birth outcomes and to provide discernment on potential risk factors which may contribute to infant mortality among women giving birth after a hurricane or tornado disaster (Buekens et al., 2006; Callaghan et al., 2007; Kanter, 2010; Zahran et al., 2010).

Accordingly, the purpose of this investigation was to examine the relationship between maternal prenatal exposure to a hurricane and tornado disaster, on pregnancy outcomes and the mode of delivery.

Purpose of Study

The purpose of this quantitative, retrospective, cross-sectional population based cohort study was to examine the association between maternal prenatal exposure to a hurricane and tornado disaster, on the mode of delivery and pregnancy outcomes, like birth weight, preterm birth, and infant mortality. Maternal characteristics, including sociodemographic factors, health behaviors, pregnancy history, and maternal health status were also studied.

The dependent variables of interest in this investigation were birth weight, preterm birth, infant mortality, and mode of delivery. The primary independent variable of interest was maternal prenatal exposure to a hurricane or tornado disaster incident; and the covariates were sociodemographic factors, health behaviors, pregnancy history, and maternal health status.

Research Questions and Hypotheses

This investigation was guided and informed by the principal question proffered by this study: What is the impact of maternal prenatal exposure to hurricane or tornado disasters on adverse maternal and infant health outcomes? To address the research question, the following subquestions and hypotheses were tested by this investigation:

Research Question 1: Does maternal exposure to hurricane or tornado disasters influence preterm birth and low birth weight; controlling for sociodemographic factors, health behaviors, pregnancy history, and maternal health status?

$H_0 1$: Maternal exposure to hurricane or tornado disasters has no significant influence on preterm birth and low birth weight; controlling for sociodemographic factors, health behaviors, pregnancy history, and maternal health status.

$H_a 1$: Maternal exposure to hurricane or tornado disasters has a significant influence on preterm birth and low birth weight; controlling for sociodemographic factors, health behaviors, pregnancy history, and maternal health status.

Research Question 2: Does maternal exposure to hurricane or tornado disasters impact infant mortality; controlling for sociodemographic factors, health behaviors, pregnancy history, and maternal health status?

$H_0 2$: Maternal exposure to hurricane or tornado disasters has no significant impact on infant mortality; controlling for sociodemographic factors, health behaviors, pregnancy history, and maternal health status.

$H_1 2$: Maternal exposure to hurricane or tornado disasters has a significant impact on infant mortality; controlling for sociodemographic factors, health behaviors, pregnancy history, and maternal health status.

Research Question 3: Does maternal exposure to hurricane or tornado disasters influence mode of delivery; controlling for sociodemographic factors, health behaviors, pregnancy history, and maternal health status?

$H_0 3$: Maternal exposure to hurricane or tornado disasters has no significant influence on mode of delivery; controlling for sociodemographic factors, health behaviors, pregnancy history, and maternal health status.

$H_a 3$: Maternal exposure to hurricane or tornado disasters has a significant influence on mode of delivery; controlling for sociodemographic factors, health behaviors, pregnancy history, and maternal health status.

In this investigation, the dependent variables were birth weight, preterm birth, infant mortality and mode of delivery. These data are vital statistics figures reported by the department of health and measured in this study as dichotomous variables. The principal independent variable was maternal prenatal exposure to a hurricane or tornado disaster measured as a dichotomous variable and discerned from county-level data and corresponding evidence reported in the Spatial Hazard Event and Loss Database for the United States (SHELDUS); covariates were sociodemographic factors, health behaviors, pregnancy history, and maternal health status as recorded on the birth certificate and measured as categorical variables.

Theoretical Framework

The life course approach was the theoretical framework guiding this investigation, and provided the scaffold for comprehending the plausible implications of maternal prenatal exposure to hurricane and tornado disasters on adverse maternal and infant health outcomes. The life course perspective as a theoretical framework espouses a multidisciplinary approach and acknowledges conceptual pathways congruent with biological, social, and psychological perspectives; and purports that age, relationships, life transitions, culture, community, social issues, and social change influences an individual's life from birth to death (Ben-Shlomo & Kuh, 2002; Elder & Giele, 2009; Elder, Kirkpatrick, & Crosnoe, 2003; Giele & Elder, 1998). The model similarly considers influences such as mental and physical health, well-being, poverty, adequate diet and nourishment, and the physical environment as equal contributors, and posits circumstances confronted in life are influenced by prior experiences (Ben-Shlomo & Kuh, 2002; Elder et al., 2003; Lu & Halfon, 2003; Misra, Guyer, & Allston, 2003). Figure 1 illustrates the interaction and means by which biological, behavioral, social, and environmental factors may have a concomitant effect on maternal and infant health outcomes. In this study, the life course model was adapted to examine how maternal prenatal exposure to an acute stressor like a hurricane or tornado natural disaster incident, in conjunction with sociodemographic factors such as health behaviors, pregnancy history, and maternal health status may influence maternal and infant health outcomes.

The life course perspective integrates the fetal origins or early programming concept, connecting adverse exposure experiences in utero to chronic disease risks and poor health outcomes later in life (Barker, 2004; Ben-Shlomo & Kuh, 2002). The model equally suggests the potential causal pathways underwriting poor birth outcomes may be characterized according to diverse experiences across the various stages of the life course, and these influences can individually, incrementally, and interactively impact health and disease conditions later in life (Ben-Shlomo & Kuh, 2002; Elder et al., 2003; Lu & Halfon, 2003; Misra et al., 2003). Biological credibility has added credence to the theory of previous experiences influencing future birth outcomes, as previous animal and human research has established an affiliation between perinatal stress, and a predisposition to prodigious stress reactivity later in life (Lu & Halfon, 2003; Lu, Kotelchuck, Hogan, Jones, Wright, & Halfon, 2010).

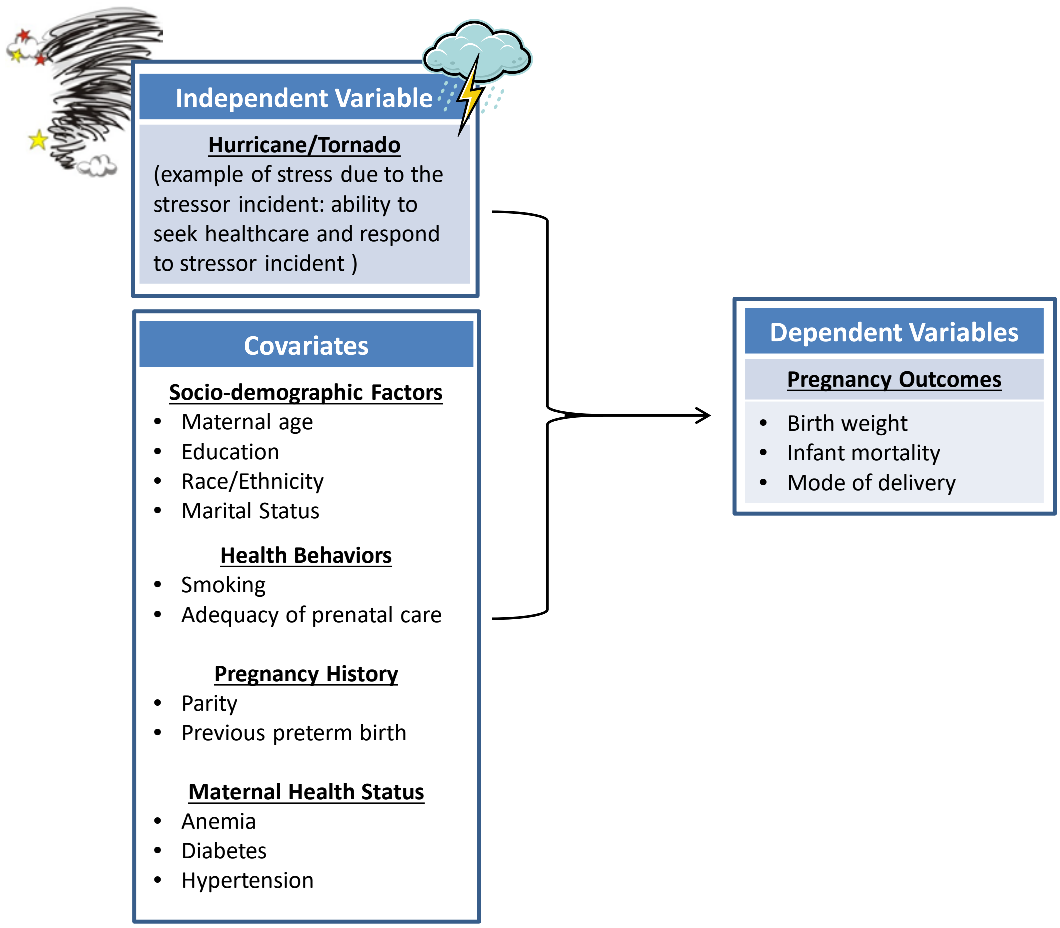

Figure 1. Life course perspective approach theoretical framework.

Moreover, researchers have provided evidence showing that prenatal stress is associated with early life factors such as fetal programming and has substantial neurobiological influences on the developing fetus (Talge, Neal, & Glover, 2007; Wadhwa, 2005; Wadhwa et al., 2011).

The life course approach considers the contribution, influences, and associations of early life factors, developmental experiences, and later experiences over the life span

(Ben-Shlomo & Kuh, 2002; Elder et al., 2003; Lu & Halfon, 2003; Lu et al., 2010). It incorporates biological and social risk factors to facilitate understanding of the possible concomitant effects of maternal prenatal exposure to natural disasters on maternal and infant health outcomes (Ben-Shlomo & Kuh, 2002; Elder et al., 2003; Lu & Halfon, 2003; Lu et al., 2010). The general aim of this research was to examine the effects of maternal prenatal exposure to a hurricane and tornado disaster on pregnancy outcomes to include preterm births, low birth weight, infant mortality, and mode of delivery. Accordingly, the life course as a theoretical model was appropriate to this investigation as it codifies pathways associating exposures during certain periods of time in the life course such as gestation, with health outcomes later in life (Ben-Shlomo & Kuh, 2002). Chapter 2 provides a meticulous elucidation of the life course perspective and its application as the theoretical framework in this investigation.

Nature of the Study

Hurricanes and tornadoes were the exposure variables of interest in this investigation as they both comprise natural disaster storms which impact the United States annually, with vigorous rotating winds and significant potential to engender substantial morbidity, mortality, and property damage. The research method and design for this investigation was a quantitative, retrospective, cross-sectional, cohort with a population-based secondary data analysis of birth outcomes utilizing county-level linked birth and infant death files. This research approach was applicable to this inquiry as the retrospective, cross-sectional design facilitated an analysis of the relationship between maternal prenatal exposure to a hurricane and tornado disaster and birth outcomes, with evidence reported by the state department of health in the linked birth and infant death data. Moreover, it is consistent with Dodds and Nuehring's (1996) cross-sectional, cohort design for retrospective examination of exposure status and possible post disaster outcomes among comparison groups. A retrospective, cross-sectional, cohort design is the most adequate approach to this investigation as it is unethical, inhumane, and illegal to deliberately subject participants to the investigational and control conditions necessary for this study in a true experimental design. Correspondingly, a quantitative method is appropriate to this study as the research questions mandate a quantitative response to statistically explain associations between the variables of interest, and to enable analysis of exposures and probable outcomes amongst a cohort of pregnant women and impute inferences to larger populations.

An aim of this investigation was to examine the correlation between the independent variable of interest, maternal prenatal exposure to a hurricane disaster with the dependent variable of interest pregnancy outcomes, controlling for sociodemographic factors, health behaviors, pregnancy history, and maternal health status. A second aim of this study was to examine the association between maternal prenatal exposure to a tornado disaster and pregnancy outcomes, equally controlling for the covariates sociodemographic factors, health behaviors, pregnancy history, and maternal health status.

To realize these aims, the primary independent variables of interest, maternal prenatal exposure to a hurricane or tornado disaster was determined by comparing and reconciling SHELDUS data reflecting specific disaster time periods and county locations of interest, which were impacted by a hurricane or tornado, with residence data obtained from the county-level linked birth and infant death files. In this study, data from the linked birth and infant death files of a cohort of pregnant women were exploited to appropriately test exposures and probable outcomes, and characterize prevalence and health status in the population of interest. The population sample was stratified by impacted counties and a predisaster period, established as a 12-month point of reference before the disaster; and a disaster/postdisaster period, which was characterized as the date of the disaster impact and a 12-month period after the disaster. For Hurricane Katrina, which impacted Mississippi, on 29 August 2005 the predisaster period was established as 1 July 2004 to 31 July 2005, and the sample included pregnant women with residence in the counties of Hancock, Harrison, Jackson, and Jones, Mississippi. The disaster/postdisaster period was defined as 1 August 2005 to 31 August 2006. The predisaster period for the 27-28 April 2011 Alabama tornado disaster incident was established as 1 March 2010 to 31 March 2011, and the population sample was comprised of pregnant women with residence in the counties of Calhoun, DeKalb, Franklin, Jefferson, Lawrence, Limestone, Madison, Marion, St. Clair, and Tuscaloosa, Alabama. The disaster/postdisaster period was defined as 1 April 2011 to 31 April 2012. Covariate data was captured from the birth certificate and recorded as categorical variables. Data for the dependent variables were obtained from the linked birth and infant death data as reported by the state department of health, and coded for this study as dichotomous variables.

Descriptive and inferential statistics were used to exploit the data. Descriptive statistics were employed to characterize the sample population. Inferential statistics were used to identify associations among the variables of interest and ascribe inferences to a larger population as appropriate. Chapter 3 provides greater fidelity of information on the study sample, and the methods of data collection and analysis delineated in this investigation.

Definitions

The definition of essential terms and key concepts utilized in this study are provided in this section. The dependent variables in this investigation were birth weight, preterm birth, infant mortality, and mode of delivery; whereas the independent variables were maternal prenatal exposure to a hurricane and tornado disaster, and the covariates of interest: sociodemographic factors, health behaviors, pregnancy history, and maternal health status. The descriptions and connotations of the dependent variables, independent variables, and operational terms are enumerated as follows:

Birth weight: Birth weight is characterized as the weight of an infant at the period of birth, and measured in either pounds and ounces, or grams. In this investigation, birth weight was denoted as the infant's weight reported in grams according to the certificate of live birth (NCHS, 2012).

Enhanced Fujita Scale (EF Scale): A rating scheme used in the United States to estimate, classify, and report on the intensity of tornadoes according to the degree of destruction associated with various damage indicators like vegetation and different types of structures. The EF Scale utilizes six categories from 0 to 5, to represent the degrees of damage and characterize a tornado's intensity (Schmidlin, 2013).

Health behaviors: In this study, health behaviors are those activities which sustain good health or adversely influence well-being, and include considerations for adequacy of prenatal care, and life-style factors such as the use of tobacco during pregnancy (Coreil, 2010).

Hurricane: A powerful low-pressure weather system or tropical cyclone, birthed in the warm bodies of water of the North Atlantic, Caribbean, Gulf of Mexico, west coast of Mexico, and the eastern North Pacific, with a distinct circulation and maximum sustained winds of 74 miles per hour or greater (Done, 2011; Klein & Shih, 2010; Korty, 2013).

Infant mortality: Infant death occurring before the attainment of the infant's first birthday (CDC, 2014).

Low birth weight: Infant weight at birth less than 2,500 grams (WHO, 2011).

Maternal health status: In this study, maternal health status was defined as any illness and disease conditions like anemia, diabetes, and hypertension experienced by the birth mother during the perinatal period (NCHS, 2012; Osterman, Martin, Mathews, & Hamilton, 2011).

Mode of delivery: Mode of delivery or method of delivery is the physical process by which delivery of a complete fetus is originated, and is classified as either a vaginal delivery or cesarean section (NCHS, 2012).

Pregnancy history: The obstetrical account of the number of pregnancies attributed to the birth mother (NCHS, 2012). For this study pregnancy history was delimited to the number of live births of viable offspring, and previous preterm births.

Preterm birth: Birth of an infant before the full 37 weeks of gestation (CDC, 2013).

Saffir–Simpson Hurricane Intensity Scale: A system of estimating, classifying, and reporting on the dangers and damage potential from tropical cyclone hurricanes of the North Atlantic, Caribbean, Gulf of Mexico, west coast of Mexico, and the eastern North Pacific, according to five distinctive categories of sustained wind intensity (Kelman, 2013).

Sociodemographic factors: The consideration of social and demographic characteristics of a population, like maternal age; marital status; race or ethnicity; and socioeconomic status as defined by educational level achieved (Osterman et al., 2011). In this investigation, socio-demographic factors included maternal age (age of the mother giving birth); marital status (married or unmarried status of the birth mother); maternal race or ethnicity (as defined by birth certificate data such as White, African American, American Indian; or Hispanic or Latino), and socioeconomic status (maternal education level realized as provided in the nativity data).

Tornado: An intense mobile destructive zone of violently rotating columns of winds with ground contact, either suspended from the body of a concentrated cloud mass or situated beneath a cloud form, and may be visible as a distinctive funnel cloud (Bluestein, 2013; Wallace, 2010).

Assumptions

A number of assumptions were considered and applied in the conduct of this investigation. The suppositions were required to provide context to the variables of interest, and help explicate conditions within the investigation to facilitate discernment of the study's validity. As secondary data of linked nativity and infant death files, and hurricane and tornado disaster incidence, their intensities, and associated damages were examined in this study, it is imperative to consider assumptions relative to the representativeness and quality of the available data.

First, it is noteworthy to highlight this investigation was predicated on the principal supposition portending stress concomitant with exposure to a hurricane or tornado natural disaster has a deleterious influence on birth outcomes. As hurricanes and tornadoes have great potential for much devastation and poses a significant threat to life and property, it was assumed Hurricane Katrina and the 2011 Alabama tornadoes were catastrophic, injurious, and disruptive to communities; thus triggering general stress among residents. Moreover, consistent with the fetal origins hypothesis, it is believed in utero exposure to a hurricane or tornado disaster engenders a much more intense adverse shock experience than postpartum exposure. Accordingly, it was assumed developing fetuses of mothers exposed to a hurricane or tornado disaster experience more stress-induced disruptions and a potentially greater sub optimal intrauterine environment than the fetuses of cohorts who do not have a maternal prenatal exposure experience.

Second, it was assumed the county of residence information provided in the nativity records is the area wherein the birth mother resided throughout the prenatal period. Accordingly, with the delimitation of maternal prenatal exposure to Hurricane Katrina and the 27-28 April 2011, Alabama tornado disaster, it was assumed that the birth mother did not evacuate prior to the storm's impact; and geographical presence and spatial track of the storms are related to disaster proximity and experience. Third, it was assumed comparison cohorts in this analysis do not have a maternal prenatal exposure experience to a natural disaster related incident during the period of gestation. Fourth, it was expected for the data collected and reported by the departments of health and analyzed in this study to be complete, of a high quality, entered into the appropriate databases accurately, and considered reliable as the information is not collected primarily for this investigation. Fifth, it was presumed the data set of live births will provide a full representation of live singleton births to the population of pregnant county residents delivering babies during the period of 2002 through 2012, in the aforementioned designated counties of Alabama and Mississippi. Sixth, it was assumed the data reported in the SHELDUS database closely represents the incidences of hurricane and tornado disasters and the effects ascribed to the impacted counties for the time period queried, with consideration given to the probability of underreporting of damage outcomes in some regions. Finally, it was also assumed the research design and methods grounding this study are the best promising implements and approaches to address the research questions in this investigation.

Scope and Delimitations

This investigation examined the association between maternal prenatal exposure to Hurricane Katrina on adverse maternal and infant health outcomes in Mississippi; and maternal prenatal exposure to the April 2011 tornado disaster on adverse maternal and infant health outcomes in Alabama; and provides acumen in understanding prospective risk factors which may contribute to infant mortality. The exposure variables and covariates in this investigation included maternal prenatal exposure to a hurricane and tornado disaster and maternal socio-demographic factors (age, education, race/ethnicity, and marital status), maternal health behaviors (smoking and adequacy of prenatal care), pregnancy history (parity and previous preterm birth), and maternal health status (anemia, diabetes, and hypertension). Birth weight, infant mortality, and mode of delivery were the explicit maternal and infant health outcomes of interest examined. The effects in this study will be of particular interest due to the dearth of primary investigations conducted on adverse maternal and infant health outcomes in U.S. counties vulnerable to recurring hurricane and tornado natural disaster hazards.

Delimitations of this investigation include the population of pregnant women most likely impacted by Hurricane Katrina in Mississippi; and the April 2011 Alabama tornado disaster. For Hurricane Katrina, the population was delimited to pregnant women residing in the counties of Hancock, Harrison, Jackson, and Jones, Mississippi, who experienced a live singleton birth which survived or was born and died between the periods of July 1, 2004 to August 31, 2006. For the April 2011 Alabama tornado disaster, the population was delimited to pregnant women residing in the counties of Calhoun, DeKalb, Franklin, Jefferson, Lawrence, Limestone, Madison, Marion, St. Clair, and Tuscaloosa, Alabama who were most likely affected by the April 2011 tornado disaster, and experienced a live singleton birth which survived or was born and died between the periods of March 1, 2010 to April 31, 2012. The data included in this investigation were restricted to information gathered from linked birth and infant death files, and SHELDUS information on hurricane and tornado disasters. As the study population was constrained to pregnant women and singleton infant births and deaths occurring in the aforementioned counties, generalization of the investigation's findings were not be projected beyond the states of Alabama and Mississippi. Alternatively, the approaches employed in this investigation may be applied in future studies to isolate evidentiary trends explicit to other jurisdictions and regions.

Limitations

The limitations of this investigation include the common concerns inherent with secondary data collected retrospectively from birth certificates, including missing and incomplete data, and the incapability to account for all the prospective confounding social and behavioral determinants of health, which may influence birth outcomes. To address the probable data veracity issues, the dataset was examined to verify and confirm incomplete and duplicate records were extracted before exploration of the data. This examination was limited to the standard data fields for U.S. birth certificate data available through the state department of health. To address prospective confounding issues, the study sample was delimited to singleton births, thus eliminating incidences of multiple births from the sample which are likely to influence and obscure interpretation of the results. In addition, statistical approaches to adjust for potential confounding factors in the analysis to include sociodemographic factors, health behaviors, pregnancy history, and maternal health status, were exploited in this study.

This investigation also had limitations in its design and measurement construct. As cross-sectional data were imputed to this study, the research questions in this investigation would not facilitate the direction of influence between the variables of interest or development of evidence for any conclusions and causal inferences between exposures and outcomes. To address this limitation in the investigation's design and measurement paradigm, correlations between the independent variables and the dependent variables were exclusively observed and exploited with the appropriate statistical analyses. No causation was attributed to the data, and the study's findings are reported as associations.

Since this study examined secondary data collected retrospectively, no biological influences and hormonal responses associated with prenatal maternal stress incidents were collected and measured in this investigation. To address this limitation, it was presumed, maternal prenatal exposure to a hurricane or tornado disaster incident prejudicially heighted anxiety and concern for safety, security, and social needs; and thus, triggered stressor responses with emotional and biological implications and hormonal alterations in mothers who experienced the disaster. This study was also limited in the precise isolation of subjects with maternal prenatal exposure to Hurricane Katrina and the 27-28 April 2011, Alabama tornado disaster, as there has been little consistency across studies in measurement approaches used to define maternal prenatal exposure retrospectively (Chan, Lowe, Weber, & Rhodes, 2015; Chan & Rhodes, 2014; Grabich, Horney, Konrad, & Lobdell, 2015). Moreover, the available collected county-level linked birth and infant death files and SHELDUS data, do not specifically identify pregnant women with hurricane or tornado exposure experiences; or with sustained injuries; loss of property, or displacement consequential to Hurricane Katrina or the 27-28 April 2011, Alabama tornado disaster. To mitigate this constraint, the calculation of exposure experiences was informed by the county of maternal residence information contained in the dataset, and spatial data related to the precise trajectory and specific geographical county-level, area of impact of Hurricane Katrina and the 27-28 April 2011, Alabama tornado disaster storms. Investigators examining disaster storms and pregnancy outcomes have previously exploited the spatial methods of storm trajectory to classify potential exposure incidents (Antipova & Curtis, 2015; Currie & Rossin-Slater, 2013; Simeonova, 2011; Zahran et al., 2010).

Set against these limitations are several essential factors which enhance and validate the strength of this study. First, the exploitation of birth certificate data provides certain remunerations as it is population based, and affords a well-established and indispensable foundation of evidence ordinarily used to detect and monitor health indicators in communities (Andrade et al., 2013; Martin, Wilson, Osterman, Saadi, Sutton, & Hamilton, 2013; Vinikoor, Messer, Laraia, & Kaufman, 2010). Accordingly, the data facilitates a county-level population based examination of the association between maternal prenatal exposure to hurricane and tornado disasters on adverse maternal and infant health outcomes amongst the population of interest. Second, birth certificate data is a stable source of cohort information and yields a large sample size for investigations (Andrade et al., 2013; Martin et al., 2013; Vinikoor et al., 2010). A large sample size enables more evidence to be collected and examined, and enhances the power and statistical significance of the findings of this investigation. Third, birth certificate data is a strategic source of evidence for detecting some maternal and infant health outcomes, and risk factors which may contribute to infant mortality (Andrade et al., 2013; Martin et al., 2013; Vinikoor et al., 2010). Finally, the utilization of linked birth and infant death registration files affords a comprehensive and fundamentally complete dataset with records on about 99% of all U.S. live births and infant deaths; and the linked data files are instrumental in facilitating time-based contrasts and evaluations of multiple disparate communities (Mathews & MacDorman, 2013; Schoendorf & Branum, 2006).

Significance of Study

Maternal prenatal exposure to natural disasters may contribute to an increased risk for infant mortality, and adversely affect healthy pregnancies, fetal development, and birth outcomes; and consequentially impose substantial social, emotional, health, and financial burden on families and communities (Currie & Rossin-Slater, 2013; Owen et al., 2013; Russell et al., 2007; Simeonova, 2011; Zahran et al., 2013; Zhang et al., 2013). Scientific evidence is needed to determine the influence of maternal prenatal exposure to natural disasters like hurricanes and tornadoes, on adverse pregnancy outcomes and help elucidate potential risk factors which may contribute to infant mortality (Buekens et al., 2006). Cummings, Browner, and Hulley (2013) suggested clinical research endeavors should pose a question which is noteworthy to the scientific community and public, has relevance and usefulness of its outcomes, and advances public health policy and current scientific knowledge. To accomplish these explicit measures, a significant question which is important to the scientific and public health and medical communities, and society at large, was articulated in this study; and the discourse of its outcomes could provide relevance and usefulness to advance public health policy and current scientific knowledge.

The discoveries from this study could make a contribution to the scientific community and public by providing evidence to: (a) advance the state of knowledge regarding the maternal and infant health consequences of maternal prenatal exposure to hurricane and tornado disasters, (b) help reduce and eliminate preventable exposures, and (c) help inform and educate pregnant women about the risks of maternal prenatal exposure, and enable them to initiate appropriate measures aimed at protecting their health and well-being and their unborn child. By examining the effects of maternal prenatal exposure to hurricane and tornado natural disasters on unfavorable pregnancy outcomes, discernments from this investigation can help the scientific community and public, by providing evidence of specific public health challenges to pregnant women and the developing fetus, who reside in areas prone to hurricane or tornado disasters. For localities with increased incidences of poor pregnancy outcomes, burdens of healthcare costs may be incurred by communities, as a result of caring for these infants during the birth period and continuing on throughout the life course of the individual (Halfon & Hochstein, 2002; Lu & Halfon, 2003; Owen et al., 2013; Russell et al., 2007; Zhang et al., 2013). Through the identification of risk factors which may contribute to adverse birth outcomes, social change could originate with public health and medical practitioners and policymakers establishing and implementing relevant public health strategies and programs to address and amend these undesirable impacts.

Moreover, the results from this study could similarly provide acumen in understanding the impacts of natural disaster-induced maternal stress concomitant with hurricane or tornado disasters, on pregnancy outcomes; and help enlighten and enable disaster preparedness efforts to meet the needs of maternal and neonatal populations. The findings of this investigation could also validate previous research on the impacts of hurricanes on poor birth outcomes, and add scholarship on the influence of tornado disasters on pregnancy outcomes. Discoveries from this investigation could perhaps help improve approaches to evaluating and measuring the effects of maternal stress on adverse pregnancy outcomes, such as infant mortality; and create an aperture for future research on the impact of exposure to maternal stress on the neonate in-utero, and across the life course. Correspondingly, the conclusion of this study may possibly make important contributions to public health and medical practitioners and policymakers. As a result of this investigation, public health and medical practitioners, and policymakers could be afforded insights to help inform their decision-making and advance the concept and implementation of funding and programs for maternal and infant health disaster preparedness, facilitating an improved readiness posture for vulnerable maternal and neonatal populations and their communities, to prepare for and respond to future hurricane and tornado natural disasters.

Acumens from this scholarship could similarly engender social change by inspiring and catalyzing development and implementation of appropriate disaster preparedness plans, programs, and social support systems essential to advancing maternal and infant disaster preparedness; and by addressing the specific social and public health preparedness needs of maternal and neonatal populations, prior to, during and after natural disaster situations. As a result, pregnant women, the developing fetus, and communities, may be much more prepared and perhaps less vulnerable to increased pregnancy risk factors and adverse birth outcomes consequential to hurricane and tornado disasters.

Summary

This chapter introduced the research which examined the effects of maternal prenatal exposure to hurricane and tornado disasters on pregnancy outcomes and mode of delivery, and provided background highlighting a lacuna in knowledge related to the focus of this investigation. A problem statement sustained by current literature is subsequently provided to frame the research problem and present evidence substantiating a relevant problem of interest undeniably exists, while equally addressing apparent gaps in the literature. This is then followed by a statement of purpose tersely describing the research model, the general aim of the study, the phenomenon and variables of interest; and the research questions and null and alternative research hypotheses guiding the investigation.

Next, the life course perspective theory is provided to describe and define the theoretical framework grounding this study, and explicate how coherent influences among strategic elements of the theoretical framework relate to the research model and research questions. This is followed by a concise description of the nature of the study articulating the description of the research design, variables of interest, an encapsulation of the research methodology; a definition of essential terms and key concepts; an enumeration of assumptions applied to the conduct of the investigation; and the scope and delimitations of the study elucidating the explicit boundaries of the research, and the potential generalization of the research findings. Limitations associated with the design, methodological weaknesses, potential confounding variables, measures to address the limitations, and strengths of the study are then described. The chapter concludes with a narrative justification of the significance of the study and inferences for informing and advancing public health knowledge, practices and policies, as well as prospective implications for positive social change.

The search strategy employed in the conduct of the review of the literature, and a comprehensive elucidation of the theoretical framework underpinning this study is described in Chapter 2. A review of relevant data from the body of available literature is also presented in the next chapter, including pertinent studies and information relating to hurricane and tornado natural disasters, pregnancy outcomes to include birth weight and preterm birth, major risk factors for infant mortality, the influence of hurricane and tornado disasters on pregnancy outcomes, and prenatal maternal stress and birth outcomes.

Chapter 2: Literature Review

Introduction

This chapter describes the examination of the current body of literature on the effects of maternal prenatal exposure to hurricane and tornado disasters on pregnancy outcomes. The exploration of the body of available evidence was based on published information relevant to hurricanes and tornadoes, and the influence of natural disasters on maternal and infant health outcomes. The review of the literature section is organized into three discrete segments. The first subdivision of the chapter provides an elucidation on the literature search strategy. It is followed by the second segment, which encompasses a description of the theoretical framework, the life course perspective. The life course perspective theory provides the theoretical contours for this empirical investigation, and is the cornerstone to understanding the possible associations of maternal prenatal exposure to hurricane and tornado disasters on adverse maternal and infant health outcomes. The third and final segment of the chapter describes the review of the relevant literature with specific attention given to hurricanes and tornadoes, key concepts related to the variables of interest in this study, a review of the pertinent literature regarding natural disasters and maternal and infant health outcomes, and a concluding summary of the chapter and transition to Chapter 3.

A few investigators have provided evidence showing natural disaster storms like hurricanes, can have an austere and devastating consequence on affected communities and populations, in particular pregnant women and the unborn child (Antipova & Curtis, 2015; Currie & Rossin-Slater, 2013; Sastry & Gregory, 2013; Simeonova, 2011; Zahran et al., 2013; Zahran et al., 2014). This evidence has imputed various detrimental effects including low birth weight, preterm birth, spontaneous abortions, premature labor, fetal distress, maternal distress and post-traumatic stress disorder with these natural disaster storms (Antipova & Curtis, 2015; Currie & Rossin-Slater, 2013; King & Laplante, 2015; Simeonova, 2011; Zahran et al., 2014; Zahran et al., 2013). Although emerging evidence from research investigators have suggested there is a correlation between natural disasters and adverse pregnancy outcomes, the current literature does address a need to further examine the effects of maternal prenatal exposure to natural disasters on maternal and infant health outcomes including infant mortality and mode of delivery (Buekens et al., 2006; Currie & Rossin-Slater, 2013; Hamilton et al., 2009; Harville, Tran, Xiong, & Buekens, 2010; Kanter, 2010; Zahran et al., 2014; Zahran et al., 2013). Given the recent frequency, intensity, and detrimental effects of weather related natural disasters in the United States over the past few years--both in human toll and property damages, examining the impact of these cyclonic natural disaster incidents on maternal and infant health is imperative and essential (Zahran et al., 2013; Zotti et al., 2012).

Gaps in the existing literature include only a few studies address maternal prenatal exposure to hurricanes and maternal and infant health outcomes; and there is a lacunae on the influence of hurricanes on infant mortality, and the effects of tornadoes on maternal and infant health outcomes (Buekens et al., 2006; Kanter, 2010; Zahran et al., 2014; Zahran et al., 2013). As a result, this investigation could contribute to the body of the public health and medical literature by investigating the effects of maternal prenatal exposure to a hurricane and tornado disaster on pregnancy outcomes and mode of delivery.

Literature Search Strategy

A systematic review of primary source published reports identified pertinent articles related to natural disasters and maternal and infant health outcomes, as summarized in Table 2. A medical subject headings (MeSH) search in PubMed—a U.S. National Institute of Health database which offers access to and catalogs all MEDLINE records and abstracts was used to identify relevant medical articles. Similarly, the key word search functionality was imputed to the CINAHL (Cumulative Index to Nursing and Allied Health), Scopus, Embase, Springer Link, Google, and Google Scholar databases to examine the body of available literature on the research topic. The Boolean search function was exploited to facilitate navigation of the constellation of information and rapid identification of pertinent articles from primary sources. The Boolean operator 'AND' was used to broaden the database searches by linking word phrases from the search category and search terms, so the phrase relationship is strengthen and the search expanded (see Table 2).

Table 2

Key Terms Search Strategy

Search type	Databases	Search category	Search terms
MeSH	PubMed (Medline)	Cyclonic storms	Hurricanes; cyclone; tropical cyclone; tropical storm
MeSH		Natural disaster	Disaster; emergencies; mass casualty incidents; disaster victims
MeSH		Tornado	Tornadoes
MeSH		Birth weight	Extremely low birth weight; low birth weight; low birth weight infant; very low birth weight; very low birth weight infant
MeSH		Infant mortality	Infant mortality
MeSH		Infant welfare	Infant health
MeSH		Maternal welfare	Maternal health
MeSH		Premature birth	Preterm premature rupture of fetal membranes; preterm infants; preterm birth; premature birth
MeSH		Pregnancy complications	Spontaneous abortion; fetal death; maternal death; obstetric labor complications; perinatal death
MeSH		Pregnancy outcome	Pregnancy outcomes
Key Words	CINAHL (Cumulative Index to Nursing and Allied Health); Scopus; Embase; Springer Link; Google; and Google Scholar	Natural disaster	Natural disasters; hurricanes; cyclone; tropical cyclone; tropical storm; tornado; cyclonic storms; extreme weather events; weather cyclones; catastrophic events
Key Words		Pregnancy outcome	Adverse birth outcomes; birth outcomes; birth weight; low birth weight; preterm birth; premature birth; fetal outcomes; fetal growth restriction; infant mortality; poor pregnancy outcomes; maternal and infant health; maternal morbidity; maternal stress; pregnancy outcome; pregnancy complications; reproductive health outcomes

During the initial review phase, article titles were scanned for relevance and appropriateness. The abstracts of articles which appeared relevant were analyzed to determine their suitability. The full texts of relevant abstracts were subsequently examined for prospective data extraction. Articles were deemed eligible, if they were an original empirical study, published in a peer-reviewed journal within the last 10 years, and written in the English language. Reports identified as review articles and commentaries were considered if they were peer-reviewed, specifically addressed the research topic, and meet the publication time period constraints. A modicum of articles with a publication date older than 2005, are included in this literature review. These literature sources serve as a citation source for definitions, and they provide seminal and historical context. In addition, specific websites from authoritative sources in the health and meteorological domains are included as citation sources. A secondary review of citations published in primary source literature documents initially extracted for analysis, were also scanned and selected for inclusion in the review, if they were relevant to the research topic. Full-text articles and textbook chapters which were unfeasible to acquire through immediate download from the databases and internet websites, or required a paid subscription, were obtained via the Walden University library's document delivery service.

Theoretical Foundation

The life course perspective is an interdisciplinary population-based approach for analyzing associations of health trajectories and disease risk of exposure experiences on health outcomes across time--like during the periods of gestation, infancy, puberty, young adulthood, and outcomes in later life (Elder & Giele, 2009; Elder et al., 2003; Giele & Elder, 1998). The life course approach provides a theoretical framework to guide scientific inquiry on health, human development, and aging, exploiting philosophies and observations from diverse disciplines including history, social demography, anthropology, psychology, biology, and sociology as the cornerstone discipline (Elder & Giele, 2009; Elder et al., 2003; Giele & Elder, 1998). The genesis of this theoretical and analytical approach is rooted in the ground-breaking social research studies by William

Isaac Thomas and Florian Znaniecki regarding the migration of Polish immigrants to Europe and America; and Samuel Stouffer and colleagues, on the lived experiences of American service members assigned to racially integrated military units during World War II (Elder & Giele, 2009; Elder et al., 2003; Giele & Elder, 1998). The advent of the life course approach can equally be traced to assertions by William Isaac Thomas in the 1920s, declaring the need for approaches to better examine and comprehend human experiences across time and place (Elder & Giele, 2009; Elder et al., 2003; Giele & Elder, 1998).

Influenced by the theoretical underpinnings of longitudinal studies, and a desire to fathom and capture the breadth and dimensions of human lives over time, Dr. Glen Elder fashioned and advanced the life course theory (Elder, 1998; Elder & Giele, 2009; Elder et al., 2003). His early 1960s pioneering research at the Berkeley Institute of Human Development, on American children in the Great Recession, was the watershed for the construct and emergence of the life course approach (Elder, 1998; Elder & Giele, 2009; Elder et al., 2003). Five key conceptual principles characterize Elder's life course perspective: (a) Human development and aging is temporal over the life course (concept of timeline), (b) historical and social circumstance governed by individual choices and engagements, influence the life course of individuals (concept of equity), (c) experiences shaped by physical location and historical times impact the life course (concept of environment), (d) the impact of age-related transitions are variable and contingent upon when it occurs in an individual's life (concept of timing); and (e) lives are linked and embodied through inter-personal and shared networks, which influence individual social outcomes (concept of environment; Elder et al., 2003).

Over the years, the life course approach has matured and emerged to help inform awareness and acumen of associations between exposures and outcomes (Ben-Shlomo & Kuh, 2002; Elder et al., 2003). Two wide-ranging conceptual approaches, the *cumulative pathway* and *early programming*, are advanced in the life course perspective theory (Halfon & Hochstein, 2002; Lu & Halfon, 2003). The cumulative pathway concept hypothesizes enduring stress exposure engenders aggregate weathering effects on the body's regulatory system, perpetrating conditions for a chemical imbalance known as allostatic load (Halfon & Hochstein, 2002). Alternatively, the early programming approach postulates stress exposures during a critical period of early human development can adversely impact the structure and functions of cells, organs, and body systems, and subsequently manifest in health risks and disease conditions (Halfon & Hochstein, 2002; Lu & Halfon, 2003).

The early programming concept advances theoretical considerations regarding maternal prenatal exposure influences like stressor incidents during critical periods of gestation; and underpins the early programing and developmental origins of disease premise posited by Barker (2004). Moreover, the early programming concept has been exploited as a research model by several investigators, to examine the associations of maternal prenatal exposure to natural disasters on birth and developmental outcomes (Currie & Rossin-Slater, 2013; Fuller, 2014; Simeonova, 2011; Zahran et al., 2014; Zahran et al., 2013). Currie and Rossin-Slater (2013), and Simeonova (2011) utilized the early programming concept to proffer inferences and elucidate correlations between hurricanes and low birth weight, and preterm births; and Fuller (2014) applied the model to help elucidate the relationship between prenatal disaster exposure to hurricanes, winter storms, and extreme weather storms linked with flooding and tornadoes to educational outcomes. Zahran et al. (2014) also imputed the early programming model to investigate the effects of maternal prenatal exposure to hurricanes on fetal deaths; and Zahran, Peek, Snodgrass, Weiler, and Hempel (2013) employed the model to examine and interpret the incidence of spontaneous abortions, premature labor, high rates of cesarean deliveries, and fetal distress among pregnant women exposed to hurricanes. The life course perspective theory recognizes influences and correlations between programming, early developmental experiences, as well as latent experiences over the life span, and provides the essential structure to examine the associations of natural disaster stressors during critical periods of gestation on adverse maternal and infant health outcomes (Ben-Shlomo & Kuh, 2002; Elder et al., 2003; Halfon & Hochstein, 2002; Halfon, Larson, Lu, Tullis, & Russ, 2014; Lu, 2014; Lu & Halfon, 2003; Lu et al., 2010).

The life course perspective is a valid and germane approach to this investigation as it provides the structure and analytical framework to facilitate comprehension and discernment of plausible inferences correlating exposure experiences and environmental influences during critical or sensitive periods of time in the life course (including in utero), to health trajectories later in life (Ben-Shlomo & Kuh, 2002). The life course approach could provide occasion to consider certain biological, behavioral, social, and environmental factors which may synergistically influence maternal and infant health outcomes. The general intent of this research was to examine the effects of maternal prenatal exposure to a hurricane and tornado disaster on pregnancy outcomes, including mode of delivery. By exploiting the life course perspective as this investigation's principal theoretical and analytical framework, discoveries from this study could be used to support policies and programs aimed at enabling social change to advance hurricane and tornado disaster preparedness among vulnerable maternal and neonatal populations, and mitigate risk factors and improve pregnancy outcomes.

Hurricane and Tornado Natural Disasters

Hurricanes and tornadoes are natural disaster incidents, which pose a dynamic and prominent threat to the health and welfare of individuals and communities (Klein & Shih, 2010; Sastry & Gregory, 2013). These natural disaster storms recurrently strike the United States with disconcerting frequency, and have enormous potential to perpetrate a substantial public health burden on impacted populations; compromise the capacity and delivery of local health and human services; and cause intense social, economic, and psychological effects in their wake (Bourque, Siegel, Kano, & Wood, 2006; Klein & Shih, 2010; Sastry & Gregory, 2013; Wallace, 2010; Zotti et al., 2012). Similar to other natural disasters, the adverse effects of these storms are characteristically measured according to direct effects such as loss of life and economic losses calculated as estimates in dollar value of property damaged or destroyed (Lazzaroni & van Bergeijk, 2014). However, these assessments classically do not consider the indirect effects of hurricane or tornado disasters, like illnesses concomitant with environmental alterations; population displacement; and disruption of social systems and services, including psychological effects such as fear, anxiety, stress, and PTSD (Bourque et al., 2006; Greenough et al., 2001).

Notwithstanding its established direct effects, hurricane and tornado natural disasters also impute indirect adverse health effects like stress; anxiety; fear; and PTSD on impacted populations (Bourque et al., 2006; Klein & Shih, 2010; Reissman et al., 2010; Sastry & Gregory, 2013; Simeonova, 2011; Wallace, 2010; Xiong et al., 2010); and pregnant women may be particularly vulnerable (Harville, Xiong et al., 2009; Harville et al., 2010). As hurricane and tornado natural disasters are known to engender indirect adverse health effects such as stress, anxiety, fear, and PTSD--and pregnant women may be especially sensitive; the indirect impacts of these storms on the developing fetus are equally disconcerting for adverse birth outcomes (Harville et al., 2009; Harville, Xiong et al., 2009; Harville et al., 2010; Simeonova, 2011; Xiong et al., 2008; Xiong, 2010; Zahran et al., 2014; Zahran et al., 2013).

Evidence suggests adverse exposure experiences in utero to natural disaster storms like hurricanes, are predictive of adverse birth and developmental outcomes, and may impact fetal development during critical or sensitive periods of gestation (Currie & Rossin-Slater, 2013; Fuller, 2014; Harville et al., 2009; Simeonova, 2011; Zahran et al., 2014; Zahran et al., 2013; Zotti et al., 2012). Moreover, prenatal stress, anxiety, fear or depression may contribute to poor birth outcomes like low birth weight and preterm birth (Dunkel Schetter, 2011; Dunkel Schetter & Tanner, 2012; Kramer et al., 2009). The indirect adverse health effects of hurricane and tornado natural disasters, although not easily measured, are serious and pervasive (Greenough et al., 2001). Whereas hurricanes and tornadoes are cyclonic atmospheric storms with acute onsets and have certain fundamental resemblances, they are dissimilar in their major characteristics and points of origin (Klein & Shih, 2010; Wallace, 2010).

Hurricanes

Hurricanes are a weather-related phenomenon nurtured purely in oceanic waters, and could have a durational life spanning two weeks or greater, throughout their maturation and periods of navigation in warm oceans (Klein & Shih, 2010). These powerful cyclonical rotating low-pressure weather systems are born as tropical cyclones in the warm waters of the North Atlantic, the Caribbean, Gulf of Mexico, west coast of Mexico, and the eastern North Pacific (Done, 2011; Klein & Shih, 2010; Korty, 2013). Hurricanes and typhoons (cyclonic storms in the Northwest Pacific) are among the family of tropical cyclones in the Northern Hemisphere which rotate in a counterclockwise motion (Done, 2011; Klein & Shih, 2010; Korty, 2013). Tropical cyclones occurring in the Southern Hemisphere rotate clockwise and are classified as cyclones in the Indian Ocean and South Pacific (Done, 2011; Klein & Shih, 2010; Korty, 2013).

The center of a hurricane, known as the *eye* is reputed to maintain a lucid and moderately calm domain, typically covering about 20 to 40 miles diagonally; but may be larger or smaller contingent upon the construct of a storm (NOAA NWS, 2010). The eye wall encapsulates the eye of the hurricane as it contains a profuse partition of intense thunderstorms with potent winds and substantial rains (Korty, 2013; NOAA NWS, 2010). Alterations in the contours of the hurricane’s eye and eye wall could trigger variations in a hurricane’s wind speed and strength (Korty, 2013; NOAA NWS, 2010). A dense arm of clouds and thunderstorms surrounds the eye wall and produces the characteristic large swathe of spiraling counterclockwise rainbands, unique to hurricanes (Korty, 2013; NOAA NWS, 2010). The spiral rainbands can extend in range from a few miles to several hundred miles from the eye of a hurricane, and are capable of generating considerable downpours of rain and wind gusts (Korty, 2013; NOAA NWS, 2010). Hurricanes could range in size from a few tens of kilometers to about two thousand kilometers in diameter (Chavas & Emanuel, 2010).

The U.S. Gulf and Atlantic coasts are particularly vulnerable to hurricanes during the peak period of their formation (from August to October), during the official annual hurricane season occurring from 1 June through 30 November (Klein & Shih, 2010; Korty, 2013; Malmstadt, Elsner, & Jagger, 2010; Trepanier, 2014). Researchers conducting retrospective studies examining historical hurricane trajectories for the U.S. Gulf and Atlantic coasts have reported that Florida, Louisiana, and North Carolina were more susceptible and experienced higher incidences of hurricanes, during the periods of 1851 to 2003 (Zandbergen, 2009), and 1949 to 2006 (Changnon, 2008).

A hurricane's strength is the harbinger of the destruction and injury the storm may perpetrate, and its intensity and damage potential is measured on the Saffir-Simpson Hurricane Wind Scale (Klein & Shih, 2010; Korty, 2013; NOAA NWS NHC, 2013). Table 3 shows the Saffir-Simpson Hurricane Wind Scale categories, associated sustained wind speeds, and the potential damages concomitant with hurricane force winds. Whereas a hurricane's classification is based upon the force and power of the winds, it is imperative to recognize these variables do not consistently describe the scope and accretion of damage and harm a storm may impose (Klein & Shih, 2010). Hurricanes frequently engender extensive damages; losses; and injuries due to strong winds, associated storm surges, torrential rains and flooding; and on occasion, tornadoes (Klein & Shih, 2010; Kunkel et al., 2010; Shepherd, Grundstein, & Mote, 2007).

Hurricane Katrina's impact on Mississippi. Hurricane Katrina was one of the most austere hurricanes to impact the northern U.S. Gulf Coast, since Hurricane Camille in 1969 (Graumann et al., 2006; Knabb, Rhome, & Brown, 2011). Whereas numerous researchers have focused attention and provided evidence of Hurricane Katrina's catastrophic impacts on the New Orleans metropolitan area and elsewhere in Louisiana; the storm also triggered numerous fatalities, and imposed an overwhelming amount of property damage in Mississippi (Graumann et al., 2006; Knabb et al., 2011).

Table 3

Saffir-Simpson Hurricane Wind Scale

Category	Sustained winds	Types of damage due to hurricane winds
1	74-95 mph 64-82 kt 119-153 km/h	**Very dangerous winds could produce some damage:** Well-constructed frame homes could have damage to roof, shingles, and vinyl siding and gutters. Large branches of trees could snap and shallowly rooted trees may be toppled. Extensive damage to power lines and poles may likely result in power outages, which could last several days.
2	96-110 mph 83-95 kt 154-177 km/h	**Extremely dangerous winds likely to cause extensive damage:** Well-constructed frame homes could sustain major roof and siding damage. Many shallowly rooted trees may be snapped or uprooted and block numerous roads. Near-total power loss could occur with outages which could last several days to weeks.
3 (Major)	111-129 mph 96-112 kt 178-208 km/h	**Devastating damage may occur:** Well-built framed homes may incur major damage or removal of roof decking and gable ends. Many trees may be snapped or uprooted, blocking numerous roads. Electricity and water may be unavailable for several days to weeks after the storm passes.
4 (Major)	130-156 mph 113-136 kt 209-251 km/h	**Catastrophic damage likely to occur:** Well-built framed homes could sustain severe damage with loss of most of the roof structure and/or some exterior walls. Most trees may be snapped or uprooted and power poles downed. Fallen trees and power poles could isolate residential areas. Power outages could last weeks to possibly months. Most of the area may be uninhabitable for weeks or months.
5 (Major)	157 mph or higher 137 kt or higher 252 km/h or higher	**Catastrophic damage expected to occur:** A high percentage of framed homes may be destroyed, with total roof failure and wall collapse. Fallen trees and power poles could isolate residential areas. Power outages may last for weeks to possibly months. Most of the area could be uninhabitable for weeks or months.

Note: From “Saffir-Simpson Hurricane Wind Scale,” by National Oceanic and Atmospheric Administration, National Weather Service, National Hurricane Center, 2013. Retrieved from http://www.nhc.noaa.gov/aboutsshws.php

Hurricane Katrina was an enormous hurricane, owning a radius of maximum sustained winds ranging from 25 to 30 nautical miles, and a wide band of hurricane force winds, which extended about 75 nautical miles to the east from the storm's eye wall (Graumann et al., 2006; Knabb et al., 2011). On 26 August 2005, Hurricane Katrina entered the Gulf of Mexico as a tropical storm, where it intensified to a category 5 hurricane (winds 160 to 175 mph), and mounted a northerly trajectory toward the northern segment of the Gulf (Graumann et al., 2006; Knabb et al., 2011). The storm weakened to a category 3 hurricane, with winds of about 125 to 127 mph; prior to its landfall in the northern Gulf, in Plaquemines Parish, around Buras, Louisiana on 29 August 2005 (Graumann et al., 2006; Knabb et al., 2011). During this landfall, Hurricane Katrina remained a colossal storm, with tropical storm force winds extending 200 nautical miles and hurricane force winds at 90 nautical miles from the storm's eye, respectively (Graumann et al., 2006; Knabb et al., 2011). Hurricane Katrina continued on a north northeast (NNE) path as it made a second Gulf Coast landfall as a category 3 hurricane (winds about 120 to 126 mph); on the northern Gulf, near the Pearl River, close to the Louisiana and Mississippi border (Graumann et al., 2006; Knabb et al., 2011). The storm's eye wall at this landfall contained penetrating winds with speeds at or near 121 mph (Graumann et al., 2006; Knabb et al., 2011).

Hurricane Katrina packed and maintained a large and turbulent wind field (see figure 2), with sustained wind effects encompassing segments of the Florida panhandle, and extended west to the Louisiana and Texas border (Graumann et al., 2006; Knabb et al., 2011). Because the storm reserved a potent right quadrant; substantial wind, rain, and storm surge damages were perpetrated on Mississippi (Graumann et al., 2006; Knabb et al., 2011). The storm deteriorated as it continued inland over Mississippi, and was downgraded to a category 1 hurricane, and then weakened to a tropical storm on the evening of 29 August 2005 (Graumann et al., 2006; Knabb et al., 2011). On 30 August 2005, the storm was significantly diminished, and was downgraded to a tropical depression as it approached Clarksville, Tennessee (Graumann et al., 2006; Knabb et al., 2011).

The aftershock of Hurricane Katrina was devastating, especially in the counties of Hancock, Harrison, Jackson and Jones, Mississippi; where Katrina wrought significant catastrophic and devastating effects, fatalities, and a sizeable displacement of the population (Graumann et al., 2006; Governor's Commission on Recovery, Rebuilding, and Renewal, 2005; Knabb et al., 2011). Within this region, damaging hurricane-force winds, rain induced flooding, and a storm surge of roughly 24 to 28 feet, affected the greatest number of residents and resulted in substantial destruction (Graumann et al., 2006; Governor's Commission on Recovery, Rebuilding, and Renewal, 2005; Knabb et al., 2011).

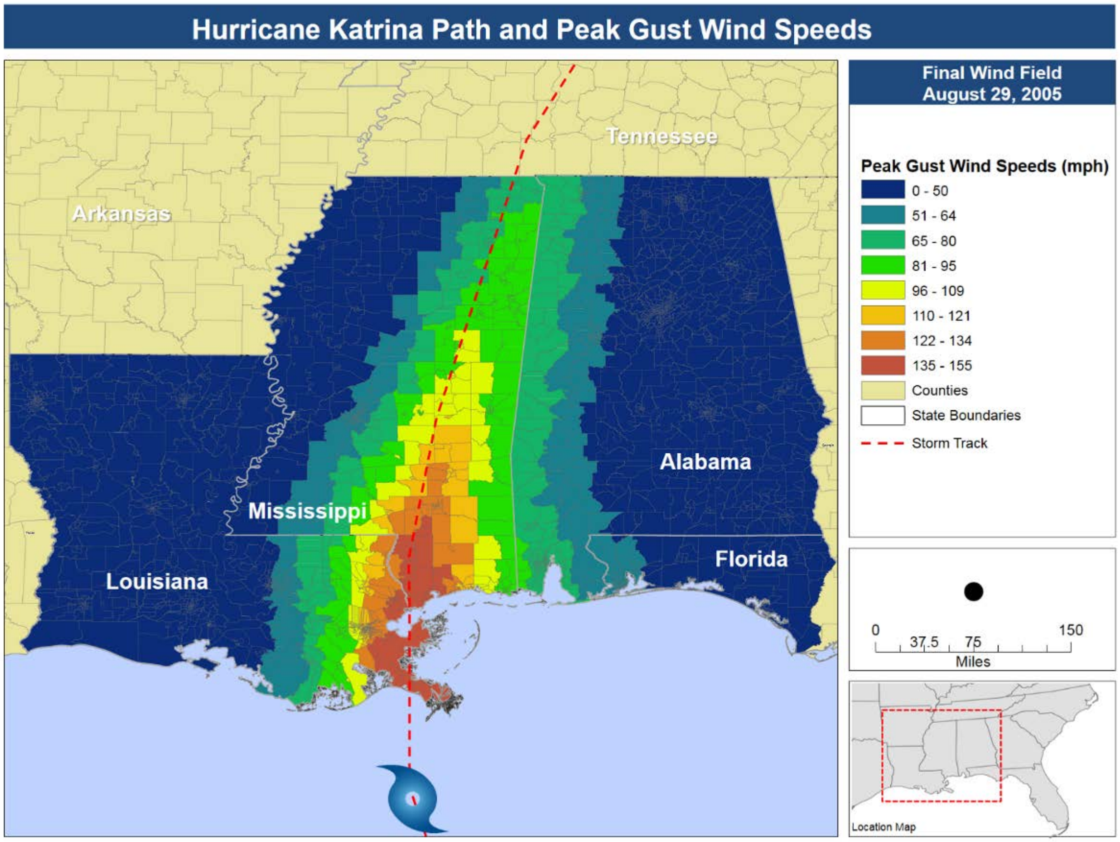

Figure 2. Path of Hurricane Katrina and wind field with peak gust wind speeds. From "Hazus-MH (Multi-hazard), Version 2.1 [Software application]," by Federal Emergency Management Agency, 2015, February 06. Retrieved from http://www.fema.gov/hazus-software#2

Furthermore, an estimated 230 to 238 individuals were killed and thousands more suffered serious injuries (Graumann et al., 2006; Governor's Commission on Recovery, Rebuilding, and Renewal, 2005; Knabb et al., 2011). Hundreds of thousands of Mississippi residents were displaced and homeless, requiring temporary housing in shelters, trailers, and mobile homes; nearly one million were without power; and water, sanitation, and community infrastructure and services—including healthcare and school systems, were completely disrupted (CDC, 2006; FEMA, 2012; Graumann et al., 2006;

Governor’s Commission on Recovery, Rebuilding, and Renewal, 2005; Knabb et al., 2011; Ward & Shelley, 2008).

Over 94,000 homes were destroyed, with an estimated $5.5 billion in property loss; and many of the state’s industry and commerce (tourism, casinos, and oil production) were disrupted; largely due to severely damaged or destroyed companies and supporting infrastructure, resulting in substantial jobs lost (Governor’s Commission on Recovery, Rebuilding, and Renewal, 2005; Hazards and Vulnerability Research Institute, 2014; HUD PD&R, 2006; Knabb et al., 2011). Many hurricane exposed residents also endured disaster related traumatic experiences from various stressors, to include the specter of loss of life; widespread damage to individual homes and communities; bereavement; and prolonged social and community disruptions--including loss of contact with family and friends, and prolonged displacement (Galea, Tracy, Norris, & Coffey, 2008). The U.S. Census Bureau (2014a) estimated the population of the counties of Hancock, Harrison, and Jackson, Mississippi decreased by approximately 50,000 people or about 14%, between the period of 1 July 2005 and 1 January 2006.

Tornadoes

Tornadoes are narrow, powerful cyclonic storms which occur on all landmasses worldwide, except for Antarctica (Bluestein, 2013; NOAA NCDC, n.d.b; NOAA NWS SPC, 2015; Wallace, 2010). Although tornadoes are proportionally smaller than hurricanes, they are considered the fiercest and most intense, severe weather phenomena on earth (Bluestein, 2013; NOAA NCDC, n.d.a; NOAA NWS SPC, 2015; Wallace, 2010). Tornadoes are reputed to occur more frequently in the United States, thereby causing more substantial tornado disasters, globally (Bluestein, 2013; Elsner & Widen, 2014; NOAA NCDC, n.d.b; NOAA NWS SPC, 2015; Wallace, 2010). According to the NOAA NCDC (n.d.b), an average of about 1,253 tornadoes occurs in the United States, annually. Specific regions over the Great Plains known as the Plains Tornado Alley (encompassing north and central Texas, Oklahoma, Kansas, Iowa, and Nebraska); and in the Interior Lowlands and Coastal Plains region referred to as Dixie Tornado Alley (inclusive of Louisiana, Arkansas, Mississippi, Alabama, western and central Tennessee, and northern and central Georgia), are alleged to have the highest incidence of tornado strikes (Bluestein, 2013; Gagan, Gerard, & Gordon, 2010; NOAA NCDC, n.d.c). Even though the processes and circumstances contributing to the emergence of tornadoes are not fully understood, certain weather-related conditions appear to reliably support the prospect and frequency of tornado activity in these regions (Bluestein, 2013; Gagan et al., 2010; Wallace, 2010). A widely held belief suggests these areas may favor the amalgamation of warm moisture from the Gulf of Mexico and cold atmospheric jet stream influences from the Northwest, which establishes climatic conditions supportive of increased thunderstorms and tornado activity (Bluestein, 2013; Elsner & Widen, 2014; Gagan et al., 2010; NOAA NCDC, n.d.b; Wallace, 2010).

Tornadoes are slender, tapered storms; usually about 200 meters in diameter, but can range from 10 meters to as wide as 2 kilometers (Bluestein, 2013). Tornadoes could also develop over water or transition from land and traverse across water masses, where they are called water spouts or tornadic waterspouts (NOAA NWS NOS, 2014). Proportionate with their smaller size in contrast to a hurricane, tornadoes have a short-lived duration, ranging from seconds to greater than an hour; but on average, they generally last about 10 minutes (Bluestein, 2013; NOAA NWS SPC, 2015; Wallace, 2010). Tornadoes occasionally, but do not consistently, portray a distinctive, and observable narrow funnel shaped cloud, which appear to suspend from a thunderstorm cloud layer with a cone shaped funnel arm extended towards the ground (Bluestein, 2013; NOAA NWS SPC, 2015; Wallace, 2010). Tornadoes also herald a sporadic and distinctive perceptible roar, analogous to a train, or a loud whistling articulation (Bluestein, 2013; NOAA NWS SPC, 2015).

Tornadoes can occur rapidly with no-notice, or imminently with little advanced notification (Bluestein, 2013; NOAA NWS SPC, 2015; Wallace, 2010). Despite advances in tornado forecasting, the surreptitious nature of tornadoes is known to trigger extensive localized property damages, injuries, and mortality (Bluestein, 2013; NOAA NWS SPC, 2015; Wallace, 2010). Tornadoes are categorized according to their strength and the assessment of the interaction between the storm's wind speed and destruction (Bluestein, 2013; NOAA NWS SPC, 2015; Wallace, 2010). Table 4 provides the Enhanced Fujita Scale (EF Scale) used to ascribe strength and intensity ratings to tornadoes, with a general, though not all inclusive, description of the projected damages likely to occur due to tornado force winds. The EF Scale is employed in the United States, and accepted worldwide as a standardized measure to estimate, classify, and report on the intensity of tornadoes, according to the degree of destruction imposed (Schmidlin, 2013).

Table 4

Enhanced Fujita Scale

EF scale	3-Second Gust wind speed (mph)	Types of damage due to tornado
EF0	65 - 85	Dangerous winds could produce damage to siding, shingles and gutters; and cause some loss of roofing materials; and break small limbs and large branches from trees and overturns trees with shallow roots.
EF1	86 - 110	Considerable roof damage can occur; uprooting of softwood trees and snapping of trunks of hardwood trees, bending of flagpoles and large signs; could also rip exterior doors, break windows and cause damage to single and double family residences.
EF2	111 - 135	Destruction of most manufactured single and double wide homes; remove large sections of roof structures of one and two family residences and shifts these homes from their foundations; could uproot or snap large trees; toss and overturn cars; and collapse flag poles and large signs.
EF3	136 - 165	Debarkation of softwood and hardwood trees; destruction of significant segments of houses; could cause severe damage to office buildings or shopping malls; uplifts or collapses roof structures to school buildings; overturns and throws vehicles; and upsets and throws structures with frail foundations.
EF4	166 - 200	Catastrophic damage with wholesale destruction to sturdy residences could occur, and impact huge segments of school buildings and large metal and office structures; could also maneuver and throw small objects like projectiles.
EF5	>200	Extremely disastrous and tragic winds could cause significant structural deformation and collapse of mid- and high-rise buildings, large isolated retail buildings, and large shopping malls; large objects could also become missile projectiles.

Note: From "*The Enhanced Fujita Scale (EF Scale)*," by National Oceanic and Atmospheric Administration, National Weather Service, Storm Prediction Center, 2014. Retrieved from http://www.spc.noaa.gov/efscale/

27 April 2011 Tornado impact on Alabama. An extended and very destructive outbreak of tornadoes occurred in three consecutive waves across the state of Alabama, on 27 April 2011 (Knupp et al., 2014; NOAA NWS, 2011; Tornado Recovery Action Council of Alabama, 2012). The triad of sequential tornadoes initially commenced in the early morning hours--preceding sunrise, and lasted just over three hours (Tornado Recovery Action Council of Alabama, 2012). The second wave of tornadoes erupted at mid-day, and persisted for about 50 minutes (Tornado Recovery Action Council of

Alabama, 2012). The third wave ignited during the early afternoon--around 2:40 p.m., and continued into the evening hours (Tornado Recovery Action Council of Alabama, 2012). The third wave of the attack produced a barrage of the most vicious, destructive, and deadliest storms of the extended outbreak (Tornado Recovery Action Council of Alabama, 2012). Approximately 62 tornadoes (see figure 3), to include nine EF-3s; seven EF-4s; and two EF-5 tornadoes, were spawned from the outbreak and produced catastrophic tornado damage in about 35 counties across Alabama (Tornado Recovery Action Council of Alabama, 2012). These fierce tornadoes triggered nearly 248 fatalities in 14 counties; caused more than 2,219 injuries; perpetrated devastation on over 23,000 homes and other structures; displaced thousands of families, and caused substantial job losses among residents; resulted in over $2.4 billion of property loss; and produced disruptions to infrastructure and services in communities, including potable water, power and sanitation, and healthcare services and school systems (NOAA NCDC, n.d.d; NOAA NWS, 2011; Tornado Recovery Action Council of Alabama, 2012).

The third wave commenced around 2:40 p.m., when supercell thunderstorms spawned an EF-4 tornado, in the north central segment of the state (Tornado Recovery Action Council of Alabama, 2012). This twister, identified as tornado number 37, owned peak winds of 190 mph; a path width of about one mile; and negotiated a 47 mile track, as it originated in Cullman County and traversed across Morgan and Marshall Counties (Tornado Recovery Action Council of Alabama, 2012). Although no fatalities or injuries were recorded with this storm, emergency management officials have linked this twister with the destruction of two churches, substantial vegetation, numerous homes, and various retail structures (Tornado Recovery Action Council of Alabama, 2012).

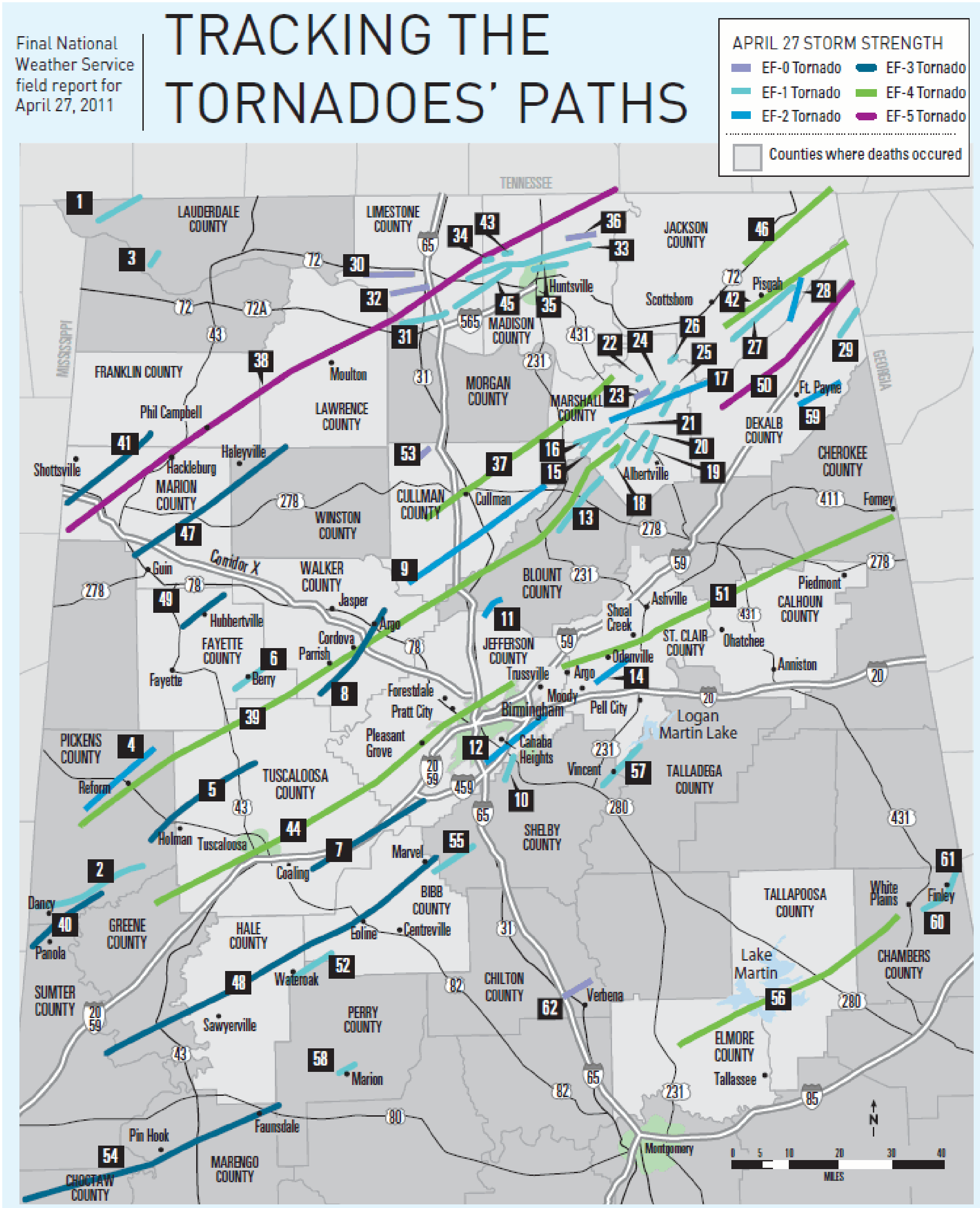

Figure 3. Illustration of the paths and types of tornadoes impacting Alabama on 27 April 2011. Adapted from “Cultivating a State of Readiness: Our Response to April 27, *2011*,”by Tornado Recovery Action Council of Alabama, 2012, p. 17. Retrieved from ema.alabama.gov/filelibrary/TRAC_Report.pdf

At 3:05 p.m., tornado number 38, originated as an EF-3, in Marion County, just east of the Mississippi-Alabama border and continued on a southwest to northeast track, and strengthened to an EF-4, close to the city of Hamilton, the county seat of Marion County (Tornado Recovery Action Council of Alabama, 2012). This storm matured to an EF-5, achieved a path width of about one mile and a quarter, packed wind speeds of roughly 210 mph, and traversed approximately 119 miles through the counties of Franklin, Lawrence, Morgan, Limestone, and Madison, respectively (Tornado Recovery Action Council of Alabama, 2012). This storm was responsible for 72 fatalities: about 26 in Franklin, 14 in Lawrence, 4 in Limestone, 25 in Marion, and 3 in Madison; and over 145 injuries, as it negotiated six counties (Tornado Recovery Action Council of Alabama, 2012). Shortly after tornado number 38 appeared, at about 3:40 p.m.; tornado number 39 touched down in Pickens County, and traveled nearly 128 miles across Pickens, Tuscaloosa, Fayette, Walker, Cullman, Blount, and Marshall Counties (Tornado Recovery Action Council of Alabama, 2012). This storm was rated as an EF-4 with a path width greater than three quarters of a mile wide (Tornado Recovery Action Council of Alabama, 2012). Tornado number 39 was also responsible for about 13 fatalities, and over 15 injuries (Tornado Recovery Action Council of Alabama, 2012).

Tornado number 44, the Tuscaloosa Tornado, was the largest and most deadly of the tornado attacks, on 27 April 2011 (Tornado Recovery Action Council of Alabama, 2012). As illustrated in figure 4, this EF-4 storm, with winds at 190 mph, had a track which extended roughly 81 miles (Tornado Recovery Action Council of Alabama, 2012). This twister initially touched down in Greene County, traveled northeast across

Tuscaloosa around 4:43 p.m., and continued into Jefferson County near the Birmingham metropolitan area (Tornado Recovery Action Council of Alabama, 2012). The Tuscaloosa Tornado made an indelible mark across Tuscaloosa as it dissected a path about six miles long, and more than half-a-mile wide; caused about 64 deaths, and over 1,500 injuries; destroyed more than 1,257 homes, and over 114 commercial structures; damaged over 4,105 residential and greater than 242 commercial structures; brought devastation to about 12% of the city; and triggered economic hardship and substantial job loss among more than 7,000 residents (Tornado Recovery Action Council of Alabama, 2012).

Tornado number 51 touched down at 6:28 p.m., in Jefferson County, adjacent to the Birmingham metropolitan area (Tornado Recovery Action Council of Alabama, 2012). It was characterized as an EF-4 twister, with winds ranging from 170-180 mph (Tornado Recovery Action Council of Alabama, 2012). The storm contained a path width of about a mile wide, and traversed northeast roughly 71 miles, from Jefferson County across St. Clair, Calhoun, and Cherokee Counties (Tornado Recovery Action Council of Alabama, 2012).

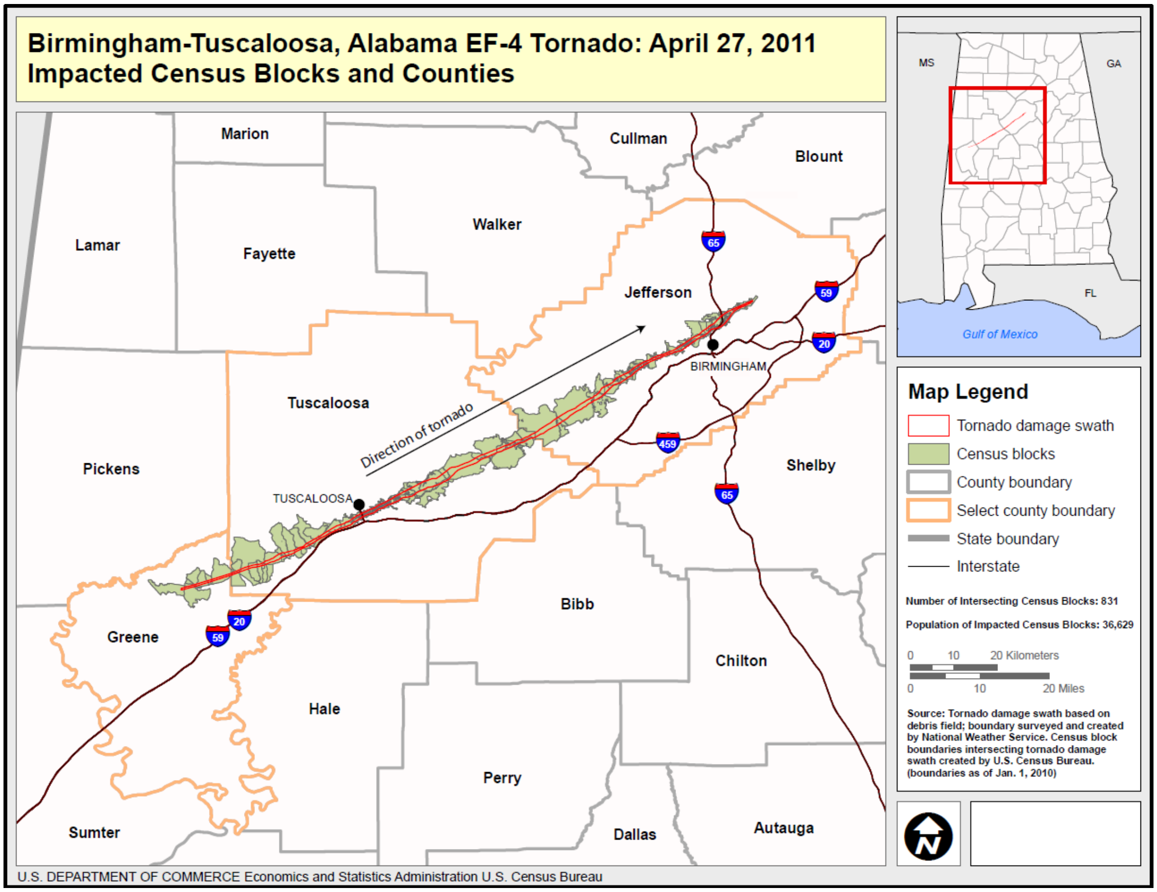

Figure 4. 2011 Alabama EF-4 Tornado track. From U.S. Department of Commerce, U.S. Census Bureau, Census Data & Emergency Preparedness, 2011 Tornadoes, Birmingham-Tuscaloosa Alabama EF-4 Tornado, 2014b. Retrieved from https://www.census.gov/newsroom/emergencies/2011_tornadoes.html

This twister was responsible for 22 deaths and over 80 injuries; and causing damage or destruction to over 256 homes, numerous commercial structures, and acres of vegetation (Tornado Recovery Action Council of Alabama, 2012).

For Alabama, the path width; length of trajectory and fury; death toll; damage swath; and the devastation associated with the 27 April 2011 extended tornado attacks, makes this outbreak one of the deadliest and most destructive tornado disasters recorded in the state (NOAA NCDC, n.d.d; NOAA NWS, 2011; Tornado Recovery Action

Council of Alabama, 2012). The effects of these tornadoes were tragic and overwhelming, largely in the counties of Calhoun, DeKalb, Franklin, Jefferson, Lawrence, Limestone, Madison, Marion, St. Clair, and Tuscaloosa, where the twisters created disastrous impacts, and fatalities; were injurious and disrupted communities; and displaced large segments of the population (Tornado Recovery Action Council of Alabama, 2012).

Hurricane and Tornado Studies Related to Key Variables

Researchers have suggested the environment and maternal health conditions can influence pregnancy outcomes (Barker, 2004; Ben-Shlomo & Kuh, 2002; Callaghan et al., 2007; Class et al., 2011; Dunkel Schetter, 2011; Dunkel Schetter & Glynn, 2011; Dunkel Schetter & Lobel, 2012; Dunkel Schetter & Tanner, 2012; King & Laplante, 2015; Willis, McManus, Magallanes, Johnson, & Majnik, 2014). Several investigators have posited that maternal prenatal exposure to natural disasters like hurricanes and tornadoes, could contribute to adverse pregnancy outcomes including preterm birth, low birth weight, and an unplanned mode of delivery requiring an obstetrical intervention (Antipova & Curtis, 2015; Currie & Rossin-Slater, 2013; Hamilton et al., 2009; Sastry & Gregory, 2013; Simeonova, 2011; Zahran et al., 2014; Zahran et al., 2013; Zotti et al., 2013).

Although the mechanisms connecting the natural disaster exposure experiences to adverse pregnancy outcomes are not fully understood, environmental epigenetics has been postulated as a plausible biological influence, consistent with the fetal programing hypothesis, which proposes adverse in utero conditions could adversely influence pregnancy outcomes and health trajectories later in life (Barker, 2004; Ben-Shlomo & Kuh, 2002; Novakovic & Saffery, 2012; Wadhwa, 2005; Wadhwa et al., 2011; Willis et al., 2014). Several investigators have contributed evidence to the incipient body of medical and scientific literature investigating the effects of maternal prenatal exposure to potentially traumatizing natural disaster incidents like hurricanes on a variety of maternal and infant health outcomes, including preterm birth, low birth weight, mode of delivery, and other complications like abnormal labor, fetal mortality and fetal distress (Antipova & Curtis, 2015; Currie & Rossin-Slater, 2013; Hamilton et al., 2009; Harville, Tran et al., 2010; Harville et al., 2009; Harville, Xiong et al., 2009; Sastry & Gregory, 2013; Simeonova, 2011; Zahran et al., 2014; Zahran et al., 2013; Zahran et al., 2010; Zotti et al., 2012; Zotti et al., 2013).

Storm Studies and Preterm Birth and Low Birth Weight

The exact causes of preterm birth and low birth weight are unknown, but emerging evidence suggests environmental factors such as natural disaster storms could play an influential role (Antipova & Curtis, 2015; Harville et al., 2009; Simeonova, 2011). Researchers have shown considerable interest in examining natural disaster storms like hurricanes, as determinants of adverse pregnancy outcomes (Antipova & Curtis, 2015; Currie & Rossin-Slater, 2013; Zahran et al., 2014). Several studies have examined the effect of hurricanes and severe weather storms, on preterm birth and low birth weight and reported mixed results.

Antipova and Curtis. Antipova and Curtis (2015) examined the effects of hurricane damages and social disruption on premature deliveries and low birth weight pregnancy outcomes consequential to Hurricane Andrew among pregnant women with singleton births, in Louisiana. Utilizing birth and death data, Antipova and Curtis (2015) evaluated variations in preterm births and low birth weight in Louisiana. The researchers investigated 6,202 pregnancies in areas impacted by Hurricane Andrew, encompassing over 20 central and northern Louisiana parishes before Hurricane Andrew, and 6,147 pregnancies after the storm made landfall (Antipova & Curtis, 2015). The investigation also included controls for a before impact population of 3,416 pregnant women, and a post-impact population of 2,974 pregnant women, from areas which were not directly impacted by Hurricane Andrew (Antipova & Curtis, 2015). Odds ratios and confidence intervals (95%) were calculated for the risk factors of being born premature or with low birth weight, utilizing multiple logistic regression analyses and controlling for potential confounders (Antipova & Curtis, 2015). A significant increase in preterm births among pregnant women in impacted and controlled areas, both over the short and long term periods post land fall was observed by Antipova and Curtis (2015). The researchers posited that pregnant women in the areas impacted by the hurricane were 44%more likely to deliver a preterm infant (Antipova & Curtis, 2015). No significant differences were observed for low birth weight risks and pregnancy outcome (Antipova & Curtis, 2015). The researchers concluded there was a consistent association observed between preterm births and pregnant women residing in hurricane impacted areas, suggesting a correlation between maternal prenatal exposures to hurricanes and preterm births (Antipova & Curtis, 2015).

Currie and Rossin-Slater. Currie and Rossin-Slater (2013) exploited severe tropical storms and hurricanes as the proxy measure for maternal prenatal exposure to a stressful incident, in their investigation of the effects of this weather phenomenon on birth outcomes. Currie and Rossin-Slater (2013) studied vital statistics records of 485,048 singleton births to women who resided in the path of all major tropical storms and hurricanes which produced damages in excess of $10 million, between 1996 and 2008, in the state of Texas. The health at birth of children who were born during the periods of interest was compared with siblings whose gestational period did not correspond with a significant weather-related incident. Women in the sample were stratified according to their projected residential placement in relation to the eye of the storms, such as within 30, 60, or 100 kilometers (Currie & Rossin-Slater, 2013). Those residing in areas greater than 100 kilometers from the trajectory of the storms were excluded from the study (Currie & Rossin-Slater, 2013). Consistent with previous studies, Currie and Rossin-Slater (2013) observed maternal prenatal exposure to hurricanes had a strong correlation with poor maternal and infant health outcomes. The adverse outcomes included abnormal conditions of the neonate like meconium aspiration syndrome and respiratory problems requiring assisted ventilation, and complications of labor and delivery with an increased likelihood for induced labor or a C-section, particularly among pregnant women residing within 30 kilometers of the hurricane's path during the third trimester of gestation (Currie & Rossin-Slater, 2013).

Upon examining the effects of maternal prenatal exposure to hurricanes on preterm birth and low birth weight outcomes, Currie and Rossin-Slater (2013) reported conflicting results. Exploiting estimation models employed by previous research investigations wherein plausible hurricane exposure was assessed by calculating retrospectively from the birthdate, Currie and Rossin-Slater (2013) research findings were consistent with earlier evidence, which suggested prenatal hurricane exposure increases the likelihood of delivering an infant at preterm and/or with low birth weight. Utilizing a novel assessment approach whereby probable hurricane exposure was measured by computing forward from an estimated conception date, Currie and Rossin-Slater (2013) observed little evidence supporting a relationship between maternal prenatal exposure and risks for preterm and low birth weight outcomes; and observed some evidence of effects on mode of delivery by C-sections. The researchers concluded the study suggesting prenatal hurricane exposure significantly increases the risk for abnormal conditions of the neonate and maternal complications of labor and delivery, and implicated prenatal stress as a likely contributing factor (Currie & Rossin-Slater, 2013).

Harville, Tran, Xiong, and Buekens. Harville, Tran, Xiong, and Buekens (2010) assessed the impact of Hurricane Katrina in Louisiana, on singleton birth and obstetric outcomes and the influence of race and ethnicity on these outcomes. The investigation explicitly observed the impact of demographic and population changes on preterm births, low birth weight, mode of delivery, and prenatal care (Harville, Tran et al., 2010). The study also examined the implications of the storm across racial lines and its effect on pregnancy outcomes, by equating pregnancy outcomes in New Orleans (in Jefferson, Orleans, Plaquemines, and St. Bernard parishes), and across the state of Louisiana (Harville, Tran et al., 2010). The researchers evaluated a population of 128, 624 pregnant women two years before Hurricane Katrina, and 126, 041 pregnant women two years after the storm (Harville, Tran et al., 2010). Harville, Tran, Xiong, and Buekens (2010) compared linked vital statistics and Medicaid data to assess birth outcomes. Frequency and proportion of birth outcomes, odds ratios and confidence intervals (95%), and multivariate regression analyses were calculated comparing birth outcomes before and after the hurricane; controlling for demographic, health behavioral, and biological confounding variables (Harville, Tran et al., 2010). In parishes of the New Orleans metropolitan area directly impacted by the hurricane; Harville, Tran, Xiong, and Buekens (2010) did not find an association between hurricane exposure and risk for preterm births or low birth weight. Increases in the incidence of C-sections and poor prenatal care were observed among pregnant women in areas directly affected by the storm, as well as non-impacted areas across the state (Harville, Tran et al., 2010).

Simeonova. Simeonova (2011) assessed the effects of maternal prenatal exposure to various natural disaster incidents like severe storms (n=1612), hurricanes (n=72), tornadoes (n=599), floods (n=1068), heat waves (n=78), landslides (n=15), earthquakes (n=15), and winter weather (n=1612) on preterm birth and low birth weight pregnancy outcomes across the United States, for the period of 1968 to 1988. Utilizing national vital statistics data aggregated at the county level, Simeonova (2011) examined birth records of a large sample of childbirths in the United States, among women who resided in counties impacted by various natural disaster incidents of interest, during their pregnancy. Although controls in this investigation were not imputed to precisely isolate the direct effects of hurricane and tornado disasters, Simeonova (2011) aggregated hurricanes, tornadoes, severe storms, and hail into a classification stratified and defined as severe storms. Simeonova (2011) observed small statistically significant evidence suggesting maternal prenatal exposures to the predictor variables classified as severe storms, increased the probability of shorter gestations and delivery of a low birth weight baby. Simeonova (2011) also implicated maternal prenatal exposure to natural disasters with preterm birth and low birth weight pregnancy outcomes, and posited that the magnitude of the effects varies by the disaster type and exposure experience at gestational age. The evidence provided in this study supported previous research suggesting an association between maternal prenatal exposures to a natural disaster incident like a hurricane, tornado or severe storm and adverse pregnancy outcomes (Simeonova, 2011).

Harville, Xiong, and Buekens. Harville, Xiong, and Buekens (2009) investigated the influence of maternal prenatal exposure to Hurricane Katrina on perinatal health. Exploiting data from two previous cohort studies of pregnant and postpartum women of southern Louisiana, in the wake of Hurricane Katrina; Harville, Xiong, and Buekens (2009) examined the effects of exposure to Hurricane Katrina among pregnant and postpartum women on perinatal health, including adverse pregnancy outcomes like preterm birth, low birth weight, and maternal complications; and mental health and well-being. Questionnaires and interviews to assess exposure experience, health behaviors, access to medical care, and mental health, and an evaluation of medical records to determine pregnancy outcomes, were completed for 301 pregnant women, of whom 220 were from New Orleans and 81 from Baton Rouge; and 335 postpartum women, with 221 originating from New Orleans and 114 from Baton Rouge (Harville et al., 2009). Harville, Xiong, and Buekens (2009) found infants born to women in the group classified as having a high hurricane exposure experience, were three times as likely to have a low birth weight (*OR* 3.3; 95% *CI* = [1.13–9.89]), compared with infants born to women without a high hurricane exposure experience. The risks for preterm births were 2.3 times higher (95%, *CI* = [0.82–6.38]) among women with a high hurricane exposure experience than among women without a high hurricane exposure experience (Harville et al., 2009). Although the frequency and risk for delivering an infant at low birth weight or preterm were common among women with a high hurricane exposure compared with women without a high hurricane exposure; Harville, Xiong, and Buekens (2009) did not observe these differences among mothers with PTSD or depression in contrast with mothers without PTSD or depression. However, among the study sample as a whole, a significant increase in low birth weight or preterm birth was not observed. The researchers suggested maternal prenatal exposure to austere and stressful natural disaster incidents and the intensity of the exposure experience may be concomitant with factors known to adversely influence pregnancy outcomes (Harville et al., 2009).

Xiong, Harville, Mattison, Elkind-Hirsch, Pridjian, and Buekens. Xiong, Harville, Mattison, Elkind-Hirsch, Pridjian, and Buekens (2008) examined hurricane exposure experiences, mental health, and pregnancy outcomes, among 220 women from New Orleans, and 81 women from Baton Rouge, Louisiana, who were pregnant during or became pregnant immediately after Hurricane Katrina. Rates for adverse pregnancy outcomes like low birth weight and preterm birth, were higher among women with a high hurricane exposure experience compared with women without a high hurricane exposure experience (Xiong, Harville, Mattison, Elkind-Hirsch, Pridjian, & Buekens, 2008). No substantial variances were observed in incidence rates between women with PTSD or depression compared with those without PTSD or depression (Xiong et al., 2008). The research investigators suggested high prenatal maternal hurricane exposure experiences among pregnant women increases the risks of adverse pregnancy outcomes including low birth weight and preterm births (Xiong et al., 2008). With mounting evidence showing pregnant women risk experiencing deleterious pregnancy outcomes in natural disaster situations like a hurricane, Xiong et al. (2008) posited disaster preparedness officials and public health professionals should recognize the unique needs of this population, and advance emergency preparedness efforts to abate maternal prenatal exposures and consider the application of appropriate strategies such as early evacuations, to help mitigate the effects of destructive natural disaster incidents like hurricanes.

Hamilton, Sutton, Mathews, Martin, and Ventura. In addition to the studies mentioned above, Hamilton, Sutton, Mathews, Martin, and Ventura (2009) conducted an investigation to examine the effects of Hurricane Katrina on pregnancy outcomes including mode of delivery, preterm births and low birth weight among pregnant women in Alabama, Louisiana, and Mississippi. Their research findings yielded conflicting variations for each impacted state in both preterm and low birth weight results. Decreases in preterm birth and low birth weight rates were observed in Louisiana, increases in Alabama, and no clear effect on preterm births and birth weight were observed in Mississippi (Hamilton et al., 2009).

Hurricane Studies and Mode of Delivery

Maternal prenatal exposure to hurricanes could engender an unplanned mode of delivery requiring an obstetrical surgical procedure. A few studies have provided evidence of an association between maternal prenatal exposure to hurricanes and an increased incidence of C-section deliveries (Currie & Rossin-Slater, 2013; Hamilton et al., 2009; Harville, Tran et al., 2010; Zahran et al., 2013).

Zahran, Peek, Snodgrass, Weiler, and Hempel. Zahran, Peek, Snodgrass, Weiler, and Hempel (2013) studied the effects of maternal prenatal exposure to Hurricane Andrew on the mode of delivery and risk for atypical labor, among 297,996 pregnancies in the Florida counties of Broward and Miami-Dade, during the period of 1992 to 1993. Zahran, Peek, Snodgrass, Weiler, and Hempel (2013) stratified the study population into hurricane exposed and unexposed clusters, to examine the effects of maternal hurricane exposure experiences on pregnancy outcomes like dysfunctional labor and C-section deliveries. Significantly higher rates of dysfunctional labor and C-section deliveries were observed in hurricane exposed pregnant women when compared with unexposed pregnant cohorts (Zahran et al., 2013). Increased incidences of dysfunctional labor, especially in the third trimester, were associated with prenatal maternal hurricane exposure (Zahran et al., 2013). Evidence of increased rates of C-section deliveries among hurricane exposed pregnant women, were also observed (Zahran et al., 2013). The proportion of pregnant women with no prenatal care was significantly higher among hurricane exposed expectant mothers compared with unexposed pregnant women (Zahran et al., 2013). The researchers suggested prenatal maternal hurricane exposure could increase the risk of dysfunctional labor by 50% and C-section deliveries by 20%; and posited traumatic exposure to Hurricane Andrew could have engendered maternal stress and plausibly influence stress-induce dysfunctional labor, and increase the incidences of C-section deliveries, secondary to the dystocia (Zahran et al., 2013).

Hamilton, Sutton, Mathews, Martin, and Ventura. Hamilton, Sutton, Mathews, Martin, and Ventura (2009) investigated the effects of Hurricane Katrina on mode of delivery, preterm births and low birth weight pregnancy outcomes among 81,452 births in 91 Federal Emergency Management Agency (FEMA) designated assistance counties of Alabama and Mississippi; and parishes of Louisiana 12-months after Hurricane Katrina; and utilized 85,223 births in the aforementioned areas, as controls 12-months prior to Hurricane Katrina. Of the 91 FEMA-designated assistance counties and parishes, five coastal counties in Alabama (Baldwin and Mobile) and Mississippi (Hancock, Harrison, and Jackson counties), and nine parishes in Louisiana (Iberia, Jefferson, Lafourche, Orleans, Plaquemines, St. Bernard, St. Mary, St. Tammany, and Terrebonne parishes), were within a 100-mile radius of the storm's trajectory, and were designated as regions owning the most intense impact of Hurricane Katrina (Hamilton et al., 2009). C-section mode of delivery rates for these 14 selected FEMA-designated counties and parishes rose by 10% for counties in Alabama and Mississippi, and 6% for parishes in Louisiana (Hamilton et al., 2009). These percentages were computed for the 12-month period prior to, and 12-months after Hurricane Katrina (Hamilton et al., 2009). The research investigators observed decreases in very preterm birth rates and very low birth weight in pregnancies among the FEMA-designated parishes of Louisiana, 12-

months after Hurricane Katrina compared with rates 12-months preceding the storm (Hamilton et al., 2009). Converse to the pregnancy outcomes observed in Louisiana; Hamilton, Sutton, Mathews, Martin, and Ventura (2009) found increases in very preterm birth rates, total preterm, very low birth weight, and total birth weight parturitions for the identical periods of interest, in FEMA-designated assistance counties of Alabama. No discernable evidence associating maternal prenatal exposure to Hurricane Katrina, with preterm or low birth weight was observed in Mississippi (Hamilton et al., 2009).

Associations between maternal prenatal exposure to natural disaster storms like hurricanes, and the increased incidence of C-section deliveries were also reported by Currie and Rossin-Slater (2013) in their investigation examining the effects of severe tropical storms and hurricanes occurring in the state of Texas, on pregnancy outcomes; and Harville, Tran, Xiong, and Buekens' (2010) study, which examined the effects of Hurricane Katrina in Louisiana, on singleton birth and obstetric outcomes and the influence of race and ethnicity on pregnancy outcomes. No studies from researchers examining the effects of tornadoes on mode of delivery were observed during the review of the available scientific literature.

Hurricane Studies and Fetal Mortality and Fetal Distress

A nascent body of scientific evidence has associated maternal prenatal exposure to hurricanes with adverse pregnancy outcomes. Outcomes which may be influenced by maternal prenatal exposure to hurricanes include fetal mortality and fetal distress (Zahran et al., 2014; Zahran et al., 2010). Two studies recently examined the potential effect of maternal prenatal exposure to hurricanes on fetal mortality and fetal distress.

Zahran, Breunig, Link, Snodgrass, Weiler, and Mielke. Zahran et al. (2014) examined the relationship between maternal prenatal exposure to hurricanes and risk of fetal mortality in the aftermath of Hurricanes Katrina and Rita in Louisiana. The researchers conducted a review of infant birth and death records covering the period of 1999 to 2009; with specific attention given to the periods of 1 January 2004 to 28 August 2005, and 29 August 2005 through 31 December 2007 (Zahran et al., 2014). Fetal outcomes were evaluated among pregnant women in the hardest hit areas suffering the greatest destruction to family homes, to include Jefferson, Orleans, Plaquemines, St. Bernard, St. Tammany and Vermilion parishes; and compared with cohorts in parishes unaffected by the hurricanes (Zahran et al., 2014). Adjusting for plausible confounding health issues, the researchers observed the odds of fetal death were 1.4 times higher (95%, *CI* = [1.07-1.83]) in parishes of homes with 10% to 50% of damage to the housing stock; and 2.3 times higher (95%, *CI* = [1.684-3.327]) in parishes with greater than 50% housing stock damage, compared with parishes where homes experienced no damage during the two storms (Zahran et al., 2014).

The research investigators posited that for every 1% increase in destruction of housing stock, a 1.7% increase in fetal death was observe, and suggested an estimated 117 and 205 stillbirths could be attributable to the two hurricanes, equivalent to the 17% and 31% of the 671 persons killed in the six Louisiana parishes during the storms (Zahran et al., 2014). Zahran, Breunig, Link, Snodgrass, Weiler, and Mielke (2014) concluded Hurricanes Katrina and Rita imposed a huge toll and burden on Louisiana communities in terms of fetal mortality, and suggested public health and emergency preparedness interventions could be enhanced and applied to mitigate the adverse in utero effects and pregnancy outcomes associated with natural disasters like hurricanes.

Zahran, Snodgrass, Peek, and Weiler. Zahran, Snodgrass, Peek, and Weiler (2010) estimated the prevalence and influence of maternal prenatal exposure to Hurricane Andrew on fetal distress risk among 59,056 pregnancies in hurricane impacted areas of Broward and Miami-Dade counties of Florida, during the period 1992 to 1993, in the wake of Hurricane Andrew. Frequencies and ratios of fetal distress outcomes, odds ratios and confidence intervals (95%), and multivariate regression analyses were computed comparing fetal distress outcomes before and after the hurricane made landfall, in affected counties of Broward and Miami-Dade, and unaffected counties across the state with populations of more than 100,000. Controlling for known risk factors and possible influences which could contribute to fetal distress, Zahran et al. (2010) observed infants exposed to the hurricane during the first trimester of gestation, demonstrated no evidence of increased risk of distress. Zahran et al. (2010) compared births in Broward and Miami-Dade counties and found maternal prenatal exposure to Hurricane Andrew during the second trimester increased the odds of fetal distress at birth by 20% (95%, *CI* = [1.08–1.33]); and the risk increased 26% (95%, *CI* = [1.15–1.38]) among pregnant women exposed during the third-trimester.

The comparison of births in Broward and Miami-Dade counties with unaffected Florida counties, comprised of populations greater than 100,000; revealed maternal prenatal exposure to Hurricane Andrew during the second trimester increased the odds of fetal distress at birth by 21% (95%, *CI* = [1.10–1.34]); and the risk increased 29% (95%, *CI* = [1.18–1.41]) among pregnant women exposed during the third-trimester (Zahran et al., 2010). Higher fetal distress rates were observed among African-American women as the odds of fetal distress increased 46% (95%, *CI* = [1.26 to 1.70]) among pregnant African-American women exposed during their third trimester (Zahran et al., 2010). The researchers suggested prenatal maternal hurricane exposure experiences may induce stress and influence biological pathways, which could increase the risk for complications of pregnancy; compromise the health of an unborn fetus; have serious implications for long term health in affected children; and increase maternal and neonatal healthcare costs (Zahran et al., 2010).

Pregnancy, Epigenetic Programming and Pregnancy Outcomes

Pregnancy is a remarkable phenomenon encompassing a multifaceted and exceptional biological, physiological, and psychological dynamic (Dunkel Schetter & Glynn, 2011). As pregnancy progresses, hormonal and physiological changes may influence not only physical functioning, but also psychological health and welfare, including emotional well-being (Dunkel Schetter, 2011; Dunkel Schetter & Glynn, 2011; Dunkel Schetter & Lobel, 2012; Dunkel Schetter & Tanner, 2012). Although pregnancy often heralds a period of cheerfulness and delight, it could correspondingly harvest emotional, physical and social disruptions and alternations, including adapting health behavioral changes (like smoking cessation, nutritional restrictions, and ensuring adequacy of prenatal care) to maintain a health pregnancy; which could engender stressful life experiences (Geller, 2004). These experiences commonly known as pregnancy-related stress may include maternal fears concerning the health of a developing fetus; parturition and well-being during birthing; and future parental responsibilities, and could strongly influence pregnancy outcomes (Dunkel Schetter, 2011; Dunkel Schetter & Glynn, 2011; Dunkel Schetter & Lobel, 2012; Dunkel Schetter & Tanner, 2012). Researchers have published an abundance of emerging literature suggesting prenatal maternal stress may contribute to adverse pregnancy outcomes; including data demonstrating that the intrauterine period of gestation is a critical and sensitive period with profound implications for health and birth, and developmental trajectories across the lifespan (Barker, 2004; Ben-Shlomo & Kuh, 2002; Dunkel Schetter & Lobel, 2012; Dunkel Schetter & Tanner, 2012; Halfon et al., 2014; Lu, 2014; Witt, Litzelman, Cheng, Wakeel, & Barker, 2014). Investigators conducting epidemiological research in humans and laboratory studies with animals, have proffered evidence showing the fetus is especially susceptible to environmental influences with adverse consequences at birth and across the life span (Baibazarova et al., 2013; Barker, 2004; Beijers, Buitelaar, & de Weerth, 2014; Ben-Shlomo & Kuh, 2002; Halfon et al., 2014; Kingston, Heaman, Fell, Dzakpasu, & Chalmers, 2012; Lu, 2014; Lu et al., 2010).

Barker (2004) advanced the fetal programming hypothesis positing that adverse experiences and exposure conditions in utero contribute to epigenetics, a profound change in gene expression without fundamental changes in genetic material. Several investigators have supported this theory with compelling evidence suggesting epigenetic alterations could lead to poor pregnancy outcomes including low birth weight, preterm birth, and infant mortality (Billack, Serio, Silva, & Kinsley, 2012; Class et al., 2011; Gapp, von Ziegler, Tweedie-Cullen, & Mansuy, 2014; Dunkel Schetter & Glynn, 2011;

Dunkel Schetter & Lobel, 2012; Provençal & Binder, 2014; Reynolds, Labad, Buss, Ghaemmaghami, & Räikkönen, 2013; Wadhwa et al., 2011). Prenatal maternal stress has been implicated as a significant risk factor for adverse birth outcomes (Dunkel Schetter, 2011; Dunkel Schetter & Glynn, 2011; Dunkel Schetter & Lobel, 2012; Dunkel Schetter & Tanner, 2012; Witt et al., 2014).

The association between stressful life events and poor health and developmental trajectories has serious health implications for pregnant women, especially those with exposure experiences to natural disasters (Callaghan et al., 2007; Class et al., 2011; Dunkel Schetter, 2011; Dunkel Schetter & Glynn, 2011; Dunkel Schetter & Lobel, 2012; Dunkel Schetter & Tanner, 2012; Witt et al., 2014). Whereas high winds, storm surge and flooding in hurricanes, and projectiles and highly destructive tornado winds are perhaps the most important components contributing to disaster-related morbidity and mortality among exposed individuals, these constituents may not independently pose a threat to the well-being of pregnant women and the developing fetus. As these storms are known to portend catastrophic damage to individuals and property, warnings of an inherently unpredictable storm and the actual exposure experience are known to induce stress in exposed populations, and could impute adverse consequences for pregnant women and the developing fetus (Dunkel Schetter, 2011; Dunkel Schetter & Tanner, 2012; Klein & Shih, 2010; Kramer et al., 2009; Wallace, 2010).

Normal Pregnancy

Pregnancy or the period of gestation, is defined as the interval of time between conception and the birth of a neonate (Jones & Lopez, 2014; Newman & Newman, 2015). A normal full-term of pregnancy generally occurs over a period of 39 to 40 weeks or nine months of gestation, and is organized into three month phases called trimesters (ACOG, 2013; Jones & Lopez, 2014; Newman & Newman, 2015). The first trimester, encompassing week zero through weeks 13, is the most active period of gestation (Newman & Newman, 2015). It represents a phase of rapid establishment of organ systems, and a segment of development which is reputedly sensitive and susceptible to birth defects and malformations, which could contribute to miscarriages (Branch & Wong, 2014; Jones & Lopez, 2014; Newman & Newman, 2015).

The second trimester, weeks 14 through weeks 24, is a period of discernable growth and maturation of the fetus (Branch & Wong, 2014; Jones & Lopez, 2014; Newman & Newman, 2015). Parallel with the first trimester, normal fetal maturation at this period is essential to a healthy pregnancy as disruptions to placental circulation and endocrinological influences could adversely impact pregnancy outcomes (Branch & Wong, 2014; Jones & Lopez, 2014). Fetal growth continues throughout the third and last trimester (Branch & Wong, 2014; Jones & Lopez, 2014; Newman & Newman, 2015). During this stage of fetal gestation, organs of the growing fetus begin to mature and the fetus effects much movement and positional changes, to include posturing for birth by normally plunging the head toward the pelvis and presenting for vaginal delivery (Branch & Wong, 2014; Jones & Lopez, 2014; Newman & Newman, 2015).

The birth of a neonate at weeks 39 through 40 is considered full-term, affording a comprehensive maturation of the neonate's organs and body structures (ACOG, 2013). Births at weeks 37 through 38 are considered, early term; at week 41, late term; and weeks 42 and beyond, post-term (ACOG, 2013). An infant carried to full-term has distinct benefactions over an infant born preterm, including the potential for a much improved capacity for self-governance of breathing functions, stronger and more efficient digestion and waste excretion, and a more enhanced and fully balanced control of body temperature (Newman & Newman, 2015).

Each trimester during the period of gestation, has inherent phases of fetal maturation to which various factors and influences including biological and environmental, could contribute and potentiate the risks for adverse pregnancy outcomes (Branch & Wong, 2014; Jones & Lopez, 2014; Newman & Newman, 2015). Several researchers have contributed evidence suggesting adverse experiences, biological influences, and exposure to high levels of prenatal maternal stress in utero could adversely influence pregnancy outcomes (Barker, 2004; Novakovic & Saffery, 2012; Reynolds, Labad, Buss, Ghaemmaghami, & Räikkönen, 2013; Wadhwa, 2005; Wadhwa et al., 2011; Willis et al., 2014). All the trimesters of gestation, are fundamental to the activities necessary for normal fetal growth and development; and any disruption or aberrations in the routine processes and procedures required for fetal gestation could contribute to an adverse pregnancy outcome (Newman & Newman, 2015).

Stress, Epigenetics, and Fetal Programming

Although gestation confers inherent pregnancy-related stress, exposure to potentially traumatizing incidents like natural disasters, can similarly enflame stress through acute stress reactions; thus increasing the risk of poor maternal and infant health outcomes, beyond the salient threat of physical injury (Callaghan et al., 2007; Class et al., 2011; Dunkel Schetter, 2011; Dunkel Schetter & Glynn, 2011; Dunkel Schetter & Lobel, 2012; Dunkel Schetter & Tanner, 2012; Geller, 2004; King & Laplante, 2015). Traumatizing incidents may include direct exposure experience to, or witnessing in person an incident involving actual or threatened death, or serious injury (APA, 2014). Several investigators have provided evidence implicating traumatic exposure to natural disasters like hurricanes, with producing maternal distress, PTSD, and adverse pregnancy outcomes among exposed pregnant women (Antipova & Curtis, 2015; Currie & Rossin-Slater, 2013; Harville et al., 2009; Harville, Xiong et al., 2009; Harville et al., 2010; Zahran et al., 2014; Zahran et al., 2013). Traumatic experiences often trigger acute stress responses which interrupt homeostasis, the ability of body systems to work in harmony and regulate internal conditions through feedback mechanisms (McEwen, 2010). Threats to homeostasis instigates allostasis, a neurochemical process facilitated primarily by the body's hypothalamic-pituitary-adrenal (HPA) axis (comprised of endocrine glands: the hypothalamus, pituitary gland, and adrenal gland) of the neuroendocrine system and the sympathetic nervous system, to establish equilibrium (McEwen, 2010). During prenatal development, exposure to traumatic incidents could impact the neuroendocrine system and induce acute stress reactions including allostasis, establishing conditions to adversely influence maternal, fetal, and infant health outcomes (Callaghan et al., 2007; Class et al., 2011; Dunkel Schetter, 2011; Dunkel Schetter & Glynn, 2011; Dunkel Schetter & Lobel, 2012; Dunkel Schetter & Tanner, 2012; King & Laplante, 2015; Reynolds et al., 2013).

Researchers have provided a number of sophisticated models elucidating potential causal pathways of how stress could influence adverse pregnancy outcomes (Abdou et al., 2010; Billack et al., 2012; Dunkel Schetter, 2011; Dunkel Schetter & Lobel, 2012; Dunkel Schetter & Tanner, 2012; Gapp et al., 2014; Novakovic & Saffery, 2012; Provençal & Binder, 2014; Reynolds et al., 2013 Wadhwa, 2005; Wadhwa et al., 2011). A potential mechanism garnering significant interest involves changes in the maternal HPA axis activity during critical and sensitive periods of fetal development, which could induce epigenetic influences on gene expression and critically determine risks for poor pregnancy outcomes (Billack et al., 2012; Gapp et al., 2014; Novakovic & Saffery, 2012; Provençal & Binder, 2014; Reynolds et al., 2013). This consideration of a plausible biological mechanism is consistent with the fetal programing theory posited by Barker (2004), and supports theoretical foundations suggesting disturbances during a critical and sensitive period of prenatal development could lead to adverse pregnancy outcomes and poor health consequences across the life course (Barker, 2004; Ben-Shlomo & Kuh, 2002; Wadhwa, 2005; Wadhwa et al., 2011).

A number of researchers have conducted epidemiological studies examining correlations between adverse intrauterine conditions and birth outcomes (Barker, 2004; Ben-Shlomo & Kuh, 2002; Lumey & van Poppel, 2013). The pioneering research by Barker and colleagues postulated the fetal programing hypothesis suggesting an association between adverse in utero conditions and low birth weight, as well as poor health trajectories for ischemic heart disease and mortality later in life (Barker, 2004; Ben-Shlomo & Kuh, 2002). The epidemiological discovery by Barker (2004) from a historical cohort study, unearthed a process in which adverse perinatal environmental influences occurring as early as the first trimester of gestation, could moderate fetal developmental programming contributing to a higher risk factor for poor pregnancy outcomes and health trajectories across the life span (Barker, 2004; Ben-Shlomo & Kuh, 2002). Correspondingly, Lumey and van Poppel's (2013) retrospective study of men and women exposed to the Dutch famine of 1944-1945, examined associations between adverse exposure experiences to starvation during pregnancy, and birth outcomes and health trajectories. In this investigation, Lumey and van Poppel (2013) observed correlations between adverse in utero conditions as influenced by the famine, and poor birth outcomes, as well as diseases and poor health conditions later in life.

During traumatic exposure experiences, activation of the acute stress response mechanism engages the release of several stress hormones including cortisol, ACTH, and catecholamine (McEwen, 2010). Numerous investigators have provided evidence suggesting the perinatal period is concomitant with increased HPA axis activity, and as pregnancy progresses cortisol (glucocorticoid), adrenocorticotrophic hormone (ACTH), and placental corticotrophin releasing hormone (CRH) levels increase (Austin, Leader, & Reilly, 2005; Braun, Challis, Newnham, & Sloboda, 2013; Dunkel Schetter & Glynn, 2011; Dunkel Schetter & Lobel, 2012; Gangestad, Caldwell Hooper, & Eaton, 2012; Jung et al., 2011; King & Laplante, 2015; Smith et al., 2011). Accordingly, exposure to acute stress responses during the perinatal period could contribute to excess levels of cortisol, ACTH, and catecholamine (Beijers et al., 2014; Dunkel Schetter & Glynn, 2011; Dunkel Schetter & Lobel, 2012; Novakovic & Saffery, 2012; Provençal & Binder, 2014; Reynolds et al., 2013). As a result, critical considerations of the influence of prenatal maternal adverse exposure experiences during gestation on birth outcomes would likely include mediations through maternal and fetal interactions (Reynolds, 2013). Investigators have advanced putative data implicating overexposure of the fetus during early gestation, to higher levels of cortisol in the placenta as a plausible linkage to the fetal programming concept (Beijers et al., 2014; Kleinhaus et al., 2010; Reynolds, 2013; Seckl, 2014; Wyrwoll, 2014). Although the mechanistic pathways correlating adverse intrauterine conditions to poor birth outcomes are not fully understood, it is possible the placenta may serve as a crucial actor within these pathways (Gangestad et al., 2012).

The placenta is an indispensable transitory organ which unites the developing fetus with the uterus, and serves as an important conduit between the maternal and fetal environments (Challis et al., 2014; Jones & Lopez, 2014). The placenta is paramount with enabling the effective intrauterine exchange of gases, nutrients, and waste between the mother and the developing fetus (Challis et al., 2014; Jones & Lopez, 2014). It produces its own CRH, a stress response hormone; secretes CRH to both mother and fetus--usually during the second and third trimesters, and stimulates placental CRH (Challis et al., 2014; Gangestad et al., 2012). The placenta also mediates secretion of pregnancy-related hormones, and protects the fetus from assaults perpetrated by the maternal immune system (Challis et al., 2014). Adverse pregnancy outcomes including preeclampsia, preterm birth, and intra uterine growth restrictions are frequent associated with pathologies of the placenta (Huppertz, 2011; Vedmedovska, Rezeberga, Teibe, Melderis, & Donders, 2011).

As the placenta serves as a crucial maternal-fetal interface, epigenetic influences associated with this structure could have substantial programming implications for pregnancy outcomes and health trajectories (Challis et al., 2014; Novakovic & Saffery, 2012; Seckl, 2014; Wyrwoll, 2014). Several investigators have proffered plausible elucidations positing that prenatal maternal stress is transferred to the fetus through the movement of maternal stress hormones from the placenta, and as a result of the release of placental CRH to the fetus (Beijers et al., 2014; Dunkel Schetter & Glynn, 2011; Dunkel Schetter & Lobel, 2012). Researchers espousing the fetal programming concept have suggested that maternal prenatal exposure to stress influences biological stress responses, including stimulation of the maternal HPA axis and an increase in maternal cortisol, which successively stimulates placental CRH causing higher cortisol levels with adverse implications for pregnancy and health outcomes (Braun et al., 2013; Dunkel Schetter & Glynn, 2011; Dunkel Schetter & Lobel, 2012).

As depicted in figure 5, adverse in utero conditions as influenced by maternal prenatal exposure to a hurricane or tornado natural disaster, could induce epigenetic alterations, possibly establishing conditions for environmental epigenetic effects (Novakovic & Saffery, 2012; Willis et al., 2014). The fetal programming model shows how adverse environmental exposure influences could interrupt placental epigenetics with potential adverse consequences for fetal development, poor maternal and neonate health, and disease vulnerability later in life (Novakovic & Saffery, 2012). Accordingly, environmental epigenetic effects could impact the developing fetus and fetal programming with implications for adverse pregnancy outcomes including preterm births, low birth weight, and infant mortality; and poor health consequences across the life course (Novakovic & Saffery, 2012; Willis et al., 2014).

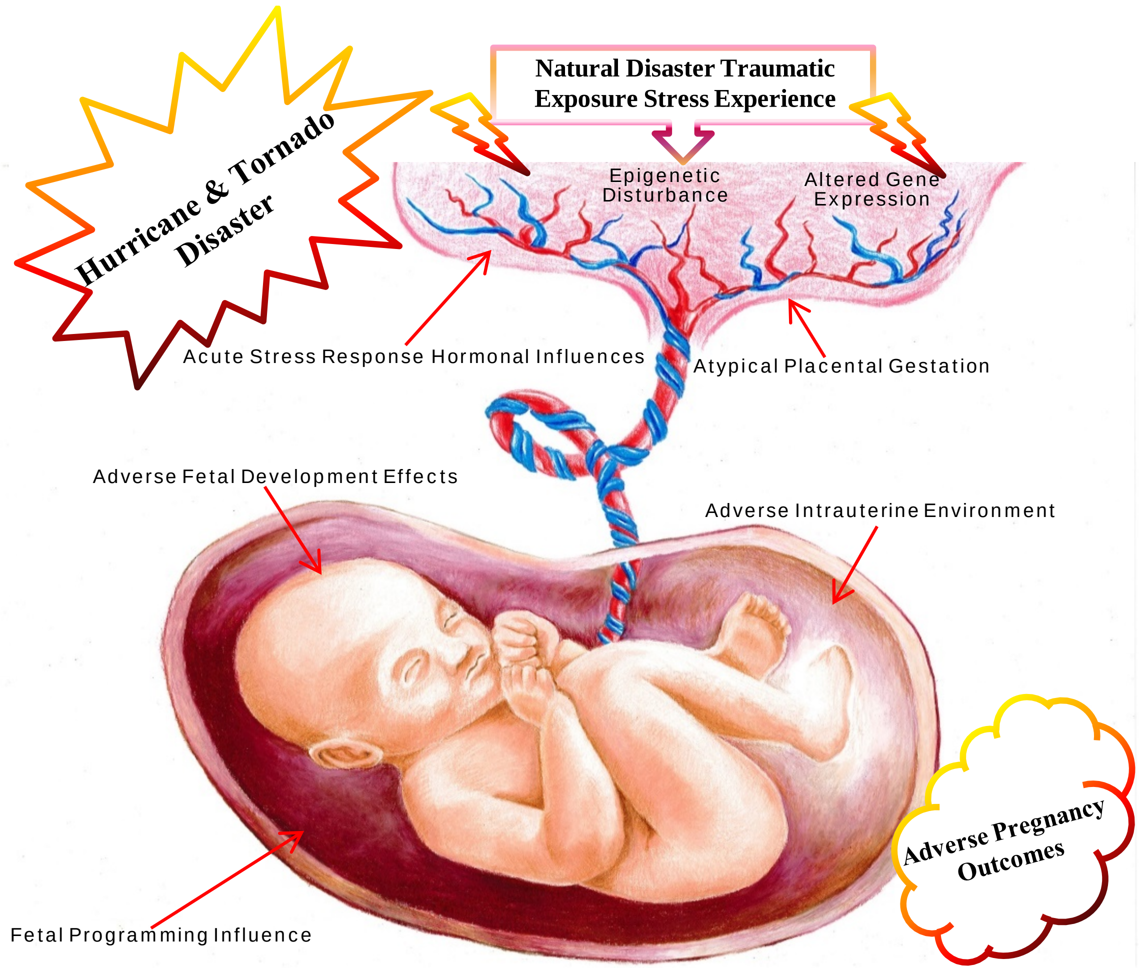

Figure 5. Summary description of the fetal programming model. Adapted from "The Ever Growing Complexity of Placental Epigenetics–Role in Adverse Pregnancy Outcomes and Fetal Programming,"by B. Novakovic and R. Saffery, 2012, *Placenta, 33*, p. 960. Copyright 2012 by Elsevier Ltd. Adapted with permission.

Adverse Pregnancy Outcomes

An adverse pregnancy outcome is an event which reduces the chance of delivering a healthy baby, and includes but is certainly not limited to, incidences of early pregnancy loss (spontaneous abortion), pre-eclampsia or eclampsia, preterm birth, delivery of low birth weight infants, and infant mortality (Pandolfi et al., 2014). Adverse pregnancy outcomes like preterm birth and low birth weight are serious public health concerns because their prevalence are concomitant with substantial perinatal mortality and morbidity, and poor health trajectories in later life (Ben-Shlomo & Kuh, 2002; Blencowe et al., 2013; Dunkel Schetter & Lobel, 2012; Dunkel Schetter & Tanner, 2012; Halfon et al., 2014; Lu, 2014; Morken, 2012). Understanding the attribution of the associations and potential pathways to adverse pregnancy outcomes like preterm birth, low birth weight, infant mortality is extremely important as the consequences include increased risk of morbidity, longer-term health and social complications, financial and emotional cost for impacted families, and an economic burden on communities due to increasing healthcare costs and long term treatment requirements (Johnson et al., 2013; Pandolfi et al., 2014; Soilly et al., 2014; Owen et al., 2013; Russell et al., 2007; Zhang et al., 2013).

Several researchers have suggested that adverse pregnancy outcomes like preterm birth, low birth weight, and infant mortality are a result of multiple considerations including direct health behavioral risk factors, and also detrimental environmental exposures during critical stages of fetal development (Barker, 2004; Ben-Shlomo & Kuh, 2002; Callaghan et al., 2007; Class et al., 2011; Dunkel Schetter, 2011; Dunkel Schetter & Glynn, 2011; Dunkel Schetter & Lobel, 2012; Dunkel Schetter & Tanner, 2012; Geller, 2004; Halfon et al., 2014; King & Laplante, 2015; Lu, 2014). Moreover, investigators have provided evidence implicating maternal prenatal exposure to environmental stress as a significant risk factor for adverse pregnancy outcomes (Callaghan et al., 2007; Class et al., 2011; Dunkel Schetter, 2011; Dunkel Schetter & Glynn, 2011; Dunkel Schetter & Lobel, 2012; Dunkel Schetter & Tanner, 2012; Geller, 2004; King & Laplante, 2015; Witt et al., 2014). A constellation of researchers have proposed that adverse pregnancy outcomes like preterm birth, low birth weight, infant mortality, and high incidents of cesarean deliveries are sensitive indicators of plausible maternal and infant health threats from environmental hazards such as hurricanes and tornadoes (Buekens et al., 2006; Currie & Rossin-Slater, 2013; Harville et al., 2009; Harville, Xiong et al., 2009; Harville et al., 2010; King & Laplante, 2015; Simeonova, 2011; Xiong et al., 2008; Xiong, 2010; Zahran et al., 2014; Zahran et al., 2013; Zahran et al., 2010; Zotti et al., 2012). In this study, adverse pregnancy outcomes include neonatal and maternal complications such as preterm birth, low birth weight, infant mortality, and mode of delivery via cesarean section. These pregnancy outcomes are population health measurements and leading health indicators of the U.S. Department of Health and Human Services Healthy People 2020 (2015) concept, which reflect major public health concerns of maternal, infant, and child health in individual U.S. communities, and nationwide.

Preterm birth. One in ten, or an estimated 15 million pregnancies were adversely impacted by preterm births internationally in 2010 (Blencowe et al., 2013; Blencowe et al., 2012). According to Liu et al., (2012, 2015) about 1 million preterm births contributed to neonatal mortality worldwide, in both calendar years 2010 and 2013. Globally, preterm birth is a significant public health concern as it is the second leading cause of death in children under the age of five, a major contributor to neonatal mortality and morbidity, and has long-term adverse health outcomes and significant cost implications for families and communities (Behrman & Butler, 2007; Blencowe et al., 2012; Liu et al., 2012; Liu et al., 2015). Commonly defined as a birth occurring prior to

37 complete weeks of gestation, subcategories of preterm birth classifications include extremely preterm birth (< 28 weeks), very preterm birth (< 32 weeks), early preterm birth (< 34 weeks), and late preterm (34-36 weeks); of which, late preterm comprises the most prevalent of the preterm classifications (Aylward, 2011; Jones & Lopez, 2014; Martin et al., 2015). Whereas the risks for morbidity and mortality are most significant for infants in the early preterm birth subcategory, even late preterm neonates are considered to have a higher probability for complications and poor health trajectories in later life, compared to infants born on or at 39-40 weeks, the full-term of gestation (Martin et al., 2015; McCabe, Carrino, Russell, & Howse, 2014).

In the United States, preterm births are a prominent public health concern due to the high burden of morbidity and mortality, and significant financial liability imposed on healthcare systems, and impacted families and communities (Behrman & Butler, 2007; Johnson et al., 2013; King et al., 2014; Mathews & MacDorman, 2013; McCabe et al., 2014; Soilly et al., 2014; Owen et al., 2013; Russell et al., 2007; Zhang et al., 2013). According to researchers for the U.S. Centers for Disease Control and Prevention, National Center for Health Statistics, the U.S. rate of preterm births in 2013 was approximately 11.4% (Martin et al., 2015). This proportion of preterm births is considered high in contrast to other developed countries, wherein 22 developed nations are reputed to have preterm birth rates below 7% (Chang et al., 2013; McCabe et al., 2014). Moreover, the 11.4% preterm birth rate ranks the United States thirty-seventh among thirty-nine countries with a very high human development index (VHHDI; Chang et al., 2013; McCabe et al., 2014). Figure 6 provides the percentage of U.S. preterm births for 2013, as reported by the National Center for Health Statistics (2014a).

Of the 11.4% U.S. preterm births in 2013, 8% were classified as late preterm infants, born around 34 to 36 weeks of gestation; and 3.4% early preterm neonates, born under 34 weeks of gestation (Martin et al., 2015). For the period of 2006 through 2013, the percentage of early term infants born in the United States declined about 14%, late preterm births dropped 13%, and full term birth increased 13% (Martin et al., 2015). Notwithstanding these improvements, researchers have posited that the U.S. preterm birth rate is substantively high considering more U.S. money per capita is spent on healthcare, than just about any other country in the world, and a reduction in the preterm birth rate to about 5% is imperative to endow children born in the United States, with a healthy start in life (McCabe et al., 2014). Whereas the outcomes of preterm birth are well-recognized, and despite the dedication of significant funding and research efforts, events contributing to its occurrence are not fully understood, and the etiology and causal pathway is allegedly multidimensional (Behrman & Butler, 2007; Blencowe et al., 2012; Liu et al., 2012; Liu et al., 2015; Martin et al., 2015; McCabe et al., 2014; Muglia & Katz, 2010). Contributing factors associated with preterm births include, but are not limited to, maternal-fetal influences and medical conditions, maternal health behavioral factors, socio-economic conditions, and genetic influences (Behrman & Butler, 2007; Muglia & Katz, 2010).

Preterm birth has been associated as a consequence of allostatic load, prenatal maternal stress, and environmental epigenetics (Dunkel Schetter, 2011; Dunkel Schetter

& Glynn, 2011; Dunkel Schetter & Lobel, 2012; Dunkel Schetter & Tanner, 2012; Hux, Catov, & Roberts, 2014; Wallace & Harville, 2013; Willis et al., 2014). Research investigators have given considerable attention and inquiry to the role of environmental influences such as exposure experiences to stressful incidents, including natural disasters and preterm birth outcomes (Callaghan et al., 2007; Class et al., 2011; Dunkel Schetter & Glynn, 2011; Dunkel Schetter & Lobel, 2012; Dunkel Schetter & Tanner, 2012; Geller, 2004; King & Laplante, 2015).

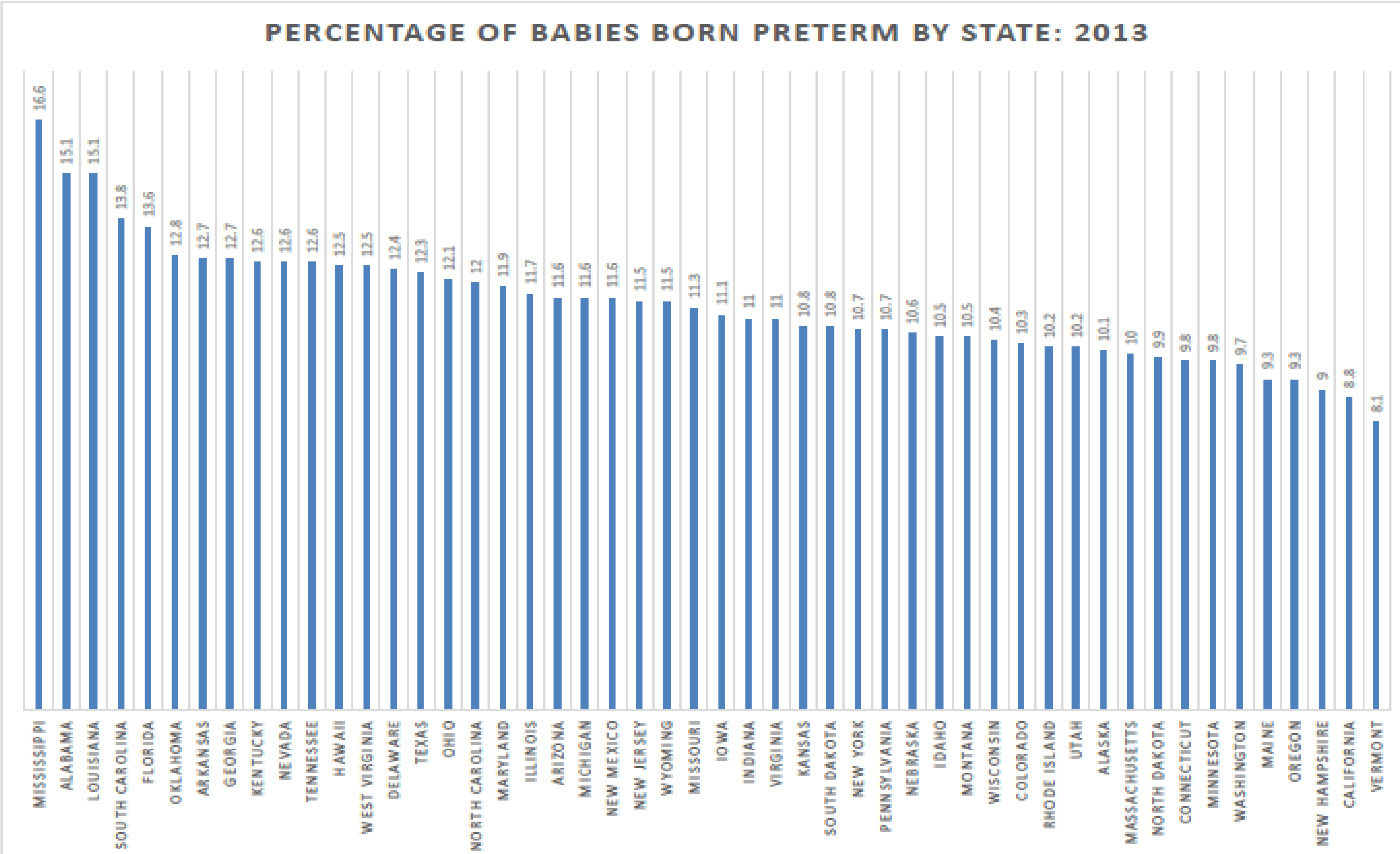

Figure 6. Proportion of U.S. infants born preterm in 2013. Adapted from "Percentage of Births Born Preterm, by State 2013, "by U.S. Centers for Disease Control and Prevention, National Center for Health Statistics, 2014a. Retrieved from http://www.cdc.gov/nchs/pressroom/states/preterm_state_2013.pdf

Several researchers have also imputed evidence suggesting maternal prenatal exposure to environmental hazards like hurricanes and tornadoes, could serve as acute stressor incidents with adverse implications for gestation and poor pregnancy outcomes, including preterm birth and low birth weight (Antipova & Curtis, 2015; Buekens et al., 2006; Currie & Rossin-Slater, 2013; Harville et al., 2009; Simeonova, 2011; Xiong et al., 2008; Zahran et al., 2014; Zahran et al., 2013; Zahran et al., 2010).

Low birth weight. Birth weight is an important indicator of fetal growth and well-being, and a significant predictor of neonatal health and survival (Baumann & Karel, 2013; Jones & Lopez, 2014). Weight at birth between 2500 grams (5.5 lbs or 2.5 kg) and 4500 grams (9.9 lbs or 4.5 kg), is regarded as within the normal birth weight range (Jones & Lopez, 2014). Infants born weighing less than 2500 grams are considered low birth weight and may be further sub-classified as very low birth weight (≤ 1,500 grams), or extremely low birth weight (≤ 1,000 grams; Aylward, 2011; Baumann & Karel, 2013; Jones & Lopez, 2014; Martin et al., 2015; Mazur-Mosiewicz & Dean, 2011). An additional subcategory of moderately low birth weight (1,500 grams to 2,499 grams) is utilized by the U.S. Centers for Disease Control and Prevention, National Center for Health Statistics to stratify and describe low birth weight infants (Martin et al., 2015). Low birth weight among a cohort of neonates could result from the effects of being small for gestational age (intrauterine growth restriction), prematurity--with the majority of very low birth weight neonates encompassing the latter category, or as a permutation of both effects (Aylward, 2011; Baumann & Karel, 2013; Mazur-Mosiewicz & Dean, 2011).

Low birth weight is a significant perinatal complication with profound public health implications worldwide (Baumann & Karel, 2013; Blencowe et al., 2013; Lee et al., 2013). Globally, about 18 to 20 million babies are born with low birth weight annually, with an estimated 59% of these attributed to growth restriction and 41% to prematurity (Lee et al., 2013). Analyses of low birth weight statistics from 138 low and middle income countries, indicate there were approximately 10.6 million low birth weight infants for the year 2010 (Lee et al., 2013). Recent data from the United Nations International Children's Emergency Fund (UNICEF, 2014) indicate there were about 22 million infants born with low birth weight worldwide (about 16% of all births), in 2013. In the United States, the average full-term neonate's weight at birth is between 3175 grams (7.0 lbs or 3.2 kg) and 3400 grams (7.5 lbs or 3.4 kg; Jones & Lopez, 2014; Newman & Newman, 2015).

According to Martin, Hamilton, Osterman, Curtin, and Mathews (2015) and the National Center for Health Statistics (2014b), data for the United States show 8.02% of all infants born in 2013, were at low birth weight. Of the 8.02% low birth weight infants, 6.61% were classified as moderately low birth weight and 1.41% at very low birth weight (Martin et al., 2015). The rates of very low birth weight and low birth weight were incrementally higher for the period of 2004 to 2006; respectively peaking at 1.49 and 8.26, but decreasing modestly to 1.41 and 8.02 in 2103 (Martin et al., 2015). A state by state comparison of low birth weight figures for 2013 is provided in figure 7.

Several factors appear to influence fetal growth and increase the risks of delivering a low birth weight infant, including issues associated with the fetus, maternal health behavioral factors, maternal-fetal influences and medical conditions, placental considerations, and other influences generated from the interaction among these elements and dynamics (Jones & Lopez, 2014; Newman & Newman, 2015; Nkwabong, Nounemi, Sando, Mbu, & Mbede, 2015). But, the placenta, as the principal interface with maternal and fetal exchange of essential constituents like nutrients and oxygen, has a profound influence on birth weight and conditions in which there are disturbances with efficient placental circulation appear concomitant with adverse pregnancy outcomes such as intrauterine growth restriction and low birth weight (Challis et al., 2014; de Jongh, Mackley, Jain, Locke, & Paul, 2015; Jones & Lopez, 2014; Nkwabong et al., 2015;).

Despite the fact advances in maternal-fetal and neonatal medicine has enhanced the prospects for neonates born at low birth weight, prudent approaches in moderating its consequences may include identifying, eluding and mitigating those risk factors which engender this condition.

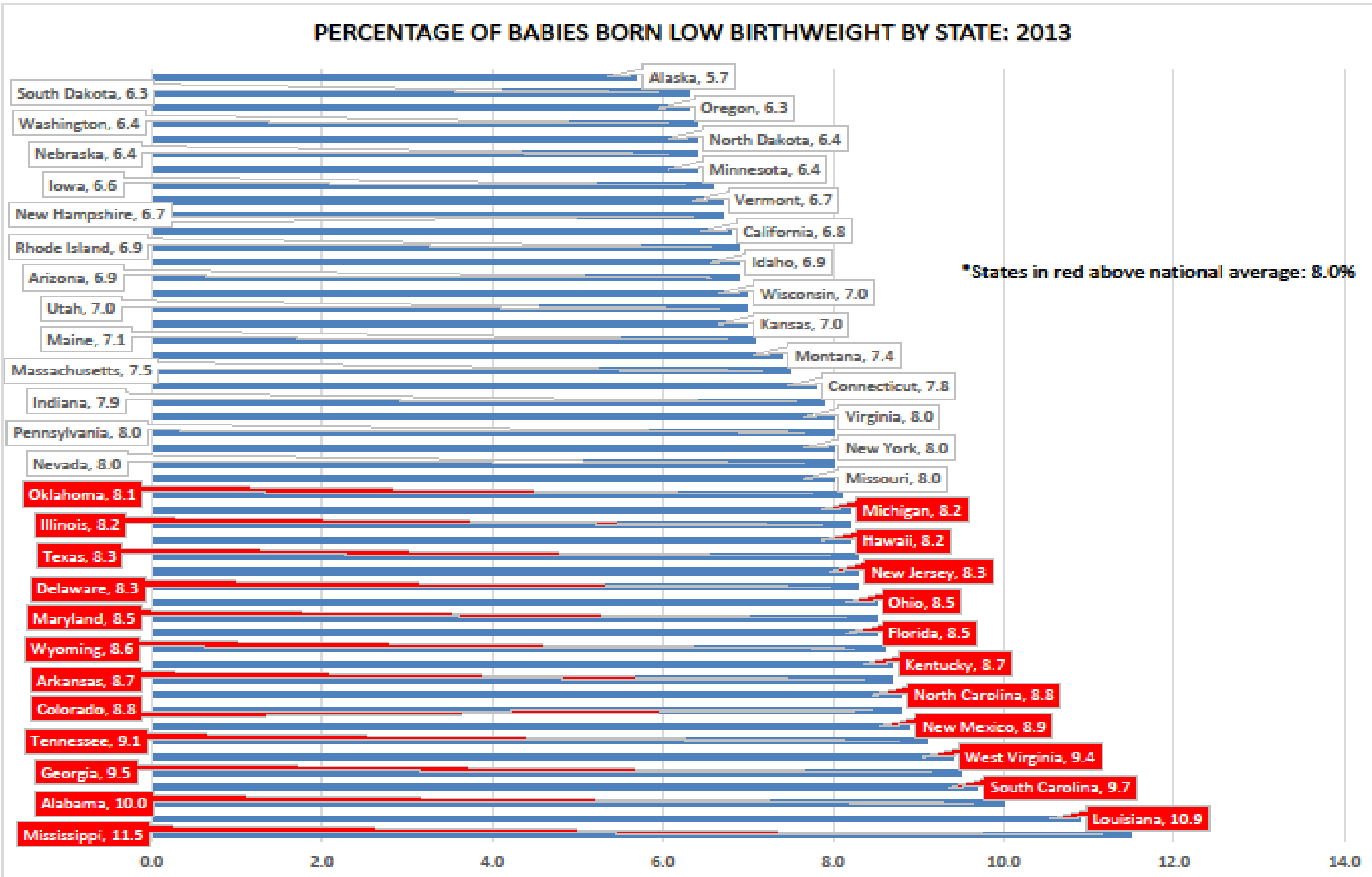

Figure 7. Percentage of U.S. infants born at low birth weight in 2013. Adapted from "Percentage Born Low Birthweight by State 2013, "by U.S. Centers for Disease Control and Prevention, National Center for Health Statistics, 2014b. Retrieved from http://www.cdc.gov/nchs/pressroom/states/lbw_state_2013.pdf

Similar to preterm birth, researchers have implicated environmental influences such as exposure experiences to natural disasters, and prenatal maternal stress and the stress response effects (allostatic load) to adverse pregnancy outcomes like low birth weight (Callaghan et al., 2007; Class et al., 2011; Dunkel Schetter, 2011; Dunkel Schetter & Glynn, 2011; Dunkel Schetter & Lobel, 2012; Dunkel Schetter & Tanner, 2012; Geller, 2004; King & Laplante, 2015; Oyarzo et al. , 2012; Sherrieb & Norris, 2013; Simeonova, 2011; Tong et al., 2011; Torche, 2011; Torche & Kleinhaus, 2012; Xiong et al., 2008).

There are numerous consequences associated with suboptimal birth weight which are not individually limited to the neonate. Low birth weight as a pregnancy outcome could have substantial financial, emotional, and health impacts for families and communities, as low birth weight infants are more likely--in comparison to infants born at normal birth weight, to experience lengthy hospitalizations at birth, a greater risk for neonatal morbidity and mortality, and a poor health trajectory in later life (Aylward, 2011; Behrman & Butler, 2007; Baumann & Karel, 2013; Dunlop, Salihu, Freymann, Smith, & Brann, 2011; King et al., 2014; Mathews & MacDorman, 2013). Investigators from the U.S. Centers for Disease Control and Prevention, National Center for Health Statistics found low birth weight as a substantial contributing factor to severe infant mortality (Kochanek, Murphy, Xu, & Arias, 2014). Moreover, low birth weight among infants in the United States, was the second leading cause of neonatal deaths in 2013 (Kochanek et al., 2014).

Infant mortality. Infant mortality is a term used to describe deaths among infants who experienced a live birth and subsequently expired during the first year of life

(CDC, 2014; Stavrou & Anastassiou-Hadjicharalambous, 2011). Live births are characterized by the World Health Organization (WHO, 2014) as the complete delivery from its mother of the product of human conception either by vaginal or Cesarean section and regardless of gestational duration; which after delivery proffers evidence of life, like respiratory breathing, a heartbeat, umbilical cord pulsation, or distinct movement of voluntary muscles, for any duration of time and irrespective of the integrity of the umbilical cord or placenta. Infant mortality is often sub-classified as neonatal mortality (occurring during zero to 27 days of life), or post neonatal mortality (> 27 days and less than 1 year; CDC, 2014; Stavrou & Anastassiou-Hadjicharalambous, 2011). These stratifications are valuable as the leading causes of neonatal deaths are often disparate in comparison to the principal causes of post neonatal deaths (Heron, 2013; Stavrou & Anastassiou-Hadjicharalambous, 2011). Although the antecedence of causes may vary by country, neonatal mortality is normally concomitant with short gestation and low birth weight, birth defects, and maternal complications of pregnancy (Heron, 2013; Liu et al., 2012; Liu et al., 2015). Whereas, post neonatal mortality is often correlated with Sudden Infant Death Syndrome (SIDS), congenital malformations, infectious causes, diarrhea, influenza and pneumonia, and unintentional injuries due to accidents (Heron, 2013; Liu et al., 2012; Liu et al., 2015).

Infant mortality is an important index of population health, with measures reflecting diverse issues including maternal and infant health status, the quality of and access to medical care and services, well-being, underlying socioeconomic conditions, racial disparities, and public health practices (CDC, 2014; MacDorman, Matthews, Mohangoo, & Zeitlin, 2014; Stavrou & Anastassiou-Hadjicharalambous, 2011). It is also a multifaceted phenomenon with a sundry of risk factors, including aspects related to maternal health prior to and during gravidity (e.g. maternal health behaviors, maternal prenatal stress); influences associated with the gestational experience (e.g. anemia, gestational diabetes, maternal complications, socioeconomic conditions, maternal age and education, race/ethnicity, adverse environmental exposure experiences like impacts from natural disaster stressors); issues related with birth and the neonate (e.g. low birth weight, preterm birth, congenital malformations), and factors connected with infant health during the first year of birth (e.g. infectious causes, diarrhea, influenza and pneumonia, and unintentional injuries; CDC, 2014; Hirai et al., 2014; MacDorman et al., 2014; Stavrou & Anastassiou-Hadjicharalambous, 2011). Regarded as a sentinel event, infant mortality is a major public health concern as it is a sensitive indicator of the health of communities at national and international levels (Hirai et al., 2014; MacDorman et al., 2014; Stavrou & Anastassiou-Hadjicharalambous, 2011). In calendar year 2013, approximately 6.3 million children died worldwide before their fifth birthday; and 44% (2.8 million) occurred during the neonatal period, and 55% (3.5 million) in the post neonatal period (Liu et al., 2015).

To calculate the proportional impact of infant mortality on communities, the infant mortality rate is imputed as the measure of infant deaths one year of age and younger, in a given calendar year, per 1,000 live births in the same year (CDC, 2014; Stavrou & Anastassiou-Hadjicharalambous, 2011). Considering these variables are necessary to estimate the infant mortality rate for a given year, it is worth mentioning that not all infant deaths ensue in the same calendar year of birth. Accordingly, to compute a factual probability and correlate the infant mortality rate to a firmly reported likelihood with a well-defined population at risk, it would seem prudent to ascribe infant mortality indicators from linked birth/infant death cohort data (Matthews & MacDorman, 2013). Upon imputing infant mortality data from calendar year 2010, researchers found the United States to have a higher infant mortality rate than any of the other Organization for Economic Cooperation and Development (OECD) countries evaluated, ranking the United States 26th out of 26 OECD countries examined (MacDorman et al., 2014).

In 2013, the United States was tiered as 31st in the world in infant mortality, among OECD countries (OECD, 2013). This ranking was based on a three year average of infant mortality statistics from 2009 through 2011, and placed the United States behind most European nations, Australia, Canada, Israel, Japan, South Korea, and New Zealand (OECD, 2013). Although healthcare spending in the United States is substantively higher than any other country in the world, researchers suggests an infant born in the United States is less likely to survive beyond their first birthday than an infant born in other OECD countries like Australia, Belgium, Canada, Hungary, Ireland or New Zealand (MacDorman et al., 2014; OECD, 2013). According to MacDorman et al. (2014) the U.S. infant mortality rate of 6.1 infant deaths per 1,000 live births, demonstrates that an infant born in the United States in 2010, was nearly three times as likely to die during the first year of life in comparison to an infant born in Finland (rate of 2.3 infant deaths per 1,000 live births). Correspondingly, investigators from OECD suggest that a baby born in the United States during the period of 2009 throughout 2011, were approximately six times more likely and three times as likely to experience death in the first year of life compared to a baby born in Iceland and Sweden or Japan, respectively (OECD, 2013).

The U.S. infant mortality rate (IMR) for 2012 (IMR of 6.1), conceals a sizable disparity amongst individual states (see figure 8), as Mississippi with its rate of 9.6 infant deaths per 1,000 live births, not only exceeds the national average, but would rank marginally ahead of the Russian Federation (9.8 infant deaths per 1,000 live births) at the 39th tier in the world ranking of OECD countries, and place slightly behind Turkey with its rate of 7.7 infant deaths per 1,000 live births (OECD, 2013). Upon examining the infant mortality rate in the United States, researchers found the higher rates were amongst racial and ethnic minorities; in most southern states; and may be attributable in large part to a higher proportion of preterm births, which is a significant risk factor correlated with infant mortality (Hirai et al., 2014; MacDorman et al., 2014; Matthews & MacDorman, 2013). Furthermore, other factors like the incredible disparity in the United States, with low education rates amongst certain racial, ethnic and socioeconomic classes; unmarried mothers with a lack of or limited financial, social, and emotional resources; and inequities in access to adequate and affordable healthcare service amongst less advantaged racial and ethnic groups may also own to the much higher infant mortality rates (Hirai et al., 2014; MacDorman et al., 2014; Matthews & MacDorman, 2013).

It is equally noteworthy to mention, the U.S. mortality rate appeared much higher during the post neonatal period than in the neonatal period (Hirai et al., 2014; MacDorman et al., 2014; Matthews & MacDorman, 2013).

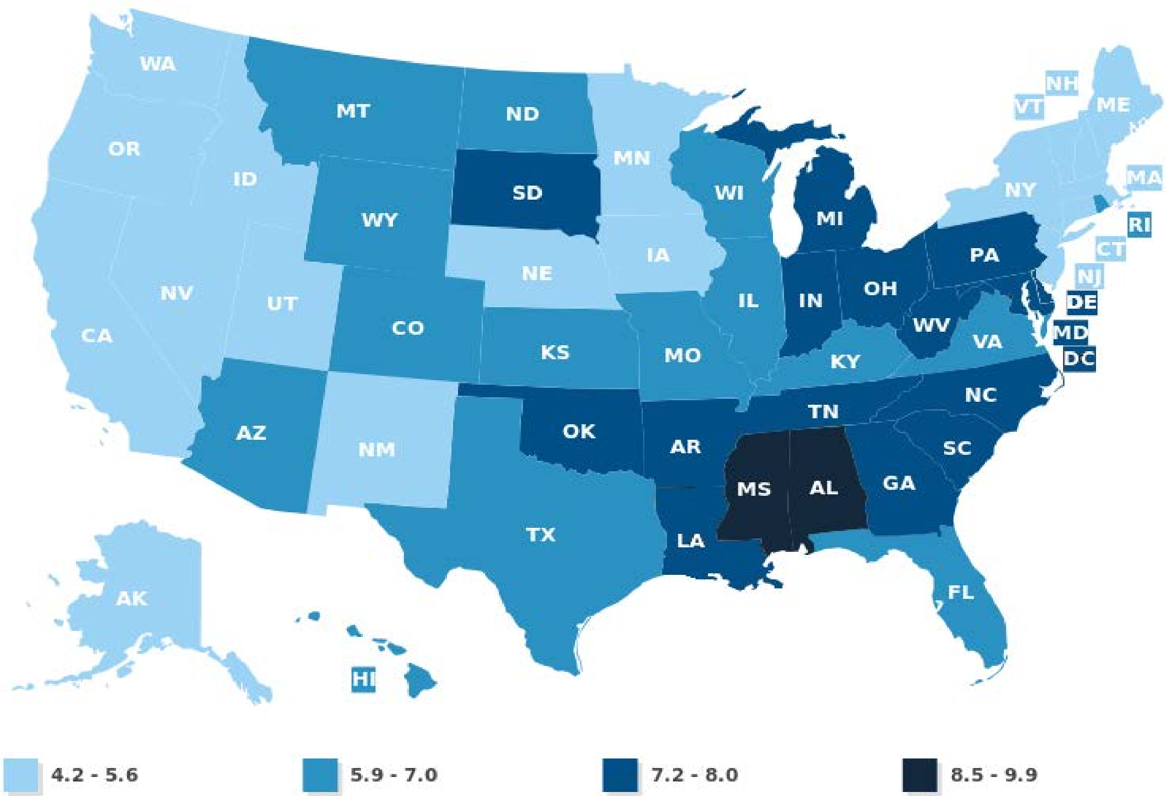

Figure 8. U.S. infant mortality rate assessed by state for 2012. Adapted from "Infant Mortality Statistics from the 2010 Period Linked Birth/Infant Death Data Set, "by Matthews & MacDorman, 2013. Retrieved from http://www.cdc.gov/nchs/data/nvsr/nvsr62/nvsr62_08.pdf

A plausible elucidation to this occurrence may be accredited to the high quality of care a neonate born preterm, at low birth weight, or with health complications receives at birth in U.S. hospitals, compared to the poor or much less access to quality healthcare, the same infant born to a disadvantaged family, may experience and have to endure throughout the post neonatal period (Hirai et al., 2014).

Mode of delivery. Mode of delivery or method of birth is a term often used to characterize the entry of a newborn to the world. The mode of delivery in childbirth occurs either through the complete expulsion and presentation of the neonate via vaginal delivery, or extraction as a result of a caesarean section (NCHS, 2012). In order to achieve an optimal pregnancy outcome, healthcare professionals often discern and apply when feasible and to the extent practical, the most ideal mode of delivery of a fetus, while measuring anticipated risks for adverse pregnancy outcomes with a preferred method of birthing (Jones & Lopez, 2014; Kaye et al., 2014; Miller, Hahn, & Grobman, 2013; Patterson, Winslow, & Matus, 2008). The mode of delivery of a fetus is particularly noteworthy as the method of birth could have a variety of consequences for both mother and the infant, including short and long term health related quality of life complications, and morbidity and mortality issues (Jones & Lopez, 2014; Miller et al., 2013; Patterson et al., 2008).

In a vaginal delivery, birth of the fetus originates with the process of labor to encourage uterine contractions and enable transit of the fetus through the cervix, and delivery of the neonate to its new environment (Jones & Lopez, 2014; Newman & Newman, 2015; Patterson et al., 2008). Vaginal deliveries could be *spontaneous* or *normal*, occurring without the utilization of medicines, surgical practices, or instruments to engender expulsion of the fetus (Jones & Lopez, 2014; Newman & Newman, 2015; Patterson et al., 2008). A vaginal delivery may also be *assisted* and facilitated by a healthcare provider with specified techniques including forceps delivery or vacuum extraction, with or without the exploitation of medications to induce labor and hasten delivery (Jones & Lopez, 2014). Similarly, vaginal deliveries could include methods employed by a healthcare provider like the use of medicines or specialized procedures, to *induce* labor and accelerate vaginal delivery (Jones & Lopez, 2014; Patterson et al., 2008).

Vaginal deliveries, including *assisted* and *induced*, have been associated with numerous maternal and neonatal risks, and complications. Maternal risks and complications could include, but are not limited to, pelvic pain, urinary and anal incontinence, vaginal soreness, perineal tearing, scar tissue constructions, urinary tract infections, postpartum hemorrhage, and pelvic organ prolapse (Andrews, Shelmeridine, Sultan, & Thakar, 2013; Gyhagen, Bullarbo, Nielsen, & Milsom, 2013; Hirayama et al., 2012; Lumbiganon et al., 2010; Svare, Hansen, & Lose, 2014; Wesnes & Lose, 2013). In the neonate, an assortment of complications may encompass adverse neonatal outcomes like intracranial trauma and hemorrhage, extra-cranial subgaleal bleeds, risks for convulsions or encephalopathy, shoulder dystocia (shoulders wedged), scalp trauma, clavicular fractures, contusions, and brachial plexus and other neurological injuries (Ekéus, Högberg, & Norman, 2014; Linder et al., 2013; Walsh, Robson, & McAuliffe, 2013; Yeomans, 2010).

Although a normal vaginal delivery is considered the most natural and optimal mode of delivery, there could be instances where a vaginal birth is not feasible due to life threatening maternal or perinatal complications, and a surgical procedure is required to extract the fetus (Jones & Lopez, 2014; Patterson et al., 2008; Smith, 2010; Walsh et al., 2013). In these occurrences, a surgical intervention called a caesarean section or C-section may be performed to deliver the newborn through a surgical incision in the expectant mother's abdominal wall and uterus (Jones & Lopez, 2014; Smith, 2010; Osterman & Martin, 2014a). C-sections are one of the most frequently performed surgeries in the United States, where approximately one in three neonates are birthed via this mode of delivery (Osterman & Martin, 2014a; 2014b). In calendar year 2013, the proportion of U.S. C-section deliveries was 32.7% (about 1.3 million) of all births, with 27% (about 340 thousand) occurring in low risk pregnancies, those characterized as gestations with no maternal or fetal influences which could threaten the pregnancy with complications (Osterman & Martin, 2014a; 2014b).

C-sections could have extreme implications for the birthing mother, neonate, and the healthcare system (Osterman & Martin, 2014a; Jackson et al., 2012; Smith, 2010; Witt et al., 2015). As C-sections are a major surgical procedure, there are inherent maternal and neonatal risk of complications, and intrinsic threats to escalate healthcare cost as fees associated with C-sections are oftentimes substantially higher than those connected with vaginal deliveries (Osterman & Martin, 2014a; Smith, 2010; Souza et al., 2010; Witt et al., 2015). Although C-sections are emerging as a common elective mode of delivery, there are circumstances and indications in the research and medical literature substantiating the medical necessity for C-section deliveries (Jones & Lopez, 2014; Smith, 2010). These indications include the inability of the fetus to navigate the pelvic canal; a breech mal-presentation; failure of labor progression; umbilical cord compression and prolapsed umbilical cord; irregular placentation such as placenta previa, placenta vasa previa, placenta abruption; preeclampsia; repeat C-section; certain maternal infections including active genital herpes, HIV infection with high viral load, and cervical cancer; fetal indications like spinal bifida, severe hydrocephaly, multi-fetal gestations (e.g. twins, triplets, and other higher order fetuses), and fetal distress and airway obstruction situations necessitating ex utero intrapartum treatment procedures (Al Rowaily, Alsalem, & Abolfotouh, 2014; Demirci, Tuğrul, Turgut, Ceylan, & Eren, 2012; Jones & Lopez, 2014; Pacher, Brix, & Lehner, 2014; Stivanello, Rucci, Lenzi, & Fantini, 2014; Unger et al., 2014; Wu et al., 2014).

Whereas C-sections as a mode of delivery could benefit the neonate in certain situations, several researchers have posited there are significant maternal and neonatal risks and adverse outcomes connected with this obstetrical intervention (Al Rowaily et al., 2014; Jones & Lopez, 2014; Mercer, 2013; Prior & Kumar, 2014; Smith, 2010; Souza et al., 2010; Werner, Han, Savitz, Goldshore, & Lipkind, 2013; Witt et al., 2015). Maternal risk and complications correlated with C-sections include anesthesia mishaps (like adverse drug responses, aspiration pneumonia, and difficulties with intubation); postpartum hemorrhages and the potential need for blood transfusions; surgical trauma to the bowels or bladder; embolisms; infections (e.g., endometritis, urinary tract infections, and surgical wound infections including cellulitis); vein thrombosis; bowel dysfunction (including bowel obstruction consequential to intra-abdominal adhesion scarring); delayed lactogenesis and decreased initiations of breast feedings; and maternal mortality (Al Rowaily et al., 2014; Jones & Lopez, 2014; Mercer, 2013; Smith, 2010; Souza et al., 2010). Moreover, C-sections often entail lengthier hospitalizations, and increases the probability of postpartum readmissions in comparison to normal vaginal deliveries (Jones & Lopez, 2014; Smith, 2010; Souza et al., 2010; Witt et al., 2015). Neonatal risks and adverse outcomes linked with C-sections include respiratory complications; trauma due to the surgical intervention; clavicle fracture; brachial plexus; skull fracture; intracranial hemorrhage (e.g., cephalo-hematoma); odds for allergic rhinitis; increased risk for neonatal mortality (particularly in instances of no labor complications); and facial nerve palsy (Jones & Lopez, 2014; Mercer, 2013; Prior & Kumar, 2014; Smith, 2010; Werner et al., 2013).

Mode of delivery (vaginal versus unplanned C-section) has been linked as a credible pregnancy outcome consequential to influences like prenatal maternal stress, and hurricane natural disaster incidents (Hamilton et al., 2009; Harville, Tran et al., 2010; Ko, Lin, & Chen, 2014; Saunders, Lobel, Veloso, & Meyer, 2006; Zahran et al., 2013). An increased occurrence of C-section deliveries have been associated with hurricane natural disasters (Hamilton et al., 2009; Harville, Tran et al., 2010; Zahran et al., 2013). Researchers have posited a plausible strong correlation between prenatal maternal stress--including exposure experiences to hurricanes, duration and difficulty of labor, the exploitation of medicines for the management of labor, and mode of delivery (Hamilton et al., 2009; Harville, Tran et al., 2010; Ko et al., 2014; Lowe, 2007; Saunders et al., 2006; Zahran et al., 2013).

A prominent elucidation suggests labor complications could be triggered by maternal stress and/or fetal distress, or may be caused by environmental exposure experiences to natural disasters like hurricanes, which consequently could necessitate the utilization of medications for episodic relief of labor pains (Ko et al., 2014; Saunders et al., 2006; Zahran et al., 2014; Zahran et al., 2013; Zahran et al., 2010). Saunders, Lobel, Veloso, and Meyer (2006) advanced the theory that pregnant women with increased prenatal maternal stress are more likely to require medicines for the effective management of labor pains, thus increasing the probability of an unplanned obstetrical intervention via C-section. Research evidence from Zahran, Peek, Snodgrass, Weiler, and Hempel (2013) show pregnant women with exposure to hurricanes had an increased likelihood of stress induced dystocia (abnormal labor), and a C-section mode of delivery. The findings of Zahran, Peek, Snodgrass, Weiler, and Hempel (2013) appear consistent with Lowe's (2007) observation that a constellation of factors including prenatal maternal stress, fetal issues, and environmental considerations could influence the mode of delivery.

Summary and Conclusions

Chapter 2 described the search strategy exploited in the review of the body of available literature, and presented relevant data on the effects of maternal prenatal exposure to hurricane and tornado disasters on pregnancy outcomes. Researchers have posited maternal prenatal exposure to natural disasters like hurricanes and tornadoes, could contribute to an increased risk of unhealthy pregnancies, adverse pregnancy outcomes, neonatal health complications, and poor health trajectories in later life (Antipova & Curtis, 2015; Currie & Rossin-Slater, 2013; Hamilton et al., 2009; Harville et al., 2009; Harville et al., 2010; Simeonova, 2011; Xiong et al., 2008; Xiong, 2010; Zahran et al., 2014; Zahran et al., 2013; Zahran et al., 2010; Zotti et al., 2013).

As the objective of this investigation was to examine the effects of maternal prenatal exposure to a hurricane and tornado disaster on pregnancy outcomes including mode of delivery, the life course perspective provided the relevant framework to examine the associations of maternal prenatal exposure to these weather phenomena on adverse maternal and infant health outcomes (Ben-Shlomo & Kuh, 2002; Elder et al., 2003; Halfon & Hochstein, 2002; Halfon et al., 2014; Lu, 2014; Lu & Halfon, 2003; Lu et al., 2010). The life course approach is appropriate to this investigation because it enables consideration of biological, behavioral, social, and environmental factors which could individually or synergistically influence maternal and infant health outcomes (Barker, 2004; Ben-Shlomo & Kuh, 2002; Elder et al., 2003; Halfon & Hochstein, 2002; Halfon et al., 2014; Lu, 2014; Lu & Halfon, 2003; Lu et al., 2010). Integral to the life course model is the early programming concept which advances the theoretical consideration that maternal prenatal exposure to experiences like natural disasters incidents, could induce stress responses during critical periods of gestation, and adversely influence the structure and functions of cells, organs, and body systems with serious implications for health risks and disease conditions (Halfon & Hochstein, 2002; Lu & Halfon, 2003).

In this literature review, contextual information on hurricanes, tornadoes, pregnancy, epigenetic programming, and adverse pregnancy outcomes is provided. Available evidence from researchers examining the effects of maternal prenatal exposure to hurricanes on maternal and infant health outcomes, including preterm birth, low birth weight, mode of delivery, and pregnancy complications like abnormal labor, fetal mortality, and fetal distress are included in the discourse. The literature review discussion also provides the groundwork to illustrate how this investigation could address several research gaps in the current literature, including limited studies investigating maternal prenatal exposure to hurricanes and maternal and infant health outcomes; the dearth of empirical evidence on the effects of hurricanes on infant mortality; and the limited research on the influence of maternal prenatal exposure to tornadoes on maternal and infant health outcomes (Buekens et al., 2006; Kanter, 2010; Zahran et al., 2014; Zahran et al., 2013).

Measuring the association of maternal prenatal exposure to hurricanes and tornadoes on maternal and infant health outcomes could help determine their effects on adverse pregnancy outcomes including mode of delivery, and help elucidate potential risk factors which may contribute to infant mortality (Buekens et al., 2006; Kanter, 2010; Zahran et al., 2014; Zahran et al., 2013). Given the incidence, strength, and deleterious effects of hurricanes and tornadoes in the United States in recent years, discoveries from this study could also help advance public health and emergency preparedness by providing evidence-based data, painting a more lucid picture of the magnitude and severity of specific public health challenges associated with pregnant women and the developing fetus, who reside in areas prone to hurricane and tornado disasters (Zahran et al., 2013; Zotti et al., 2012).

The research methodology is presented in Chapter 3, and described with the necessary fidelity of details to enable replication of this investigation. The research design and rationale for selection, study variables, target population and sampling measures, and permissions and procedures required for attaining access to the archival dataset, are described in the next chapter. Operational definitions for the variables of interest; the treatment, management and analysis of the data, including the statistical software application, statistical tests, and the parameters for the interpretation of results; threats to validity; and ethical procedures are also described in Chapter 3.

Chapter 3: Research Method

Introduction

The research design and methodology for this investigation are provided in this chapter. The purpose of this quantitative, retrospective, cross-sectional population based study was to examine the association between maternal prenatal exposure to a hurricane and tornado disaster, on pregnancy outcomes, such as birth weight, preterm birth, infant mortality, and the mode of delivery. Maternal characteristics to include sociodemographic factors, health behaviors, pregnancy history, and maternal health status were also examined. In this investigation, the dependent variables of interest were birth weight, preterm birth, infant mortality, and mode of delivery. The primary independent variable of interest was maternal prenatal exposure to a hurricane or tornado disaster incident; and the covariates were socio-demographic factors, health behaviors, pregnancy history, and maternal health status.

This chapter is organized in five sections. The first section of the chapter proffers a detailed description of the study's variables of interest, the union between the research design and the research questions, and the nomination and validation of the research approach delineated in this investigation. The second segment is the methodology section, which describes the population of interest, sampling strategy, and procedures for archival data collection and exploitation. The third segment provides an operational characterization of the variables of interest; and the projection for the analysis of the data, to include a description of the statistical software application; statistical models for analysis; and the parameters for the interpretation of the evidence. This is followed by a description of the external, internal, and statistical threats to validity in the fourth segment. The chapter then concludes with an explication on ethical procedures including Institutional Review Board (IRB) procedures; archival data access, management, and storage; a chapter summary, and a transition statement to Chapter 4.

Research and Rationale

The dependent variables of interest in this investigation were birth weight, preterm birth, infant mortality, and mode of delivery as reported by the Alabama Department of Public Health, and the Mississippi State Department of Health, in the registration of vital events reporting mechanism to the National Vital Statistics System (NCHS, 2015a). Data for the dependent variables were obtained from the national linked birth and infant death dataset, compiled by the National Center for Health Statistics (2015b). The independent variable of interest was maternal prenatal exposure to a hurricane or tornado disaster incident as determined by comparing and reconciling residence data obtained from the county-level linked birth and infant death files with SHELDUS data reflecting the severity of the effects (fatalities > 10 and property loss > $10 million) of Hurricane Katrina on 29 August 2005, in the counties of Hancock, Harrison, Jackson, and Jones, Mississippi; and the 27-28 April 2011, Alabama tornado disaster on the counties of Calhoun, DeKalb, Franklin, Jefferson, Lawrence, Limestone, Madison, Marion, St. Clair, and Tuscaloosa, Alabama.

Figure 9 describes the retrospective assessment scheme used in the selection of the aforementioned counties for this study. A detailed description of disaster impact data with observable thresholds: fatalities (>10 victims) and property damage (> $10 million), by affected states and counties with the highest fatalities and property damage, is provided in Table 1. Although Mississippi counties did not yield the highest hurricane fatalities and property damages for the period of 2002 through 2012, they were selected for this study due to a lack of systematic knowledge on the impact of Hurricane Katrina on pregnancy outcomes in Mississippi, as evidenced by a recent review of available empirical research. Covariates in this study were socio-demographic factors, health behaviors, pregnancy history, and maternal health status as reported in the linked dataset (NCHS, 2012; 2015b).

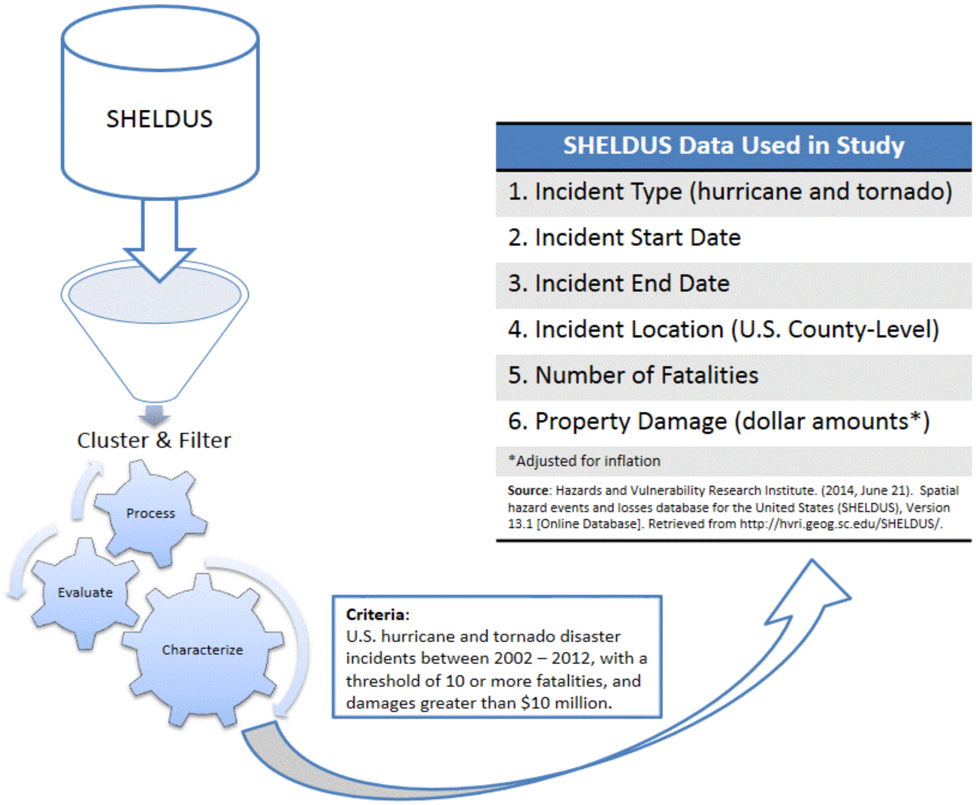

Figure 9. Retrospective assessment scheme used for disaster selection by severity effects, state and county. By K. Christopher, 2015.

The research design was a retrospective, cross-sectional, cohort, with a population-based secondary data analysis of birth outcomes, exploiting the Alabama and Mississippi Linked Infant Births and Deaths Record File for 1997-2013. A retrospective, cross-sectional design is appropriate to this study as it is unethical, unlawful, and inhumane to deliberately subject participants to the investigational and control conditions necessary for this inquiry in a genuine experimental design. Furthermore, since experimental approaches necessitate the random assignment of research subjects to experimental and control conditions, and disasters often emerge unpredictably; a research study exploiting a natural disaster as a mediating variable is appropriate as a retrospective, cross-sectional, cohort design with comparison groups and not controls, and is consistent with Dodds and Nuehring (1996) public health and social inquiry model for ex post facto analysis of exposure status and disaster outcomes, among comparison groups (Aschengrau & Seage, 2014; Jacobsen, 2012).

A quantitative methodology, and retrospective, cross-sectional, cohort design is equally appropriate to this study for several reasons. First, the aim of this investigation was to test a hypothesis. Second, the focus of the investigation was aimed at addressing the research questions, which mandate a quantitative response to statistically explain associations between the variables of interest, and enable analysis of exposures and probable outcomes among a cohort of pregnant women (Aschengrau & Seage, 2014; Creswell, 2014; Jacobsen, 2012). Third, this study exploited population-based linked birth and infant death data to produce statistical values, which could successively be translated to either support or reject the hypotheses, and impute inferences to larger populations (Aschengrau & Seage, 2014; Creswell, 2014; Jacobsen, 2012). And fourth, cross-sectional design research investigations are typically generalizable and economical as they could be conducted over reduced periods of time (Aschengrau & Seage, 2014; Jacobsen, 2012). Therefore, the quantitative, cross-sectional, cohort approach would facilitate county level comparisons of birth outcomes among pregnant women exposed to the disaster variable, with pregnant women who were not exposed, and statistically elucidate relationships and help postulate factors discerning the scope of the association between the variables of interest (Aschengrau & Seage, 2014; Creswell, 2014; Jacobsen, 2012).

The secondary data analysis approach offered several advantages to this research endeavor. First, it afforded an immense cost-effective benefit, as it significantly decreased the amount of time needed to collect data (Aschengrau & Seage, 2014; Boslaugh, 2007; Bryman, 2012). Second, it offered a greater breadth of available data from secondary sources such as the national vital statistics birth and death data files, which have a predisposition for a larger sample size and representativeness of the data to generalized populations (Aschengrau & Seage, 2014; Boslaugh, 2007; Bryman, 2012). And third, the data collection procedures from a cooperative enterprise system like the national vital statistics instruments, are standardized and normally informed by a degree of proficiency and competence, thereby increasing confidence in the fidelity of the data and reducing elements of bias (Aschengrau & Seage, 2014; Boslaugh, 2007; Bryman, 2012). Conversely, there are disadvantages and limitations associated with the use of secondary data, including the inability of the investigator to control the data collection process and effect techniques required to regulate the selection and quality features of the data, thus constraining specific elements of information to only those facts defined in the initial dataset; and restricted awareness of the collection methodology may yield trepidations with respect to data validity (Boslaugh, 2007; Bryman, 2012). However, pregnancy outcomes research designs frequently exploit a secondary analysis of natality data, as it is population based and offers vital evidence for the analysis of trends relative to birth outcomes (Andrade et al., 2013; Minsart et al., 2012; Schoendorf & Branum, 2006). The quantitative methodology, and retrospective, cross-sectional, cohort, with a population-based secondary data analysis of birth outcomes design is equally applicable to this investigation as it is a common research method and design, in empirical studies investigating the effects of natural disasters on pregnancy outcomes, utilizing population health data from various state health department vital statistics datasets (Antipova, & Curtis, 2015; Currie, & Rossin-Slater, 2013; Hamilton et al., 2009; Harville, Tran et al., 2010; Simeonova, 2011; Zahran et al., 2014; Zahran et al., 2013; Zahran et al., 2010).

There were time constraints concomitant with this research design. As this study exploited county-level linked birth and infant death files obtained from individual state and local government official recordings of live birth and death events, the burden of time associated with effecting appropriate authorizations and clearances in gaining access to the dataset, was levied as a limiting factor on this research project. In order to safeguard the privacy and confidentiality of certain health information, some states may constrain public access to county-level vital statistics data. To address this limitation, access to the county-level linked birth and infant death dataset was sought through the National Association for Public Health Statistics and Information Systems (NAPHSIS). NAPHSIS facilitates access to and use of national vital statistics datasets for public health research endeavors aiming to advance population health (NAPHSIS, 2014). Once official clearance was acquired, there were further time constraints connected with transmitting the approval to the National Center for Health Statistics (NCHS), where official national vital statistics are reported through the Vital Statistics Cooperative Program (NCHS, 2014c). Extra time was equally required for the NCHS staff to field the data request, amalgamate and construct the dataset, and then transmit the data files to the research investigator. Additionally, the scope of the investigation was constrained by the data fields available from the birth and infant mortality data reported on the birth and death certificate files; and the level of available health behavioral, and socio-demographic information authorized as a statistical resource.

Methodology

Population

In this study, the target population was pregnant women residing in the states of Alabama and Mississippi. The study population was pregnant women residing in the counties of Calhoun (Federal Information Processing Standards (FIPS) Code 01-015), DeKalb (FIPS Code 01-049), Franklin (FIPS Code 01-059), Jefferson (FIPS Code 01-073), Lawrence (FIPS Code 01-079), Limestone (FIPS Code 01-083), Madison (FIPS Code 01-089), Marion (FIPS Code 01-093), St. Clair (FIPS Code 01-115), and Tuscaloosa (FIPS Code 01-125), Alabama who were most likely affected by the April 2011 tornado disaster, and experienced a live singleton birth which survived or was born and died between the periods of March 1, 2010 to April 31, 2012; and pregnant women residing in the counties of Hancock (FIPS Code 28-045), Harrison (FIPS Code 28-047), Jackson (FIPS Code 28-059), and Jones (FIPS Code 28-067), Mississippi, who experienced a live singleton birth which survived or was born and died between the periods of July 1, 2004 to August 31, 2006. As the purpose of this investigation was to determine the association between maternal prenatal exposure to Hurricane Katrina of 29 August 2005, on adverse maternal and infant health outcomes in Mississippi; and maternal prenatal exposure to the 27-28 April 2011 tornado disaster, on adverse maternal and infant health outcomes in Alabama, the study population consisted of target population members with the aforementioned specific sampling criteria.

Approximately 59,322 pregnant women experienced a live birth in the state of Alabama in 2011 (ADPH, 2013). About 1,422 of these pregnant women resided in Calhoun County; 815 in DeKalb County; 412 in Franklin County; 8,861 in Jefferson County; 373 in Lawrence County; 992 in Limestone County; 4,153 in Madison County; 305 in Marion County; 1,035 in St. Clair County; and 2,363 in Tuscaloosa County (ADPH, 2013). According to live birth statistics from the Mississippi Department of Health (2007), there were an estimated 42,327 pregnant women with live births across the state in 2005, the calendar year of Hurricane Katrina. Of these pregnant women, 452 were from Hancock County; 2,374 from Harrison County; 1,706 from Jackson County; and 1,068 from Jones County (MSDH, 2007).

Sampling and Sampling Procedures

A probability sampling method was employed in this investigation to ensure each sample of the population studied has the same probability of being selected (Aschengrau & Seage, 2014; Jacobsen, 2012). Probability sampling enables the conditions which could establish a high likelihood of assurance the sample is representative, have an encouraging level of confidence in the data collection, and may be able to estimate errors for the sampling (Aschengrau & Seage, 2014; Jacobsen, 2012). This investigation exploited the stratified sampling feature of probability sampling. In the stratified sampling design, sample elements from every one of the established strata assure the research effort of full representation of all segments of the population in the sample (Aschengrau & Seage, 2014; Jacobsen, 2012). Accordingly, with stratified sampling, the targeting of an explicit number of the study sample based upon the percentage of the total population sharing the same characteristics, normally occurs (Aschengrau & Seage, 2014; Jacobsen, 2012).

In this investigation, individuals were sampled according to county-level identifiers, to include county of residence and home location by FIPS Code, suggesting individual exposure or non-exposure to the natural disaster. Accordingly, samples of the population were drawn based upon a precise time frame and location (July 1, 2004 to August 31, 2006 for Mississippi; and March 1, 2010 to April 31, 2012 for Alabama), when the natural disaster incident occurred, along with the type of natural disaster incident (hurricane or tornado), and the population frame involving pregnant women. As the purpose of the study focused on pregnancy outcomes, a 12-month framework parameter, before and after the disaster incident, was applied in this study to facilitate delimitation of the study population. The overall aim of the 12-month framework was to generate enough data on women who gave birth at the time of the incident, and those who were pregnant or got pregnant and gave birth sometime within the 12-month framework after the disaster incident occurred. Previous researchers have applied this model to investigate natural disasters and pregnancy outcomes (Antipova & Curtis, 2015; Simeonova, 2011; Zahran et al., 2013; Zahran et al., 2010). In applying all of these conditions, the Statistical Package for the Social Science (SPSS) software application, version 21.0, was utilized to extract the sample from the entire linked birth and infant death dataset for a specific timeframe of interest as chronicled by the state and local government official recordings of live birth and death events, and by specifying “select cases” from the “data” command in the main bar menu of SPSS.

The study sample was drawn from the Alabama and Mississippi Linked Infant Births and Deaths Record File for 1997-2013, with county-level identifiers for women residing in and giving birth in the state. The dataset was comprised of all Alabama and Mississippi births in a given year with linkages to the infant death certificate data (NCHS, 2015b). The sampling frame included all pregnant women with a singleton birth delimited with county-level identifiers, which survived or was born and died between the time periods of July 1, 2004 to August 31, 2006 (for Mississippi), and March 1, 2010 to April 31, 2012 (for Alabama), in the dataset. All subjects in the cohort were included in the analysis as either the exposure group, or the control group or comparison group. The analysis sample for the exposure group was limited to those pregnant women with plausible exposure experience to Hurricane Katrina of 29 August 2005, or the 27-28 April 2011 Alabama tornado disaster based upon county-level identifiers for residence in the aforementioned counties impacted by Hurricane Katrina in Mississippi, and the 27-28 April 2011 Alabama tornado disaster. Additional inclusion criteria consisted of linked birth and infant death records with serviceable data on the infant’s date of birth, birth weight; mother’s residency data, demographic (age, race/ethnicity, marital status, education), pregnancy history (parity, previous preterm birth), mode of delivery, labor and delivery complications, maternal health status (anemia, diabetes, hypertension), and maternal health behaviors (prenatal care, smoking) information. The analysis sample for the control group or comparison group, included those pregnant women in the counties of interest for the designated pre-disaster time periods, and were consistent with the aforementioned supplementary eligibility criteria. Records excluded from the analysis included those not meeting the eligibility criteria for this investigation.

Statistical power analysis. Statistical power is the likelihood a given statistical test will detect a significant effect or association between variables, when a real effect or association truly exists in the study population (Aschengrau & Seage, 2014; Suresh & Chandrashekara, 2012). Sample size is inherently concomitant with statistical power, and robust power to detect a statistical significance for an expected effect of association reduces the occasion for chance findings (Aschengrau & Seage, 2014; Suresh & Chandrashekara, 2012). Statistical power analysis enables a research investigator to employ discrete formulas and parameters to define the minimum sample size needed to detect a significant effect, and determine the likelihood sample results would be consistent with an established hypothesis about the study population (Aschengrau & Seage, 2014; Suresh & Chandrashekara, 2012). Factors influencing statistical power include *alpha* (significance level), *beta* (power), and *effect size* (degree of association in study population; Aschengrau & Seage, 2014; Suresh & Chandrashekara, 2012). The *alpha* parameter is the significance level of the statistical test, typically owning a value of 0.05; and establishes the likelihood of committing a *type I* or *alpha* statistical error, which is the rejection of the null hypothesis although it is actually true (Aschengrau & Seage, 2014; Suresh & Chandrashekara, 2012). The *beta* or power parameter is the probability of detecting an effect, if one genuinely occurs; has a typical established value of .80, and establishes the probability of making a *type II* or *beta* error, which is a failure to reject the null hypothesis when it is false (Aschengrau & Seage, 2014; Suresh & Chandrashekara, 2012). An *effect size* parameter provides for the likelihood of detecting an association between the variables of interest in the analysis, and the extent of the relationship in the study population (Aschengrau & Seage, 2014; Suresh & Chandrashekara, 2012). Data from other investigations or pilot studies are frequently utilized to inform estimation of the effect size (Aschengrau & Seage, 2014; Suresh & Chandrashekara, 2012).

A priori sample size calculation was conducted to determine the minimum sample size needed to test the hypotheses in this investigation. Sample size computations were based on the G*power application, version 3.1.9.2 (Faul, Erdfelder, Buchner, & Lang, 2009). The sample size calculations for the three hypotheses in this study were based on 80% and 90% power for a two-tailed test to detect a small to medium effect size (odds ratio of 1.2 to 2.5) in any of the study outcomes (birth weight, preterm birth, infant mortality, and C-section mode of delivery), at an alpha level of 0.05 (two-tailed test statistic). In determining the effect size, estimates of odds ratio data regarding hurricane related adverse pregnancy outcomes such as birth weight, preterm birth, infant mortality, and C-section mode of delivery; were obtained from previous research, which investigated hurricane related adverse birth outcomes (Antipova & Curtis, 2015; and Harville, Tran et al., 2010).

The minimum sample size for this study was 1,168 participants. The sample size was determined based upon an 80% and 90% power for a two-tailed test to detect an odds ratio of 1.2 to 2.5, respectively; in low birth weight, preterm birth, infant mortality, and C-section mode of delivery, at an alpha level of 0.05 (two-tailed test).

Procedures for Recruitment, Participation, and Data Collection

There was no active recruitment soliciting participants to enroll as subjects in this study, because the investigation consisted of a secondary analysis of archived data. State and local governments in the United States, are responsible for recording official births, deaths, and other vital events, issuing formal registry certificates, and reporting to the National Vital Statistics System through the Vital Statistics Cooperative Program (NCHS, 2014c). County-level linked birth and infant death data drawn from the Alabama and Mississippi Linked Infant Births and Deaths Record File for the period 1997-2013, were exploited during the empirical analysis segment of this investigation. As the linked birth and infant death files contain medical and personally identifiable information, authorities at the state and local jurisdictional levels of government consider these data confidential, and several states have enacted statues and policies related to the confidentiality and re-release of these vital statistics (NCHS, 2011).

Customized delimited county-level linked birth and infant death data are made available under controlled conditions consistent with the review and approval of the National Association for Public Health Statistics and Information Systems (NAPHSIS) and the National Center for Health Statistics (NCHS, 2011). A request for consideration and access to the linked birth and infant death dataset was sought through NAPHSIS and NCHS, as mandated by NHCS (2011) policy regarding the release of customized restricted use county-level linked birth and infant death data. Access to this dataset required an application proposal, and data use and access agreement (NCHS, 2011). In addition, approval to initiate data collection and analyses in the conduct of this investigation, was sought from the Institutional Review Board of Walden University.

Instrumentation

The dataset for the empirical analysis of this investigation was derived from the National Vital Statistics System Linked Infant Births and Deaths Record Files. In this dataset, linked files of live births and infant deaths occurring in the United States, Puerto Rico, the U.S. Virgin Islands, and Guam connect data from the birth certificate to information from the death certificate, for each infant death in a given calendar year (Mathews & MacDorman, 2013; NCHS, 2015b). Linkage of the individual infant birth records with the death records allows for a more comprehensive analysis of factors such as characteristics of the infant and mother, which may influence infant mortality patterns (Mathews & MacDorman, 2013; NCHS, 2015b). The linked files include birth certificate data, which provides vital information for the analyses of pregnancy outcomes; and information from the death certificate elucidating the infant’s age and cause of death (Mathews & MacDorman, 2013; NCHS, 2015b).

Variables available for pregnancy outcomes analyses from the linked birth and infant death data include demographic information, such as age, race, and ethnicity of the parents; maternal education; live birth order; mother’s marital status; maternal and infant health information, such as birth weight, period of gestation, plurality (whether the infant is a singleton, or multiple birth); mode of delivery; labor and delivery complications; maternal health status (anemia, diabetes, hypertension); and maternal health behaviors data like prenatal care utilization, and smoking (Mathews & MacDorman, 2013; NCHS, 2015b). Researchers have suggested the U.S. birth certificate data from the National Vital Statistics System Linked Infant Births and Deaths Record Files, could serve as a valid and reliable source for analyzing pregnancy outcomes (Aschengrau & Seage, 2014; Martin et al., 2013; NCHS, 2015b).

Birth and death certificates are recorded for basically all births and deaths nationwide, and the large datasets supports population health, assessment of maternal and infant health trends, and research on infant mortality (Aschengrau & Seage, 2014; IOM & NRC, 2013; Martin et al., 2013; NCHS, 2015b). The utilization of U.S. standardized certificates of birth and death nationwide, allows for the homogeneousness of data collection, and the periodic review and revision--about every 10 to15 years, of the standardized certificates assures the validity and ability of these instruments to support data collection for national vital statistics (IOM & NRC, 2013; NRC, 2009). Birth and death certificate data are generally collected at the time of the infant's birth and death, utilizing a Birth Certificate Worksheet, to standardize reporting requirements (NCHS, 2012; NRC, 2009).

According to Mathews and MacDorman (2013), the linked birth and infant death dataset is about 99% effective in matching U.S. birth records to the corresponding infant death certificates. Several studies have investigated the quality, validity, and consistency of birth data derived from the birth certificate, and found a high degree of quality, authenticity and completeness in capturing demographic and certain medical and health variables (Andrade et al., 2013; Martin et al., 2013; Park et al., 2011; Vinikoor et al., 2010). Moreover, Antipova and Curtis (2015); Emuren, Chauhan, Vroman, and Beydoun (2012); Mathews and MacDorman (2013); Malabarey, Balayla, Klam, Shrim, and Abenhaim (2012); and Zahran, Breunig, Link, Snodgrass, Weiler, and Mielke (2014), among others, have used the linked birth and infant death dataset to investigate pregnancy outcomes, including the effects of maternal prenatal exposure to hurricanes on birth outcomes.

Operationalization

Study variables. The dependent variables of interest in this study were birth weight, preterm birth, infant mortality, and mode of delivery as reported by the Alabama Department of Public Health, and the Mississippi State Department of Health, in the registration of vital events reporting mechanism to the National Vital Statistics System, and computed from the national linked birth and infant death dataset (NCHS, 2015a, 2015b). The main independent variable of interest was maternal prenatal exposure to a hurricane or tornado disaster incident as determined by the reconciliation of residence data obtained from the county-level linked birth and infant death files with SHELDUS data reflecting the severity of the disaster effects of the 27-28 April 2011, Alabama tornado disaster on the counties of Calhoun, DeKalb, Franklin, Jefferson, Lawrence, Limestone, Madison, Marion, St. Clair, and Tuscaloosa, Alabama; and Hurricane Katrina in the counties of Hancock, Harrison, Jackson, and Jones, Mississippi. Covariates were socio-demographic factors, health behaviors, pregnancy history, and maternal health status as reported in the linked dataset (NCHS, 2012; 2015b). The dependent variables and the independent variable for this study were established based upon previous studies and available data. Study variables and their operationalized definitions are summarized in Table 5.

Dependent variables. The dependent variables were birth weight, preterm birth, infant mortality, and mode of delivery.

Birth weight was characterized as the weight of an infant at the period of birth, and measured in either pounds and ounces, or grams. In this investigation, birth weight was denoted as the infant's weight reported in grams according to the certificate of live birth (NCHS, 2012). Birth weight was a categorical variable, recorded with the following dichotomous values: low birth weight (<2500 grams at birth), and normal birth weight (≥2500 grams at birth).

Preterm birth was defined as birth of an infant before the full 37 weeks of gestation (CDC, 2013). It was categorized as a dichotomous variable with the following values: preterm (<37 weeks gestation), and term (≥37 weeks).

Infant mortality was categorized as death occurring before the attainment of the infant's first birthday (CDC, 2014). Infant mortality was a categorical variable, recorded with a dichotomous value: Yes/No.

Mode of delivery or method of delivery was characterized as the physical process by which delivery of a complete fetus is originated, and was classified as either a vaginal delivery or cesarean section (NCHS, 2012). Mode of delivery was a categorical variable, and classified with the following dichotomous values: Vaginal/C-section.

Independent variable. The independent variable was maternal prenatal exposure to a hurricane or tornado disaster. The exposure variable was categorized and recorded as dichotomous, Yes or No, to indicate which women experienced exposure to the disaster incident, and to facilitate placement of the participants into an exposed or not exposed category.

Covariates. Covariates were socio-demographic factors, health behaviors, pregnancy history, and maternal health status.

Socio-demographic factors were recorded as categorical variables, and coded as follows: maternal age (younger than 18, 18-26, 27-34, and older than 34 years); marital status (married or not married); maternal race or ethnicity (Hispanic, non-Hispanic black, non-Hispanic white, and other), and maternal education (<12, 12, 13-16, >16 years).

Table 5

Summary of Study Variables and Operationalized Definitions

Variable name	Type variable	Definition and coding
	Dependent variables	
Birth weight	Dichotomous	Low birth weight (<2500 g) Normal birth weight (≥2500 g)
Preterm	Dichotomous	Preterm (<37 weeks gestation) Term (≥37 weeks)
Infant mortality	Dichotomous	No=0 Yes=1
Mode of delivery	Dichotomous	Vaginal=0 C-section=1
	Independent variables	
Hurricane	Dichotomous	Unexposed=0 Exposed=1
Tornado	Dichotomous	Unexposed=0 Exposed=1
	Covariates	
Socio-demographic factors		
Maternal age	Categorical Continuous	Younger than 18=0 18-26=1 27-34=2 Older than 34 years=3
Marital status	Dichotomous	Not married=0 Married=1
Maternal race or ethnicity	Categorical	Hispanic=0 Non-Hispanic black=1 Non-Hispanic white=2 Other=3
Maternal education	Categorical	<12=0 12=1 13-16=2 >16 years=3
Health behaviors		
Prenatal care	Dichotomous	Untimely=0 Timely=1
Smoking	Dichotomous	No=0 Yes=1
Pregnancy history		
Previous live births	Categorical	No previous live birth=0 1 previous live birth=1 ≥ 2 previous live birth=2
Preterm births	Dichotomous	No=0 Yes=1

Table continues

Variable name	Type variable	Definition and coding
Maternal health status		
Anemia	Dichotomous	No=0 Yes=1
Diabetes	Dichotomous	No=0 Yes=1
Hypertension	Dichotomous	No=0 Yes=1

Health behaviors were classified as those activities which sustain good health or adversely influence well-being, and include considerations for adequacy of prenatal care, and life-style factors such as the use of tobacco during pregnancy (Coreil, 2010). Health behaviors included, initiation of prenatal care and smoking; and were recorded as dichotomous variables. These values were coded as: prenatal care (*Timely*--prenatal care initiated in the first trimester, and *untimely*--prenatal care began in the second trimester, third trimester, or none was received); smoking: Yes/No.

Pregnancy history was classified as the number of times a woman was pregnant and was delimited to the number of live births of viable offspring, and previous preterm births. The number of previous live births were categorized as follows: (0, 1, ≥2); previous preterm births were coded as dichotomous, Yes or No.

Maternal health status was defined as any illness and disease conditions like anemia, diabetes, and hypertension experienced by the birth mother during the perinatal period (NCHS, 2012; Osterman et al., 2011). Disease conditions experienced during pregnancy included anemia, diabetes, and hypertension; and were coded as dichotomous, Yes or No.

Data Analysis Plan

The statistical application SPSS, version 21.0, was utilized for data entry, data management, statistical analyses (including descriptive statistics, bivariate statistics, and predictive analytics), and to produce graphs of distributions and trends, and tabulated reports and charts (Field, 2013). Data analysis was conducted systematically with data screening, cleaning, and coding occurring respectively; prior to the application of any statistical models.

During the data screening phase, records in the linked birth and infant death files were examined to confirm the requisite data elements are contained in the dataset. In the data cleaning segment, files with incomplete data, anonymous values, and duplicate records were purged from the dataset. During the coding phase, established coded values as noted in Table 5, were imputed to the data files to facilitate data manipulation and analysis within SPSS. Descriptive statistics were used to summarize and describe the variables in the dataset. Categorical variables were described by presenting them using frequency distributions, and scale continuous variables were summarized with measures of central tendency and included the mean and measures of dispersion, to include the range and standard deviation.

Statistical tests and models were exploited to test the hypotheses in this study. The main independent variable in this investigation was maternal prenatal exposure to a hurricane or tornado, and the categorical outcome variables included low birth weight, infant mortality, and mode of delivery. Accordingly, testing of the study hypotheses required statistical analyses to test for the significance of associations between two categorical variables (Field, 2013; Jacobsen, 2012). As a result, a chi-square test for independence of attributes was used to test the hypotheses in this study. Furthermore, to adjust for the effect of covariates and isolate the pure effect of the exposure on the different response variables, the binary logistic regression model was used.

The logistic regression model was an appropriate statistical test to apply as the outcome variables were binary and categorical, and the study predictor was a categorical variable with a set of covariates to be included in the model (Field, 2013; Jacobsen, 2012). Logistic regression takes the log odds given by log (p/(1-p) as the dependent variable (Field, 2013; Jacobsen, 2012). Here p is the probability the dependent variables take value 1 (called event; Field, 2013). The overall model of significance was tested using -2log likelihood measure and the associated chi-square test. Logit coefficients and the associated Wald's test for the significance of each predictor variable in the model, including the exposure variable were reported. All the statistical tests were performed at the .05 level of significance.

Management of missing data. The Alabama and Mississippi customized delimited county-level linked birth and infant death data provided by NCHS, contained missing data, which may have resulted due to errors in the data collection process. Missing data could adversely impact statistical models and contribute to the introduction of bias in statistical analyses, inefficient data analysis; compromise the generalizability and validity of the research findings; and replicability of the investigation (Liu & De, 2015; Osborne, 2013; Roda, Nicolis, Momas, & Guihenneu, 2014; Young & Johnson, 2013). Thus, analytical approaches and measures must be employed to mitigate the effects of missing data (Osborne, 2013). There is no gold standard for effectively discerning how much missing values are permissible in secondary data analysis (Liu & De, 2015; Roda, Nicolis, Momas, & Guihenneu, 2014; Young & Johnson, 2013). Researchers have recommended the retention of serviceable information in the dataset and the exclusion of only those missing data elements from the analysis, so as to sustain sampling variability and statistical power (Liu & De, 2015; Roda, Nicolis, Momas, & Guihenneu, 2014; Young & Johnson, 2013). In this study, the outcome variable, mode of delivery, was excluded from the investigation due to a significant percentage of missing data. Although mode of delivery was originally included in the research questions for this investigations, the high proportion of missing data for this outcome variable in the dataset, mandated its exclusion from the study. Similarly, the covariates, previous live births, prenatal care, smoking, anemia, and diabetes were excluded from the chi-square and logistic regression models for the combined sample, due to missing values in the dataset. Maternal education, previous live births, prenatal care, smoking, anemia, and diabetes were also excluded from the bivariate and multivariate models for the sample in Alabama. Likewise, previous live births, prenatal care, anemia, and diabetes were excluded from the chi-square and logistic regression models for the sample in Mississippi. The percentages of missing data for the combined sample included the outcome variable, mode of delivery (88%); and the covariates, previous live births (65%), and anemia (50%). The proportion of missing data for Alabama sample consisted of mode of delivery (100%), maternal education (60%), previous live births (100%), prenatal care (60%), and anemia (100%). The percentages of missing data for the sample in Mississippi, included mode of delivery (76%), and diabetes (100%).

Analysis of research questions. Data analyses were performed to answer the research questions and test the hypotheses, restated herein:

Research Question 1: Does maternal exposure to hurricane or tornado disasters influence preterm birth and low birth weight; controlling for sociodemographic factors, health behaviors, pregnancy history, and maternal health status?

$H_0 1$: Maternal exposure to hurricane or tornado disasters has no significant influence on preterm birth and low birth weight; controlling for sociodemographic factors, health behaviors, pregnancy history, and maternal health status.

$H_a 1$: Maternal exposure to hurricane or tornado disasters has a significant influence on preterm birth and low birth weight; controlling for sociodemographic factors, health behaviors, pregnancy history, and maternal health status.

Chi-square analyses and logistic regression models were used to answer this research question. The chi-square test of independence of attributes was utilized to test for significant associations between the independent variable, maternal prenatal exposure to a hurricane or tornado disaster and the pregnancy outcome variables, preterm birth and low birth weight. The Fisher's exact test was utilized when an expected value of a cell reported five or less values in a two by two contingency table for the chi-square analyses (Field, 2013). The binary logistic regression model was used to adjust for the effects of covariates, and to isolate the pure effect of exposure on the preterm and low birth weight outcome variables. Odds ratios (OR) and 95% confidence intervals (CI), were computed to examine associations between maternal prenatal exposure to a hurricane or tornado disaster, and preterm birth and low birth weight. The p-value was also imputed to this analysis to calculate significance among the values; and the null hypothesis was rejected where $p < .05$.

Research Question 2: Does maternal exposure to hurricane or tornado disasters impact infant mortality; controlling for sociodemographic factors, health behaviors, pregnancy history, and maternal health status?

$H_0 2$: Maternal exposure to hurricane or tornado disasters has no significant impact on infant mortality; controlling for sociodemographic factors, health behaviors, pregnancy history, and maternal health status.

$H_1 2$: Maternal exposure to hurricane or tornado disasters has a significant impact on infant mortality; controlling for sociodemographic factors, health behaviors, pregnancy history, and maternal health status.

To address this research question, chi-square analyses and a binary logistic regression model were used. The chi-square statistical model was used to test for significant associations between the independent variable maternal prenatal exposure to a hurricane or tornado disaster and the outcome variable, infant mortality. The Fisher's exact test was utilized when an expected value of a cell reported five or less values in a two by two contingency table for the chi-square analyses (Field, 2013). Similarly, the binary logistic regression model was applied to adjust for the effects of covariates, and to isolate the pure effect of exposure on the infant mortality outcome variable. The model was used to predict the odds (odds ratios (OR) and 95% confidence intervals (CI), maternal prenatal exposure to a hurricane or tornado disasters could impact infant mortality. The p-value was calculated to determine the level of significance among the values. The null hypothesis was rejected where $p<.05$.

Research Question 3: Does maternal exposure to hurricane or tornado disasters influence mode of delivery; controlling for sociodemographic factors, health behaviors, pregnancy history, and maternal health status?

$H_0 3$: Maternal exposure to hurricane or tornado disasters has no significant influence on mode of delivery; controlling for sociodemographic factors, health behaviors, pregnancy history, and maternal health status.

$H_a 3$: Maternal exposure to hurricane or tornado disasters has a significant influence on mode of delivery; controlling for sociodemographic factors, health behaviors, pregnancy history, and maternal health status.

No bivariate and multivariate statistical models were used to test the outcome variable, mode of delivery, due to the large percentage of missing data for this variable in the dataset. As a result, the mode of delivery outcome variable and the associated research question was excluded from the investigation.

Threats to Validity

A wide-range of conditions and events could threaten the validity of a research study and influence the quality of its findings (Aschengrau & Seage, 2014; Creswell, 2014). Accordingly, it is imperative for empirical research to have validity (Aschengrau & Seage, 2014; Creswell, 2014). Responsible, ethical, research principles mandates that threats to the validity of a study must be considered and appropriately accounted for during the research design and execution phases of the study (Aschengrau & Seage, 2014; Creswell, 2014). The validity of a research investigation is commonly evaluated according to two essential measures, external validity and internal validity **(**Aschengrau & Seage, 2014; Creswell, 2014). External validity refers to the ability to generalize the outcome of a study to the target population and other groups (Aschengrau & Seage, 2014; Creswell, 2014). Conversely, internal validity is determined by the magnitude of control achieved over extraneous factors during data collection, which could account for the study outcomes (Aschengrau & Seage, 2014; Creswell, 2014). A researcher could moderate threats to external validity by restricting assertions to groups and situations to which the outcomes of the study can be generalized; and mitigate threats to internal validity by controlling peripheral influences, like bias and confounding elements (Aschengrau & Seage, 2014; Creswell, 2014).

External validity. Threats to external validity in this study were mitigated by a large sample of exposed cases and controls, drawn from the Alabama and Mississippi Linked Infant Births and Deaths Record File, for the period 1997-2013. To help validate that the sample was representative and generalizable, the population sample was drawn from all complete records in the Alabama and Mississippi dataset, for the sampling frame. Moreover, as the study population was limited to pregnant women and singleton infant births and deaths occurring in various Alabama and Mississippi counties, generalization of the study's findings were not projected beyond Alabama and Mississippi. Equally, as this study examined cross-sectional data, and the research questions do not facilitate direction of influence between the variables of interest, no causation were attributed to the data, and the study's findings were reported as associations.

Internal validity. Internal validity in this study could be threatened by numerous factors including sample selection bias, confounding factors, instrumentation, and statistical conclusion validity.

Sample selection bias is a flaw that occurs due to utilization of nonrandomly selected samples for statistical analyses that could prejudice the results (Aschengrau & Seage, 2014; Creswell, 2014; Jacobsen, 2012). Sample selection bias could possibly be introduced by the investigator when selecting study participants for exposed cases and controls (Aschengrau & Seage, 2014; Creswell, 2014; Jacobsen, 2012). To moderate the effects of this potential threat, a probability sampling approach was exploited to make sure each sample of the population studied had the same probability of being selected (Aschengrau & Seage, 2014; Creswell, 2014; Jacobsen, 2012). Specifically, the stratified sampling feature of the probability sampling approach, was imputed to this study to enable full representation of all segments of the population in the sample (Aschengrau & Seage, 2014; Jacobsen, 2012). The stratified probability sampling approach could enable conditions which may increase the likelihood of assurance the sample is representative; and thus, decrease the threat of sample selection bias (Aschengrau & Seage, 2014; Creswell, 2014; Jacobsen, 2012).occurs

Confounding factors, a phenomena wherein the real association between dependent and independent variables could be concealed, are also a threat to internal validity (Aschengrau & Seage, 2014; Jacobsen, 2012). Confounders should be identified, and could be controlled during the study design, and data analysis phases of the research investigation (Aschengrau & Seage, 2014; Jacobsen, 2012). To lessen the influence of confounders in the research design and the empirical analysis phases of this study, potential confounders including socio-demographic factors, health behaviors, pregnancy history, and maternal health status were identified during the systematic review of the scientific literature, as influencing factors to be controlled (Hamilton et al., 2009; Harville, Tran et al., 2010; Xiong, 2010; Zahran et al., 2014; Zahran et al., 2013; Zahran et al., 2010). Confounding effects were also moderated during the statistical analysis phase of this study, by imputing logistic regression models to examine the relationship between the independent variable maternal prenatal exposure to a hurricane or tornado disaster, and the outcome variables (Aschengrau & Seage, 2014; Jacobsen, 2012).

Instrumentation is another potential threat to internal validity in this study. Instrument bias, the result of discrepancies with the testing instrument, could occur in a study and potentially impact the true outcomes of the research investigation (Creswell, 2014). To diminish the possible effect of instrument bias, this study employed the national vital statistics instrument, which exploits data collection procedures from a standardized, nationwide cooperative enterprise system, and is reputed to yield a high quality measure in assessing the outcome variables of interest in this study (Boslaugh, 2007; Bryman, 2012). The national vital statistics instrument is also known to be informed by a degree of proficiency and competence, thus, enhancing assurance in the fidelity of the data and reducing elements of bias (Boslaugh, 2007; Bryman, 2012). Researchers have utilized datasets from the national vital statistics instrument to investigate the effects of maternal prenatal exposure to hurricanes on birth outcomes (Antipova & Curtis, 2015; Zahran et al., 2014).

The statistical conclusion validity threat could occur in this study as a result of erroneous inferences. This analytical error could be consequential to inadequate statistical power, violations of statistical assumptions, and the selection of inappropriate statistical tests for data analysis (Aschengrau & Seage, 2014; Creswell, 2014). To moderate this threat and enhance statistical validity, a statistical power analysis was utilized to determine the minimum sample size needed to appropriately test the hypotheses, and detect statistical significance in this investigation (Aschengrau & Seage, 2014; Creswell, 2014). Logistic regression models and the assumption parameters and rules associated with the statistical tests, were also employed in this study to examine associations between the exposure variable, outcome variables, and confounders (Aschengrau & Seage, 2014; Creswell, 2014). Large percentages of missing data could equally compromise the quality of statistical analysis and introduce bias in the study (Liu & De, 2015; Roda, Nicolis, Momas, & Guihenneu, 2014; Young & Johnson, 2013). To limit the influence of any large proportion of missing values on the statistical tests, missing data for the variables, mode of delivery; previous live births; prenatal care; smoking; anemia; maternal education; and diabetes were excluded from certain phases of the multivariate models. This approach enabled the retention of serviceable information in the dataset, exclusion of missing data elements which could engender erroneous statistical conclusions with multivariate analysis, and sustained sampling variability and statistical power (Liu & De, 2015; Roda, Nicolis, Momas, & Guihenneu, 2014; Young & Johnson, 2013).

Ethical Procedures

The U.S. Code of Federal Regulations for the Protection of Human Subjects (2009) mandates that the rights, welfare, and safety of human subjects involved in behavioral and biomedical research must be safeguarded. Accordingly, per Title 45, Part 46, U.S. Code of Federal Regulations, 45 C.F.R. § 46 (2009), research investigations involving the study of existing de-identifiable data, such as customized restricted use county-level linked birth and infant death files, are subject to the evaluation and endorsement of an Institutional Review Board, prior to the commencement of the study. Moreover, the Protection of Human Subjects, 45 C.F.R. § 46 (2009), establishes guidance and procedures to preserve and protect the rights, privacy and confidentiality of individuals whose medical and personally identifiable information are subjected to research.

To ensure compliance with the U.S. Code of Federal Regulations for the Protection of Human Subjects (2009), Walden University Institutional Review Board approval was sought prior to the conduct of this investigation. To mitigate potential privacy risks associated with the use of linked birth and infant death data records, a customized de-identified restricted use data set was requested through NAPHSIS and NCHS, as regulated by NHCS (2011); and the principal researcher completed the National Institutes of Health, Office of Extramural Research, protecting human research participants' web-based training.

The data utilized in this study was warehoused on a password protected computer; backed up on a password protected USB device; stored in a protected private home office; and will be preserved for about five years, and destroyed utilizing applicable methods and procedures to ensure confidentiality. A data use agreement was also completed as mandated by NHCS (2011) policies for customized restricted use datasets. In addition, the findings of this study are reported in aggregate form to protect the privacy, and enhance confidentiality of records examined during this investigation. The study outcomes will also be considered for dissemination in peer-reviewed journals.

Summary

This study was a quantitative, retrospective, cross-sectional, population based, cohort study. The investigation was a secondary analysis of data, and examined the association between maternal prenatal exposure to a hurricane and tornado disaster, on the mode of delivery and pregnancy outcomes, including birth weight, preterm birth, and infant mortality. Maternal characteristics, including socio-demographic factors, health behaviors, pregnancy history, and maternal health status were also examined. The dependent variables were birth weight, preterm birth, infant mortality, and mode of delivery. The primary independent variable was maternal prenatal exposure to a hurricane or tornado disaster incident. Covariates were socio-demographic factors, health behaviors, pregnancy history, and maternal health status.

The data source for the empirical analysis in this study were county-level linked birth and infant death data drawn from the Alabama and Mississippi Linked Infant Births and Deaths Record File for the period 1997-2013, from the National Vital Statistics

System Linked Infant Births and Deaths Record Files. SPSS, version 21.0, was used for data manipulation, statistical analyses, and to generate graphs, and tabulated reports and charts. The data analysis plan delineated the use of descriptive statistics to summarize and describe variables in the dataset; and inferential statistics, including chi-square and binary logistic regression models, to generate inferences.

A report of the findings of this study is provided in Chapter 4. The report is comprised of the data collection approach; treatment of the data; assumptions of the statistical tests; and the outcome of the statistical analyses, including descriptive and demographic characteristics of the sample and statistical findings exploiting appropriate significance levels and confidence interval values. The chapter also contains a summary description of the answers to each of the research questions.

Chapter 4: Results

Introduction

A series of statistical tests were conducted to examine the association between prenatal exposure to a hurricane and tornado disaster, and pregnancy outcomes, such as birth weight, preterm birth, infant mortality, and the mode of delivery. Maternal characteristics were included in the logistic regression models, to control for the potential effects of socio-demographic factors, health behaviors, pregnancy history, and maternal health status. All research questions and hypotheses in this investigation, were examined for the combined sample, and then separately for each state. The research questions were:

Research Question 1: Does maternal exposure to hurricane or tornado disasters influence preterm birth and low birth weight; controlling for sociodemographic factors, health behaviors, pregnancy history, and maternal health status?

$H_0 1$: Maternal exposure to hurricane or tornado disasters has no significant influence on preterm birth and low birth weight; controlling for sociodemographic factors, health behaviors, pregnancy history, and maternal health status.

$H_a 1$: Maternal exposure to hurricane or tornado disasters has a significant influence on preterm birth and low birth weight; controlling for sociodemographic factors, health behaviors, pregnancy history, and maternal health status.

Research Question 2: Does maternal exposure to hurricane or tornado disasters impact infant mortality; controlling for sociodemographic factors, health behaviors, pregnancy history, and maternal health status?

$H_0 2$: Maternal exposure to hurricane or tornado disasters has no significant impact on infant mortality; controlling for sociodemographic factors, health behaviors, pregnancy history, and maternal health status.

$H_1 2$: Maternal exposure to hurricane or tornado disasters has a significant impact on infant mortality; controlling for sociodemographic factors, health behaviors, pregnancy history, and maternal health status.

Research Question 3: Does maternal exposure to hurricane or tornado disasters influence mode of delivery; controlling for sociodemographic factors, health behaviors, pregnancy history, and maternal health status?

$H_0 3$: Maternal exposure to hurricane or tornado disasters has no significant influence on mode of delivery; controlling for sociodemographic factors, health behaviors, pregnancy history, and maternal health status.

$H_a 3$: Maternal exposure to hurricane or tornado disasters has a significant influence on mode of delivery; controlling for sociodemographic factors, health behaviors, pregnancy history, and maternal health status.

The statistical analyses were conducted to examine the research questions and hypotheses presented in this chapter. The chapter is organized into three discrete divisions. The first section of the chapter describes the data collection process. The findings of this study are presented in the second section. The study results include the descriptive characteristics of the data, including covariates; and the findings of the statistical analysis for each of the research questions. The results of the bivariate statistical tests are reported with the appropriate probability values. The results section also includes the results of multivariate statistical tests. The chapter concludes with a summary of the primary findings of the study and transition to Chapter 5.

Data Collection

This study consisted of a secondary analysis of archived data derived from the National Vital Statistics System Linked Infant Births and Deaths Record Files. The data consisted of customized delimited county-level linked birth and infant death data drawn from Alabama and Mississippi Linked Infant Births and Deaths Record Files for the period 1997-2013. Therefore, the data was previously collected prior to the start of this study. The customized delimited county-level linked birth and infant death files were restricted from public access as they contained protected health information (NCHS, 2011). However, the files were made available for this investigation under controlled conditions consistent with the review and approval of NAPHSIS and the National Center for Health Statistics (NCHS, 2011).

There were no deviations or inconsistencies in the data collection plan described in Chapter 3. Data analysis began after receiving notification of the approval to conduct research from the Walden's Institutional Review Board, documented in the IRB study approval #12-10-15-0408759 (Appendix A); and authorization from NAPHSIS and NCHS to utilize the customized delimited county-level linked birth and infant death files. NCHS required a Data Use Agreement (Appendix B) to authorize access and use of the customized delimited county-level vital statistics datasets. The Data Use Agreement was endorsed and returned to NCHS. Upon receipt of the signed Data Use Agreement, NCHS supplied the dataset, which were stored on password protected compact discs (CDs), via

Federal Express (FedEx) shipping. The discs contained data files established in the American Standard Code for Information Interchange (ASCII) format, and systematized as numerator and denominator files for the period 1997-2013. The numerator records for each period contained files consisting of all infant deaths occurring in the United States; Puerto Rico; the U.S. Virgin Islands, and Guam linked to their corresponding standard birth certificates. The denominator files delimited natality records of all live births occurring in the aforementioned given years. The numerator and denominator files were imported into SPSS and converted to a proprietary (.sav) SPSS file extension format. The data files were then screened, cleaned, coded, and categorized consistent with the data analysis plan described in Chapter 3.

The study data included records with county-level identifiers of the target population, and encompassed the period of July 1, 2004 through August 31, 2006 for Mississippi; and March 1, 2010 through April 31, 2012 for Alabama. All subjects in the cohort were included in the analyses, unless their records contained incomplete data, missing data, anonymous values, or duplicate records. The total number of records available for data analyses from the target population, was 219,443. A stratified random sample (N = 1,168) was drawn from the 14 counties of interest, utilizing the pre-disaster and post-disaster periods for Alabama and Mississippi described in Chapter 3. The sample size (N = 1,168) met the minimum threshold generated by the statistical power analysis delineated in Chapter 3. The sample yielded a target population of 51% representation for Alabama, and 49% observations for Mississippi. Thus, the stratum proportion was established at .50, for each stratum.

Although the observations (*N* = 1,168) from the stratified random sample yielded a potentially large sample, this sample size provided low values for the exposure and infant mortality variables in each state. These low values adversely affected the hypotheses testing associated with the infant mortality dependent variable. As a result, the sample size was increased to (*N* = 2,000), without altering any other parameters of sampling. The random sample size of (*N* = 2,000) provided a desirable representation, and adequate values for all the variables and statistical analyses used to test the study hypotheses. The stratified random sampling approach helped to ensure the study population was representative of the general population of pregnant women in Alabama and Mississippi, with tornado and hurricane exposure experiences.

Results

The findings of the study are provided in this section. Descriptive statistics are reported for the dependent and independent variables, and covariates, providing a comprehensive profile of the study sample. This is followed by the results of the bivariate and inferential statistical analyses, with appropriate probability values and confidence intervals, used to examine each of the research questions.

Descriptive and Demographic Characteristics

Table 6 shows the descriptive and demographic characteristics of all pregnant women who were included in the study. The total sample was composed of mothers age 13 to 47 years old, with a mean age of 25.62 years (SD = 5.64). Fifty-four percent (*n* = 1,070) of the mothers were between the ages of 18 to 26 years old; 34% (*n* = 685) were age 27 to 34 years; and 5% (*n* = 92) were 18 years old or younger. The majority of mothers were Non-Hispanic Blacks or African Americans, 54% (*n* = 1,087); followed by Non-Hispanic Whites 39% (*n* = 771); and Hispanics 6% (*n* = 115). Over half of the mothers, 51% (*n* = 1,019) were married, and 49% (*n* = 981) were unmarried. A fourth (498, or 25%) had some college or graduate school education; whereas, 23% (*n* = 458) had a secondary education, and 16% (n = 326) had a primary school education or no education. The gestation period for mothers in the sample ranged from 18 to 47 weeks, with a mean gestation period of 37.97 weeks (SD = 2.84 weeks).

The characteristics of the sample for Alabama and Mississippi are shown in Table 6. Despite bearing differences in the geographical location and type of natural disaster exposure; maternal age, race and ethnicity, gestational period, and preterm births characteristics among mothers in both samples, were generally comparable. The maternal age in Alabama ranged from 14 to 47 years old, with a mean age of 26.29 years (SD = 5.74); and Mississippi mothers were between the ages of 13 to 43 years, and the mean age was 24.95 years (SD = 5.47). In Alabama, most mothers were Non-Hispanic Blacks or African Americans, 61% (*n* = 605). Similarly, the highest proportion of mothers in Mississippi were Non-Hispanic Blacks or African Americans, 48% (*n* = 484). The gestation period in Alabama ranged from 22 to 47 weeks, and the mean gestation period was 38.25 weeks (SD = 2.73 weeks). In Mississippi, the gestation period ranged from 18 to 47 weeks, and the mean was 37.97 weeks (SD = 2.94 weeks). The frequency distribution of preterm births in Alabama was about 17% (*n* = 165), and 20% (*n* = 202) for Mississippi.

Among both samples, differences existed in education, marital status, and the sample distribution of Non-Hispanic White mothers.

Table 6

Characteristics of the Sample

	Sample for States Combined		Sample for Alabama		Sample for Mississippi	
	N	%	*n*	%	*n*	%
Birth weight						
Normal Birth Weight	1752	87.6%	886	88.6%	866	86.6%
Low Birth Weight (LBW)	248	12.4%	114	11.4%	134	13.4%
Preterm (Gestational age)						
Term	1632	81.6%	835	83.5%	797	79.7%
Preterm	367	18.4%	165	16.5%	202	20.2%
Infant mortality						
No	1973	98.7%	987	98.7%	986	98.6%
Yes	27	1.3%	13	1.3%	14	1.4%
Mode of delivery						
Vaginal	158	7.9%	--	--	158	15.8%
C-section	79	4.0%	--	--	79	7.9%
Exposure						
Unexposed	1406	70.3%	568	56.8%	838	83.8%
Exposed	594	29.7%	432	43.2%	162	16.2%
Maternal age						
<18 yrs	92	4.6%	35	3.5%	57	5.7%
18-26	1070	53.5%	500	50.0%	570	57.0%
27-34	685	34.3%	386	38.6%	299	29.9%
>34	153	7.7%	79	7.9%	74	7.4%
Maternal race/ethnicity						
Hispanic	115	5.8%	77	7.7%	38	3.8%
Non-Hispanic Black	1087	54.4%	605	60.5%	484	48.4%
Non-Hispanic White	771	38.6%	305	30.5%	466	46.6%
Other	25	1.3%	15	1.5%	10	1.0%
Maternal education						
<12	326	16.3%	79	7.9%	247	24.7%
12	458	22.9%	135	13.5%	323	32.3%
13-16	498	24.9%	141	14.1%	357	35.7%
≥17	111	5.6%	42	4.2%	69	6.9%
Marital status						
Married	1019	51.0%	555	55.5%	464	46.4%
Not married	981	49.0%	445	44.5%	536	53.6%
Previous live births						
0	273	13.7%	--	--	273	27.3%
1	219	11.0%	--	--	219	21.9%
≥2	217	10.9%	--	--	217	21.7%

Note. — denotes missing data.

Table continues

	Sample for States Combined		Sample for Alabama		Sample for Mississippi	
	n	%	*n*	%	*n*	%
Prenatal care						
Untimely	9	0.5%	8	0.8%	1	0.1%
Timely	1384	69.2%	389	38.9%	995	99.5%
Smoking						
No	1231	61.6%	360	36.0%	871	87.1%
Yes	162	8.1%	37	3.7%	125	12.5%
Anemia						
No	995	49.8%	--	--	995	99.5
Yes	1	0.1%	--	--	1	0.1%
Diabetes						
No	1999	99.95%	999	99.95%	--	--
Yes	1	0.05%	1	0.05%	--	--
Hypertension						
No	1884	94.2%	936	93.6%	797	79.7%
Yes	116	5.8%	64	6.4%	202	20.2%

Note. — denotes missing data.

Fourteen percent (*n* = 141) of mothers in Alabama had 13 to 16 years of education; 14% (*n* = 135) had 12 years of education; 8% (*n* = 79) had less than 12 years of education; 4% (*n* = 42) had more than 16 years of education; and about 56% (*n* = 555) were married. Whereas, in Mississippi, more mothers had 13 to 16 years of education (36%, *n* = 357); 32% (*n* = 323) had 12 years of education; about a quarter (*n* = 247) had less than 12 years of education; 7% (*n* = 69) had more than 16 years of education; and almost half (*n* = 464) were married. Compared with Alabama, Mississippi had a higher proportion of unmarried mothers (54%, *n* = 536), and pregnant women with no education or a primary school education (25%, *n* = 247); and a larger sample of Non-Hispanic White mothers 47% (*n* = 466).

The distribution of variables measuring maternal health status and health behaviors show a large percentage of mothers were generally in good health and exercised health behaviors known to influence a healthy lifestyle. More than half (69%)

of these mothers, accessed prenatal care and did not smoke (62%); and most (94%) did not have hypertension. Although there was a significant percentage of missing data for the anemia, smoking, and diabetes covariates; analysis of the available data for Alabama indicated most mothers (99%) did not have gestational diabetes; and roughly three out of ten did not smoke. Among mothers in Mississippi, almost all (99%) did not have a history of anemia, and about one out of eight had a history of smoking. More mothers in Mississippi (20%) had maternal hypertension compared with their counterpart in Alabama (6%).

Influence of Exposure on Preterm Birth and Low Birth Weight Controlling for Maternal Characteristics

Associations of Exposure and Preterm Birth, and Low Birth Weight Controlling for Maternal Characteristics. Bivariate associations between maternal prenatal hurricane and tornado disasters exposure and preterm birth and low birth weight, and maternal characteristics were calculated using chi-square analyses. Table 7 provides a cross table display between maternal exposure to the hurricane or tornado disaster and pregnancy outcome measures, the percent distributions, and the significance (*p*) for the combined sample. Similarly, seven maternal characteristics (maternal age, maternal race/ethnicity, maternal education, marital status, previous live births, smoking history, and presence or absence of hypertension) were examined for association with the exposure variable. As shown in Table 7, no significant association between exposure to the disaster incidents and preterm birth, χ^2 (1, N = 1999) =.565, p = .452; and low birth weight, χ^2 (1, N = 2000) =.416, p = .519, were observed for the combined sample. Chi-square analyses revealed significant associations between maternal age χ^2 (3, N = 2000) =17.64, p = .001; maternal race/ethnicity χ^2 (3, N = 1998) =35.33, p = < .001; marital status χ^2 (1, N = 2000) =10.66, p = .001; and hypertension χ^2 (1, N = 2000) =10.60, p = .001 and hurricane or tornado exposure. Upon assessing the significant associations between the other maternal characteristics and exposure, a significantly higher percentage of mothers exposed to tornadoes and hurricane were older than 34 years old (40%). There was also a significant association between maternal race/ethnicity and exposure. Specifically, most exposed mothers were Hispanic (38%), Non-Hispanic Black (34%), and within the Other race/ethnicity category (48%). Most exposed mothers were also married (33%). There was a significantly high percentage of mothers with hypertension (43%) who were exposed. No significant associations between exposure and maternal education, previous live births, and smoking history were observed.

Table 7

Associations between Tornado/Hurricane Exposure and Perinatal Outcomes and Other Sample Characteristics (for Combined Sample)

	YES	NO		
Perinatal Outcomes	*n* (%)	*n* (%)	χ^2	*P*-value
Birth weight			.416	.519
Normal Birth Weight	516 (29.5%)	1236 (70.5%)		
Low Birth Weight (LBW)	78 (31.5%)	170 (68.5%)		
Preterm (Gestational age)			.565	.452
Term	479 (29.4%)	1153 (70.6%)		
Preterm	115 (31.3%)	252 (68.7%)		
Infant mortality			.173	.677
No	585 (29.7%)	1388 (70.3%)		
Yes	9 (33.3%)	18 (66.7%)		

	YES	NO		
Other Sample Characteristics	*n* (%)	*n* (%)	χ^2	*P*-value
Maternal age			17.64	.001*
<18 yrs	30 (32.6%)	62 (67.4%)		
18-26	279 (26.1%)	791 (73.9%)		
27-34	224 (32.7%)	461 (67.3%)		
>34	61 (39.9%)	92 (60.1%)		
Maternal race/ethnicity			35.33	<.001**
Hispanic	44 (38.3%)	71 (61.7%)		
Non-Hispanic Black	365 (33.6%)	722 (66.4%)		
Non-Hispanic White	173 (22.4%)	598 (77.6%)		
Other	12 (48.0%)	13 (52.0%)		
Maternal education			7.3	.063
<12	78 (23.9%)	248 (76.1%)		
12	105 (22.9%)	353 (77.1%)		
13-16	112 (22.5%)	386 (77.5%)		
≥17	38 (34.2%)	73 (65.8%)		
Marital status			10.66	.001*
Married	336 (33.0%)	683 (67.0%)		
Not married	258 (26.3%)	723 (73.7%)		
Previous live births			1.45	.484
0	39 (14.3%)	234 (85.7%)		
1	40 (18.3%)	179 (81.7%)		
≥2	34 (15.7%)	183 (84.3%)		
Smoking			.533	.465
No	25 (21.6%)	127 (78.4%)		
Yes	298 (24.2%)	933 (75.8%)		
Hypertension			10.60	.001*
No	544 (28.9%)	1340 (71.1%)		
Yes	50 (43.1%)	66 (56.9%)		

Note. **P* .001; ***P* <.001

In evaluating the associations between maternal exposure to a tornado and perinatal outcomes among the sample of mothers from Alabama, Table 8 shows a statistically significant association between tornado exposure and low birth weight χ^2 (1, N = 1000) =10.01, p = .002; and preterm deliveries χ^2 (1, N = 999) =10.37, p = .001. The results also indicate a significant association between exposure and maternal age χ^2 (3, N = 1000) =13.26, p = .004; maternal education χ^2 (3, N = 996) =10.34, p = .016; marital status χ^2 (1, N = 1000) =4.90, p = .027; and hypertension χ^2 (1, N = 1000) =14.01, p = < .001 (see Table 8). Overall, significant associations were observed between mothers' ages 18 to 26 years old; those with a college education; married; and no history of hypertension.

A significant association between maternal exposure to a hurricane and low birth weight χ^2 (1, N = 1000) =4.81, p = .028, was observed among the sample of mothers from Mississippi (see Table 9). However, no significant associations were observed between hurricane exposure and preterm births. When exposure to hurricane and sample characteristics were examined, a significant association between hurricane exposure and maternal race/ethnicity was observed χ^2 (3, N = 998) =31.14, p = < .001. No significant associations between prenatal maternal exposure to a hurricane and maternal age, maternal education, marital status, smoking history, and hypertension were observed.

Table 8

Associations between Tornado Exposure and Perinatal Outcomes and Other Sample Characteristics for Alabama

	YES	NO		
Perinatal Outcomes	*n* (%)	*n* (%)	χ^2	*P*-value
Birth weight			10.01	.002
Normal Birth Weight	367 (41.4%)	519 (58.6%)		
Low Birth Weight (LBW)	65 (57.0%)	49 (43.0%)		
Preterm (Gestational age)			10.37	.001*
Term	342 (41.0%)	493 (59.0%)		
Preterm	90 (54.5%)	75 (45.5%)		
Infant mortality			.047	1.00
No	426 (43.2%)	561 (56.8%)		
Yes	6 (46.2%)	7 (53.8%)		
	YES	NO		
Other Sample Characteristics	*n* (%)	*n* (%)	χ^2	*P*-value
Maternal age			13.26	.004
<18 yrs	20 (57.1%)	15 (42.9%)		
18-26	191 (38.2%)	309 (61.8%)		
27-34	178 (46.1%)	208 (53.9%)		
>34	43 (54.4%)	36 (45.6%)		
Maternal race/ethnicity			2.04	.564
Hispanic	32 (41.6%)	45 (58.4%)		
Non-Hispanic Black	263 (43.6%)	340 (56.4%)		
Non-Hispanic White	128 (42.0%)	177 (58.0%)		
Other	9 (60.0%)	6 (40.0%)		
Maternal education			10.34	.016
<12	35 (44.3%)	44 (55.7%)		
12	47 (34.8%)	88 (65.2%)		
13-16	65 (46.1%)	76 (53.9%)		
≥17	26 (61.9%)	16 (38.1%)		
Marital status			4.90	.027
Married	257 (46.3%)	298 (53.7%)		
Not married	175 (39.3%)	270 (60.7%)		
Prenatal care			.123	.726
Untimely	3 (37.5%)	5 (62.5%)		
Timely	170 (43.7%)	219 (56.3%)		
Smoking			.002	.966
No	157 (43.6%)	203 (56.4%)		
Yes	16 (43.2%)	21 (56.8%)		
Hypertension			14.01	<.001**
No	390 (41.7)	546 (58.3)		
Yes	42 (65.6)	22 (34.4)		

Note. **P* .001; ***P* <.001

Table 9

Associations between Hurricane Exposure and Perinatal Outcomes and Other Sample Characteristics for Mississippi

	YES	NO		
Perinatal Outcomes	*n* (%)	*n* (%)	χ^2	*P*-value
Birth weight			4.81	.028
Normal Birth Weight	149 (17.2%)	717 (82.8%)		
Low Birth Weight (LBW)	13 (9.7%)	121 (90.3%)		
Preterm (Gestational age)			2.75	.097
Preterm	25 (12.4%)	177 (87.6%)		
Term	137 (17.2%)	660 (82.8%)		
Infant mortality			.286	0.484
No	159 (16.1%)	827 (83.9%)		
Yes	3 (21.4%)	11 (78.6%)		
	YES	NO		
Other Sample Characteristics	*n* (%)	*n* (%)	χ^2	*P*-value
Maternal age			4.06	.255
<18 yrs	10 (17.5%)	47 (82.5%)		
18-26	88 (15.4%)	482 (84.6%)		
27-34	46 (15.4%)	253 (84.6%)		
>34	18 (24.3%)	56 (75.7%)		
Maternal race/ethnicity			31.14	<.001**
Hispanic	12 (31.6%)	26 (68.4%)		
Non-Hispanic Black	102 (21.1%)	382 (78.9%)		
Non-Hispanic White	45 (9.7%)	421 (90.3%)		
Other	3 (30.0%)	7 (70.0%)		
Maternal education			3.50	.320
<12	43 (17.4%)	204 (82.6%)		
12	58 (18.0%)	265 (82.0%)		
13-16	47 (13.2%)	310 (86.8%)		
≥17	12 (17.4%)	57 (82.6%)		
Marital status			.435	.510
Married	79 (17.0%)	385 (83.0%)		
Not married	83 (15.5%)	453 (84.5%)		
Smoking			.079	.778
No	141 (16.2%)	730 (83.8%)		
Yes	19 (15.2%)	106 (84.8%)		
Hypertension			.027	.870
No	8 (15.4%)	44 (84.6%)		
Yes	154 (16.2%)	794 (83.8%)		

Note. ***P* <.001

Predicting Perinatal Outcomes Based on Exposure and Controlling for Maternal Characteristics. A binary logistic regression model was used to examine to what extent maternal exposure to a hurricane and tornado disaster predicts preterm birth, and low birth weight outcomes among the combined sample (*N* = 2,000); and individually in Alabama (for tornado exposure; *N* = 1,000), and Mississippi (for hurricane exposure; *N* = 1,000), adjusting for socio-demographic factors, health behaviors, and maternal health status. The results of the binary logistic regression analyses are displayed in Tables 10, 11, and 12. For the combined sample, Table 10 shows that exposure to the tornado or hurricane disaster incidents does not influence low birth weight (*OR* = 1.10, 95% *CI* = [.825-1.64]), and preterm birth (*OR* = 1.10, 95% *CI* = [.860-1.40]). Adjusting for covariates in the model, Table 10 indicate no change in the direction of the association between exposure and the perinatal outcomes. However, mothers with hypertension were more likely to have a low birth weight infant (*OR* = 2.77, 95% *CI* = [1.64-4.66]), and a preterm delivery (OR = 2.00, 95% *CI* = [1.23-3.26]), compared with non-hypertensive mothers.

For the Alabama sample, Table 11 shows that mothers exposed to the tornadoes were 1.88 times (95% *CI* = [1.27-2.78]) more likely to have a low birth weight baby, and 1.73 times (95% *CI* = [1.24-2.42]) more likely to have a preterm delivery compared with mothers who were not exposed.

Table 10

Unadjusted and Adjusted Odds Ratios and 95% CI of Tornado/Hurricane Exposure on Low Birth Weight, Preterm Birth, and Infant Mortality (for Combined Sample)

	Low birth weight OR (95% CI)	*P*-value	Preterm birth OR (95% CI)	*P*-value	Infant mortality OR (95% CI)	*P*-value
			Unadjusted			
No exposure	Reference		Reference		Reference	
Yes exposure	1.10 [.825, 1.64]	.519	1.10 [.860, 1.40]	.452	1.19 [.530, 2.66]	.678
			Adjusted			
No exposure	Reference		Reference		Reference	
Yes exposure	.938 [.632, 1.40]	.752	.867 [.622, 1.21]	.399	1.25 [.332, 4.68]	.744
Maternal age						
<18 yrs	1.67 [.766, 3.66]	.196	1.35 [.745, 2.46]	.321	NA	NA
18-26	2.12 [.967, 4.65]	.061	1.59 [.871, 2.89]	.131	NA	NA
27-34	Reference		Reference		Reference	
>34	1.54 [.528, 4.48]	.430	1.54 [.657, 3.61]	.321	NA	NA
Maternal race/ethnicity						
Hispanic	1.25 [.512, 3.04]	.627	1.37 [.651, 2.86]	.410	.081 [.005, 1.38]	.082
Non-Hispanic Black	2.39 [.979, 5.83]	.056	1.98 [.938, 4.19]	.073	.996 [.110, 9.01]	.997
Non-Hispanic White	Reference		Reference		Reference	
Other	NA	NA	2.80 [.718, 10.92]	.138	NA	NA
Maternal education						
<12	1.84 [.879, 3.83]	.106	1.48 [.807, 2.70]	.206	NA	NA
12	1.15 [.548, 2.39]	.718	1.34 [.740, 2.41]	.337	NA	NA
13-16	Reference		Reference		Reference	
≥17	1.77 [.802, 3.90]	.158	1.46 [.762, 2.80]	.253	NA	NA
Marital status						
Married	Reference		Reference		Reference	
Not married	.908 [.610, 1.35]	.634	.944 [.677, 1.32]	.736	.981 [.230, 4.18]	.979
Hypertension						
No	Reference		Reference		Reference	
Yes	2.77 [1.64, 4.66]	<.001	2.00 [1.23, 3.26]	.005	3.09 [.643, 14.87]	.159

Note. NA = Estimates cannot be computed as cells reported zero frequency and hence odds ratios, CI and p-values are not calculated.

Table 11

Unadjusted and Adjusted Odds Ratios and 95% CI of Tornado Exposure on Low Birth Weight, Preterm Birth, and Infant Mortality for Alabama

	Low birth weight OR (95% CI)	*P*-value	Preterm birth OR (95% CI)	*P*-value	Infant mortality OR (95% CI)	*P*-value
			Unadjusted			
No exposure	Reference		Reference		Reference	
Yes exposure	1.88 [1.27, 2.78]	.002	1.73 [1.24, 2.42]	.001	1.13 [.377, 3.38]	.829
			Adjusted			
No exposure	Reference		Reference		Reference	
Yes exposure	1.91 [1.27, 2.87]	.002	1.68 [1.19, 2.39]	.004	1.17 [.384, 3.58]	.780
Maternal age						
<18 yrs	1.24 [.547, 2.81]	.607	.832 [.427, 1.62]	.590	1.08 [.123, 9.48]	.944
18-26	1.04 [.453, 2.38]	.927	.887 [.454, 1.73]	.726	.624 [.063, 6.16]	.687
27-34	Reference		Reference		Reference	
>34	.756 [.201, 2.84]	.679	.885 [.314, 2.49]	.816	1.66 [.090, 30.65]	.734
Maternal race/ethnicity						
Hispanic	.823 [.355, 1.91]	.651	.773 [.385, 1.55]	.468	.909 [.109, 7.57]	.929
Non-Hispanic Black	1.76 [.738, 4.20]	.202	1.45 [.698, 2.99]	.321	.927 [.097, 8.84]	.948
Non-Hispanic White	Reference		Reference		Reference	
Other	.659 [.073, 5.95]	.710	1.45 [.341, 6.20]	.612	NA	NA
Marital status						
Married	Reference		Reference		Reference	
Not married	1.62 [.976, 2.68]	.062	1.82 [1.18, 2.80]	.007	1.65 [.422, 6.46]	.472
Hypertension						
No	Reference		Reference		Reference	
Yes	2.64 [1.38, 5.04]	.003	3.32 [1.88, 5.88]	<.001	1.27 [.157, 10.23]	.824

Note. NA = Estimates cannot be computed as cells reported zero frequency and hence odds ratios, CI and p-values are not calculated.

Upon adjusting for maternal characteristics, these findings remain significant among mothers exposed to the disaster incident. The findings indicate mothers exposed to the tornadoes were more likely (*OR* = 1.91, 95% *CI* = [1.27-2.87]) to have a low birthweight baby, and 1.68 times (95% *CI* = [1.19-2.39]) more likely to have a preterm delivery compared with mothers who were not exposed. Hypertension also had a significant effect on low birthweight (*OR* = 2.64, 95% *CI* = [1.38-5.04]), and preterm births (*OR* = 3.32, 95% *CI* = [1.88-5.88]). However, maternal age and maternal race/ethnicity did not have a significant effect on low birth weight and preterm birth outcomes. Of the maternal characteristics, only the non-married mothers were 1.82 times (95% *CI* = [1.18-2.80]) more likely to have a preterm delivery compared with married mothers.

Table 12 presents the results of the unadjusted and adjusted logistic regression analysis examining the influence of maternal exposure to a hurricane on low birth weight and preterm birth among the sample of mothers from Mississippi. Interestingly, unadjusted odds ratios show mothers exposed to the hurricane disaster incident had a risk for low birth weight (*OR* = .517, 95% *CI* = [.284-.941]; p = .031). However, upon adjusting for other covariates these findings did not remain statistically significant (*OR* = .608, 95% *CI* = [.329-1.13]; p = .113). Maternal hypertension was a predictor for low birth weight (*OR* = 2.79, 95% *CI* = [1.46-5.34]).

Table 12

Unadjusted and Adjusted Odds Ratios and 95% CI of Hurricane Exposure on Low Birth Weight, Preterm Birth, and Infant Mortality for Mississippi

	Low birth weight OR (95% CI)	*P*-value	Preterm birth OR (95% CI)	*P*-value	Infant mortality OR (95% CI)	*P*-value
			Unadjusted			
No exposure	Reference		Reference		Reference	
Yes exposure	.517 [.284, .941]	.031	.680 [.431, 1.08]	1.00	1.42 [.391, 5.14]	.595
			Adjusted			
No exposure	Reference		Reference		Reference	
Yes exposure	.608 [.329, 1.13]	.113	.723 [.452, 1.16]	.176	.846 [.090, 7.91]	.883
Maternal age						
<18 yrs	1.83 [.694, 4.83]	.222	1.61 [.783, 3.30]	.196	NA	NA
18-26	2.57 [.968, 6.84]	.058	1.75 [.845, 3.63]	.132	NA	NA
27-34	Reference		Reference		Reference	
>34	2.24 [.643, 7.82]	.205	1.64 [.593, 4.51]	.342	NA	NA
Maternal race/ethnicity						
Hispanic	.963 [.315, 2.95]	.947	.979 [.408, 2.35]	.962	NA	NA
Non-Hispanic Black	1.85 [.613, 5.57]	.275	1.26 [.526, 3.03]	.602	.536 [.053, 5.44]	.597
Non-Hispanic White	Reference		Reference		Reference	
Other	NA	NA	3.08 [.671, 14.13]	.148	NA	NA
Maternal education						
<12	1.89 [.742, 4.79]	.183	1.46 [.707, 3.03]	.305	NA	NA
12	1.43 [.565, 3.61]	.451	1.38 [.677, 2.80]	.377	NA	NA
13-16	Reference		Reference		Reference	
≥17	2.08 [.776, 5.56]	.146	1.51 [.694, 3.29]	.298	NA	NA
Marital status						
Married	Reference		Reference		Reference	
Not married	.783 [.496, 1.24]	.293	.772 [.528, 1.13]	.184	1.21 [.227, 6.46]	.823
Smoking						
No	Reference		Reference		Reference	
Yes	.623 [.357, 1.09]	.096	1.06 [.638, 1.77]	.814	.263 [.051, 1.36]	.111
Hypertension						
No	Reference		Reference		Reference	
Yes	2.79 [1.46, 5.34]	.002	1.68 [.895, 3.15]	.106	1.59 [.190, 13.36]	.669

Note. NA = Estimates cannot be computed as cells reported zero frequency and hence odds ratios, CI and p-values are not calculated.

Pregnant mothers with hypertension and prenatal exposure to a hurricane were 2.79 times more likely to have a low birth weight baby. Although there was a significant association between hurricane exposure and the maternal race/ethnicity characteristic (p = < .001) in the chi-square analysis, maternal race/ethnicity was not a significant predictor (*OR* = .963, 95% *CI* = [.315, 2.95]; p = .947), for Hispanic and (*OR* = 1.85, 95% *CI* = [.613, 5.57]; p = .275, for non-Hispanic Black) in the logistic regression model. Furthermore, in the unadjusted (*OR* = .680, 95% *CI* = [.431, 1.08]; p = 1.00) and adjusted analyses (*OR* = .723, 95% *CI* = [.452, 1.16]; p = 1.76), maternal hurricane exposure was not a significant predictor for preterm births.

As a result of these findings, the null hypothesis is accepted for the combined sample since exposure to the tornado or hurricane disaster incidents did not influence low birth weight (*OR* = 1.10, 95% *CI* = [.825-1.64]) and preterm birth (*OR* = 1.10, 95% *CI* = [.860-1.40]). In addition, adjusting for covariates indicated no change in the direction of the association between maternal exposure to hurricanes or tornadoes and perinatal outcomes. Likewise, the null hypothesis is accepted for the Mississippi sample as the adjusted analyses showed exposure did not have a statistically significant influence (*OR* = .608, 95% *CI* = [.329-1.13]; p = .113) on low birth weight; and in the unadjusted (*OR* = .680, 95% *CI* = [.431, 1.08]; p = 1.00) and adjusted analyses (*OR* = .723, 95% *CI* = [.452, 1.16]; p = 1.76), for preterm births maternal hurricane exposure was not a significant predictor.

The null hypothesis is rejected for Alabama since there is a statistically significant association between maternal exposure to tornadoes (*OR* = 1.73, 95% *CI* = [1.24-2.42]) and preterm birth with a *p* value < 0.05, unadjusted; and when adjusted (*OR* = 1.68, 95% *CI* = [1.19-2.39]) for confounders, with a *p* value < 0.05. Correspondingly, there is a statistically significant association between maternal exposure to tornadoes (*OR* = 1.88, 95% *CI* = [1.27-2.78]) and low birthweight with a *p* value < 0.05, unadjusted; and with a *p* value < 0.05 when adjusted (*OR* = 1.91, 95% *CI* = [1.27-2.87]). These findings indicate maternal exposure to a tornado does influence preterm birth and low birth weight.

Impact of Exposure on Infant Mortality Controlling for Maternal Characteristics

Associations of exposure and infant mortality controlling for maternal characteristics. Bivariate tests for associations between maternal prenatal hurricane and tornado disasters exposure and infant mortality were calculated using chi-square analyses. Table 7 provide a cross table display between maternal prenatal exposure to the hurricane or tornado disaster and infant mortality, the percent distributions, and the significance (*p*) for the combined sample. No significant association between exposure to the disaster incidents and infant mortality were observed for the combined sample. Among the analytic sample for Alabama (*N* = 1,000), bivariate tests revealed no statistically significant associations between maternal prenatal tornado exposure and infant mortality (see Table 8). Similarly, no statistically significant associations between maternal prenatal hurricane exposure and infant mortality were observed among the analytic sample for Mississippi (*N* = 1,000; see Table 9).

Predicting infant mortality based on exposure and controlling for maternal characteristics. Logistic regression analyses for the entire sample and two sub-samples

(Alabama and Mississippi), were performed to examine the possible effects of exposure to hurricane and tornado incidents on infant mortality. Unadjusted and adjusted analyses were conducted for maternal age, maternal race/ethnicity, marital status, and hypertension on infant mortality in the combined sample (*N* = 2,000) and the two sub-samples (see Tables 10, 11, and 12). The findings in Table 10 indicate exposure to the disaster incidents did not have a significant influence on infant mortality among the combined sample, regardless of adjusting for covariates. The likelihood of infant mortality was marginally higher, although not statistically significant, among exposed mothers (unadjusted *OR*, 1.19, 95% *CI*, [.530–2.66]), whether adjusting for covariates (adjusted *OR*, 1.25, 95% *CI*, [.332–4.68]) compared with non-exposed mothers. In considering maternal race/ethnicity, though not a statistically significant factor predicting infant mortality, the likelihood of infant mortality was higher, among exposed non-Hispanic Black mothers (adjusted *OR*, .996, 95% *CI*, [.110–9.01]) compared with Hispanic mothers (adjusted *OR*, .081, 95% *CI*, [.005–1.38]). As shown in Table 11, although not a statistically significant predictor, the likelihood of infant mortality among mothers from Alabama, was higher among exposed mothers age 34 and older (adjusted *OR*, 1.66, 95% *CI*, [.090–30.65]) compared with mothers younger than 18 years of age (adjusted OR, 1.08, 95% *CI*, [.123–9.48]) and mothers age 18 to 26 years old (adjusted *OR*, .624, 95% *CI*, [.063–6.16]). Similarly, the likelihood of infant mortality was marginally higher, among exposed non-Hispanic Black mothers (adjusted *OR*, .927, 95% *CI*, [.097–8.84]) compared with Hispanic mothers (adjusted *OR*, .909, 95% *CI*, [.109–7.57]).

As a result of these findings, the null hypothesis is accepted since there is not a statistically significant association between maternal exposure to hurricanes or tornadoes (*OR* = 1.19, 95% *CI* = [.530-2.66]) and infant mortality of a significance level of 0.05, (unadjusted; or adjusted, *OR* = 1.25, 95% *CI* = [.332-4.68]) in the logistic regression model.

Influence of Exposure on Mode of Delivery Controlling for Maternal Characteristics

This research question could not be answered due to the significant percentage of missing data in the dataset, for the outcome variable, mode of delivery for the combined sample (88%). A substantial proportion of missing data for mode of delivery was also observed for the sample of mothers from Alabama (100%), and Mississippi (76%). Accordingly, this research question was excluded from the study as a substantially negligible percentage of mode of delivery data was available to this investigation.

Summary

This investigation examined the association between maternal prenatal exposure to a hurricane and tornado disaster, on pregnancy outcomes, such as birth weight, preterm birth, infant mortality, and the mode of delivery. Maternal characteristics, including socio-demographic factors, health behaviors, pregnancy history, and maternal health status were also examined. Bivariate and multivariate statistical models were employed to examine the research questions and test the hypotheses. The findings reported in this chapter answered two of the three research questions posed by this investigation. The third research question regarding mode of delivery, was excluded from this study as a substantial percentage of the mode of delivery data was missing from the dataset. Thus, the hypotheses for the combined sample and the Alabama and Mississippi individual samples, could not be tested. Moreover, the research question could not be empirically evaluated and answered appropriately.

The first research question presented an inquiry related to the influence of hurricanes and tornadoes on low birth weight and preterm birth pregnancy outcomes. The findings from this investigation indicated that exposure to a tornado or hurricane disaster incident did not influence low birth weight (*OR* = 1.10, 95% *CI* = [.825-1.64]) and preterm birth (*OR* = 1.10, 95% *CI* = [.860-1.40]), even after adjusting for covariates. As a result, the null hypothesis was accepted for the combined sample. For the Mississippi sample, adjusted logistic regression analyses showed exposure to a hurricane did not have a statistically significant influence on low birth weight (*OR* = .608, 95% *CI* = [.329-1.13]; p = .113). Furthermore, maternal hurricane exposure was not a significant predictor of preterm births in the unadjusted (*OR* = .680, 95% *CI* = [.431, 1.08]; p = 1.00) and adjusted analyses (*OR* = .723, 95% *CI* = [.452, 1.16]; p = 1.76). Accordingly, the null hypothesis was accepted for the Mississippi sample.

For the Alabama sample the null hypothesis was rejected. The findings indicated maternal exposure to a tornado does influence low birth weight and preterm birth. A statistically significant association was found between maternal tornado exposure (unadjusted *OR* = 1.88, 95% *CI* = [1.27-2.78]) and low birthweight with a p value < 0.05, even when adjusting for covariates (*OR* = 1.91, 95% *CI* = [1.27-2.87]). Similarly, a statistically significant association between maternal exposure to tornadoes (unadjusted

OR = 1.73, 95% *CI* = [1.24-2.42]; and adjusted *OR* = 1.68, 95% *CI* = [1.19-2.39]) and preterm birth was observed with a p value < 0.05.

The second research question provided a query regarding the impact of maternal exposure to hurricane or tornado disasters on infant mortality. The results of the statistical analyses showed exposure to a hurricane or tornado disaster incident (*OR* = 1.19, 95% *CI* = [.530-2.66]) did not significantly influence infant mortality among the combined sample, regardless of adjustments imputed for confounders (unadjusted; or adjusted, *OR* = 1.25, 95% *CI* = [.332-4.68]). The findings were also consistent showing exposure was not a statistically significant predictor of infant mortality among the sample of mothers from Alabama and Mississippi. Accordingly, the null hypothesis was accepted.

The third research question pertained to the mode of delivery, and provided an inquiry concerning the influence of hurricane or tornado disasters on the mode of delivery. As there was a large percentage of missing data for the mode of delivery variable, the hypotheses for the combined sample and the individual samples from Alabama and Mississippi, could not be tested. Furthermore, the research question could not be empirically examined and answered properly. As a result, this research question was excluded from the investigation.

The findings provided in this chapter are described in greater detail in Chapter 5. The discourse in Chapter 5, contrasts the current findings with the results of other studies examining the associations between maternal exposure to natural disasters and pregnancy outcomes. Limitations and the generalizability of this investigation are also discussed.

The chapter concludes with a discussion regarding public health action and associated implications for social change, and recommendations for further empirical studies.

Chapter 5: Discussion, Conclusions, and Recommendations

Introduction

The purpose of this quantitative, retrospective, cross-sectional, cohort study was to examine the relationship between maternal prenatal exposure to a hurricane and tornado disaster, on pregnancy outcomes. The dependent variables of interest in this investigation were birth weight, preterm birth, infant mortality, and mode of delivery. The primary independent variable of interest was maternal prenatal exposure to a hurricane or tornado disaster incident; and the covariates were socio-demographic factors, health behaviors, pregnancy history, and maternal health status.

This investigation was conducted to mitigate a gap in the literature regarding the association between maternal prenatal exposure to weather disasters like hurricanes and tornadoes, and unfavorable pregnancy outcomes. The existing literature include only a few studies addressing maternal prenatal exposure to hurricanes and maternal and infant health outcomes; and there is a lacunae on the influence of hurricanes on infant mortality. Furthermore, as evidenced by a recent review of available research, systematic knowledge on the impact of tornado disasters on pregnancy outcomes is also lacking. Delimited county-level linked birth and infant death data were used in this study to capture variations in birth outcomes, and provide discernment of potential risk factors which may contribute to low birth weight, preterm birth, and infant mortality among women in Alabama giving birth after the April 2011 tornado disaster, and among pregnant mothers in Mississippi, in the wake of Hurricane Katrina of August 2005.

In the bivariate and multivariate analyses examining the extent to which maternal prenatal exposure to a hurricane and tornado disaster predicts preterm birth and low birth weight outcomes among the combined sample—maternal prenatal exposure to the hurricane or tornado disaster incidents did not appear to influence preterm birth and low birth weight. In the individual analysis among Hurricane Katrina exposed mothers from Mississippi, exposure also did not have a statistically significant influence on preterm birth and low birth weight. However, in the independent analysis for tornado exposure in Alabama, a statistically significant association between maternal prenatal exposure to tornadoes and preterm birth and low birth weight was observed.

In the assessment of the possible effects of maternal prenatal exposure to hurricane and tornado incidents on infant mortality, for the entire sample; exposure to the disaster incidents did not have a statistically significant influence on infant mortality. However, the likelihood of infant mortality was marginally higher, though not statistically significant, among exposed mothers compared with non-exposed mothers. In the independent analysis for tornado exposure in Alabama, a statistically significant association between maternal prenatal exposure to the 2011 April tornadoes in Alabama and infant mortality was not observed. Likewise, in the individual analysis for hurricane exposure in Mississippi, a statistically significant association between maternal prenatal exposure to Hurricane Katrina and infant mortality was not detected.

In this chapter, an interpretation of the findings presented in Chapter 4, is provided. Limitations regarding generalizing the study’s findings, as well as the trustworthiness, validity, and reliability of this investigation are then described. This is followed by a description of recommendations proposing further research inquiry. Next, the significance of this study, within the context of public health action and associated implications for social change is provided. The chapter concludes with a summary of the overall research.

Interpretation of the Findings

The findings from this study complement prior research suggesting pregnant women and the developing fetus are vulnerable to natural disaster storms, and maternal prenatal exposure is associated with an increased risk for adverse pregnancy outcomes (Antipova & Curtis, 2015; Currie & Rossin-Slater, 2013; Hamilton et al., 2009; Harville et al., 2009; Harville, Tran et al., 2010; Simeonova, 2011; Xiong et al., 2008). The results of this investigation also show a meaningful association between maternal prenatal exposure to tornadoes and an increased risk for preterm births, and amplified odds for having a low birth weight infant. However, findings indicate hurricane and tornado exposure in pregnancy did not have a statistically significant negative effect on infant mortality. Although no significant association was detected between exposure and infant mortality in this study, this finding engenders intrigue suggesting the risk for perinatal mortality via indirect mechanisms is a plausible concern.

Hypothesis 1: Exposure Influence on Preterm Birth and Low Birth Weight

In this study, the null hypothesis statement offered that maternal prenatal exposure to hurricane or tornado disasters has no significant influence on preterm birth and low birth weight, either for the entire sample, or separately for the Alabama and Mississippi samples. This null hypothesis was accepted for the combined sample as the findings of this investigation show exposure to the tornado or hurricane disaster incidents did not influence preterm birth and low birth weight. These findings are inconsistent with prior research evidence highlighting disparities in the literature regarding the influence of severe storms on preterm birth and low birth weight. In a study investigating the association between natural disasters on pregnancy outcomes, Simeonova (2011) detected marginal statistically significant evidence correlating exposure to thunderstorms, hurricanes, and tornadoes with preterm birth and low birth weight. Interestingly, Simeonova exploited these austere weather systems in the aggregate, as a predictor variable termed severe storms. In the analyses, Simeonova detected evidence of risks for preterm birth and low birth weight with maternal prenatal exposure. However, in the current study, although tornado and hurricane exposure were pooled in the multivariate analyses, a meaningful association between exposure and perinatal outcomes was not detected, even when controlling for confounders.

In the individual analysis examining the association of maternal prenatal exposure to Hurricane Katrina on preterm birth and low birth weight among the sample of mothers from Mississippi, I did not observe a significant association between hurricane exposure and risks for preterm birth or low birth weight. This finding lends more evidence broadly supporting the results of previous reports on the influence of hurricane exposure on preterm birth and low birth weight (Antipova & Curtis, 2015; Currie & Rossin-Slater, 2013; Hamilton et al., 2009; Harville et al., 2009; Harville, Tran et al., 2010; Xiong et al., 2008). Specifically, in a study examining the effects of Hurricane Katrina on pregnancy outcomes in Mississippi, Hamilton et al. (2009) found no evidence correlating exposure with preterm birth or low birth weight. The findings in the current study are consistent with the results of Hamilton et al. (2009). Furthermore, the results of the present study also partially accords with the findings of Antipova and Curtis (2015), showing exposure was not a significant predictor of low birth weight risks. Yet, the results of the current investigation equally show disparities with Antipova and Curtis' observations suggesting an association between exposure and preterm births, and other research evidence positing a correlation between exposure and both preterm birth and low birth weight outcomes (Harville et al., 2009; Simeonova, 2011; Xiong et al., 2008).

In contrast to the Hurricane Katrina exposure analysis in Mississippi, the null hypothesis was rejected for the Alabama sample as a meaningful risk for preterm birth and low birth weight outcomes was detected. In the discrete analysis evaluating the association of exposure to the April 2011 tornadoes on preterm birth and low birth weight, exposed pregnant mothers were 1.73 times likely to have a preterm birth and 1.88 times more likely to have a low birth weight baby, compared with unexposed mothers. Research evidence of a probable correlation between tornado exposure and preterm birth and low birth weight outcomes is significantly limited. One study examining the relationship between severe storms including tornadoes, and adverse pregnancy outcomes found a negligible, but statistically significant association between exposure and preterm birth and low birth weight outcomes (Simeonova, 2011). The results of the current investigation are similar to the findings by Simeonova (2011). However, as this investigation independently examined the effects of the April 2011 Alabama tornadoes on adverse pregnancy outcomes, the results show the odds of preterm birth and low birth weight outcomes are higher and statistically significant for pregnant mothers with tornado exposure relative to mothers with no exposure.

Hypothesis 2: Exposure Impact on Infant Mortality

The null hypothesis statement in this study indicated maternal prenatal exposure to hurricane or tornado disasters has no significant impact on infant mortality, either for the entire sample, or separately for the Alabama and Mississippi samples. This null hypothesis was accepted for the combined sample, and individually for the Alabama and Mississippi samples, as the findings of this investigation show exposure to the hurricane or tornado disaster incidents did not have a significant impact on infant mortality. Information on the effects of hurricane and tornado natural disasters on perinatal mortality is limited. However, a study by Kanter (2010) examined infant mortality rates in New Orleans, Louisiana before Hurricane Katrina and post Hurricane Katrina, and found no evidence of an increase in perinatal mortality rates concomitant with hurricane exposure. An intriguing finding in Kanter's investigation was a decline in the mortality rate among neonates (less than 28 days of age), and post-neonatal infants (28 days to 12 months of age). The author hypothesized that population displacements consequential to the hurricane, could have accounted for this declining rate. The findings of the present study examining the effects of hurricane and tornado disasters on pregnancy outcomes, show exposure to the disaster incidents did not have a significant association on infant mortality, regardless of adjusting for covariates. This finding was therefore consistent with the null hypothesis examined in this study, and comport with the evidence reported by Kanter showing no association between exposure and an increase in perinatal mortality rates.

Whereas the results of this study show no significant association between maternal prenatal exposure to hurricane and tornado disaster incidents on infant mortality, it is thought-provoking to question whether these disasters could have an indirect impact on perinatal mortality. Evidence from Currie and Rossin-Slater (2013) show a strong correlation between maternal prenatal exposure to hurricanes and abnormal conditions of the neonate to include meconium aspiration syndrome and respiratory complications requiring assisted ventilation. Moreover, natural disasters like hurricanes, are known to contribute to increased incidences of morbidity, as measured by incidental medical consequences to include, acute respiratory infections; fevers; and diarrhea, to name a few (Callaghan et al., 2007; Zotti et al., 2013). Failure to apply effective and appropriate medical care and treatment of these conditions could contribute to deleterious consequences. This is particularly significant among children under the age of five, wherein both acute respiratory infection and diarrhea are the leading causes of mortality. Additionally, exposure to natural disasters could adversely influence the odds of some infants obtaining age-appropriate immunizations against vaccine-preventable diseases, which could place them at greater risk for infectious diseases (Callaghan et al., 2007; Zotti et al., 2013). It is also interesting to mention, findings from the current study show the likelihood of infant mortality was marginally higher (1.19 times higher unadjusted) among exposed mothers, whether adjusting for covariates (adjusted 1.25), compared with non-exposed mothers; though this observation was not statistically significant. This finding could lend credence to the theory that exposure may not be the primary actor in a potential association, but perhaps other factors connected with the disaster incident such as individual experiences, environmental conditions, and the state of personal affairs may also have a role to play. It would seem reasonable to suggest exposure to hurricane and tornado natural disasters could circuitously influence findings of a possible association with perinatal mortality.

Variances and Discrepancies in Similar Studies

Researchers across various disciplines have suggested in utero exposure to severe storms like hurricanes and tornadoes, are associated with adverse pregnancy outcomes, including preterm births and low birth weight (Antipova & Curtis, 2015; Harville et al., 2009; Simeonova, 2011; Xiong et al., 2008). An evolving body of literature examining the effects of hurricanes on pregnancy outcomes have suggested that exposure could serve as a stressor, and likely influence the effects of birth outcomes (Antipova & Curtis, 2015; Currie & Rossin-Slater, 2013; Harville et al., 2009; Simeonova, 2011; Xiong et al., 2008). Yet, most studies have yielded conflicting findings (Antipova & Curtis, 2015; Currie & Rossin-Slater, 2013; Hamilton et al., 2009; Harville et al., 2009; Harville, Tran et al., 2010; Xiong et al., 2008). There are several possible reasons for this lack of congruence. These inconsistencies could be attributed to empirical research approaches including small sample sizes (Xiong et al., 2008); novel research designs as performed by Simeonova (2011) with diverse natural disaster exposure variables, and in estimating exposure by computing forward from an estimated conception date and approximating gestational age (Currie & Rossin-Slater, 2013). Another plausible consideration for the disparity may include variations in defining exposure and covariate controls (Antipova & Curtis, 2015; Currie & Rossin-Slater, 2013; Hamilton et al., 2009; Harville et al., 2009; Harville, Tran et al., 2010; Xiong et al., 2008). Remarkably, few studies have examined the possible interaction between race/ethnicity (including Hispanics and other ethnicities), age, education, and exposure experiences (Antipova & Curtis, 2015; Currie & Rossin-Slater, 2013; Harville, Tran et al., 2010). In this study, covariates from other studies investigating the association of hurricane and tornado disaster incidents on pregnancy outcomes were also considered in the research design. Covariates to include socio-demographic factors, health behaviors, and maternal health status were considered in adjusting for their effects, and to isolate the unadulterated influence of the exposure variables on the response variables.

Theoretical Framework for Analyses

The life course perspective was the theoretical framework for this study. As discussed in Chapter 2, the life course perspective provides the analytical framework to facilitate comprehension and discernment of reasonable inferences correlating exposure experiences, certain biological, behavioral, social, and environmental factors which could synergistically influence maternal and infant health outcomes (Ben-Shlomo & Kuh, 2002; Elder et al., 2003; Halfon & Hochstein, 2002; Lu & Halfon, 2003). The life course perspective offers two wide-ranging conceptual approaches, the *cumulative pathway* and *early programming*, which provides context to help explain plausible associations between exposures and outcomes (Ben-Shlomo & Kuh, 2002; Halfon & Hochstein, 2002; Lu & Halfon, 2003).

Natural disasters like hurricanes and tornadoes, may establish conditions that intensify social and environmental issues which could contribute to maternal stress (Callaghan et al., 2007; Harville et al., 2009; Sastry & Gregory, 2013; Zotti et al., 2013). These social and environmental factors include, but are not limited to, an infringement upon healthcare services and community infrastructure; inadequate or a lack of prenatal care; the interruption of essential human services like nutritious sustenance, social support, and housing; and the threat of bodily harm or even loss of life (Callaghan et al., 2007; Harville et al., 2009; Sastry & Gregory, 2013; Zotti et al., 2013). Accordingly, it is perhaps reasonable to suggest exposure experiences to a hurricane or tornado, could influence the mechanisms that effect adverse pregnancy outcomes as hypothesized in the life course theoretical framework (Ben-Shlomo & Kuh, 2002; Elder et al., 2003; Halfon & Hochstein, 2002; Lu & Halfon, 2003).

Given the technological advances in weather forecasting and predicting the likely location of a hurricane or tornado impact, it is rational to consider that the anxiety and fear, associated with an impending natural disaster storm could engender maternal stress. Likewise, it is equally prudent to consider that an exposure experience (pre-incident and during the actual impact of the storm) could stimulate the effects correlated with the *early programming* pathway linked with life course perspective. As suggested by Callaghan (2007) and Zotti (2013) and their colleagues, adverse conditions such as exposure to an austere setting (involving environmental pollutants, inadequate housing, lack of electrical power, poor sanitation and water), and limited access to medical services and prenatal care during the post-disaster and recovery period of a natural disaster storm, could engender stress and depression, which may exacerbate the effects of a hurricane or tornado incident. Therefore, it is also reasonable to ponder that the effects of a hurricane or tornado disaster could similarly generate effects in pregnant women consistent with the *cumulative pathway* concept, wherein aggregate weathering effects on the body's regulatory system from a stressor, could perpetrate conditions for an allostatic load response (Halfon & Hochstein, 2002).

Limitations of the Study

A number of significant limitations should be considered when interpreting the findings of this study. First, this investigation utilized secondary data from the National Vital Statistics System Linked Infant Births and Deaths Record Files. Common concerns inherent with secondary data collected retrospectively include missing, duplicate, and incomplete data. Other noted concerns include the inability to account for prospective confounding social and behavioral determinants of health issues, which may influence birth outcomes. To mitigate possible data veracity concerns and prospective confounding issues, the dataset was examined to verify incomplete data, anonymous values, and duplicate records were purged from the dataset. The study sample was also delimited to singleton births; and statistical approaches to adjust for potential confounding factors were exploited.

Second, this study was constrained by the standard data fields for the U.S. birth certificate data available in the dataset; and the data fields with complete data. The linked birth and infant death dataset contained several missing data elements, which may have resulted due to errors in the data collection process. To moderate the effects of this limitation, serviceable information in the dataset were retained and examined, and only those specific missing data elements were excluded from the analysis, so as to sustain sampling variability and statistical power, and reduce the probability of bias in the statistical analyses (Liu & De, 2015; Roda et al., 2014; Young & Johnson, 2013).

Third, this study was cross-sectional and captured the prevalence of exposure cases to the disaster incident in the population of interest, at a given point in time. Accordingly, the development of evidence for any conclusions and causal inferences between exposures and outcomes was constrained. To address this limitation, no causation was attributed to the data and the study's findings were reported as associations. Fourth, the study population was restricted to pregnant women and singleton infant births and deaths occurring in four counties in Mississippi, and 10 counties in Alabama. As a result, generalizations of this study's findings are not projected beyond these states.

Another limitation of this study was the inability to precisely isolate subjects with maternal prenatal exposure to the predictor variables, and the impracticality of ascertaining the specific pathways linking exposure to observed pregnancy outcomes. This investigation ensued under the implicit assumption that maternal prenatal exposure to a hurricane or tornado prejudicially heighted anxiety and a concern for individual safety; and thus, triggered stressor responses among pregnant women with exposure experiences. In addition, maternal prenatal exposure was assumed based upon residence data obtained from the birth certificate and consistent with prior research approaches which exploited spatial methods of a storm's trajectory to calculate exposure (Antipova & Curtis, 2015; Currie & Rossin-Slater, 2013; Simeonova, 2011; Zahran et al., 2010).

Recommendations

Although this study builds on a nascent body of literature examining the influence of natural disasters on pregnancy outcomes, further research is needed. Future research is warranted to examine whether the results of this study regarding tornado exposure and birth outcomes, repeat in other samples and natural disasters. Moreover, there is still a significant dearth in the literature on the effects of tornadoes on maternal and infant health outcomes, and the influence of hurricanes on infant mortality (Buekens et al., 2006; Kanter, 2010; Zahran et al., 2014; Zahran et al., 2013). New studies could productively expand on the findings of this study and mitigate existing gaps in the public health and medical literature.

The county-level linked birth and infant death dataset in this investigation contained several missing data elements, and precluded the examination of the effects of exposure on the mode of delivery. As a result, this study should be replicated using a large sample with robust and complete mode of delivery data, to facilitate the examination of the effects of maternal prenatal exposure to a hurricane and tornado on the mode of delivery.

Further research is also needed to enhance our understanding of the mechanisms that lead hurricanes and tornadoes to affect health outcomes at birth, and their potential impact throughout the life course. Researchers have suggested natural disasters like hurricanes and tornadoes, could contribute to maternal stress and influence pregnancy outcomes (Callaghan et al., 2007; Harville et al., 2009; Sastry & Gregory, 2013; Zotti et al., 2013). In addition, several investigators have offered compelling evidence portending stress may induce epigenetic alterations which could contribute to poor pregnancy outcomes and developmental trajectories (Billack et al., 2012; Class et al., 2011; Gapp et al., 2014; Dunkel Schetter & Lobel, 2012; Provençal & Binder, 2014; Reynolds et al., 2013; Wadhwa et al., 2011). New research studies could exploit biologic markers of stress to investigate the possible relationship between maternal prenatal stress and adverse pregnancy outcomes.

Lastly, new studies are also needed to investigate the impact of cyclonic meteorological natural disaster incidents (like hurricanes, typhoons, cyclones, and tornadoes) in other areas of the world, to determine their effect on maternal and infant health outcomes globally. Findings from these new studies could then be compared with existing knowledge to inform the healthcare community, public health practice, and the emergency management community.

Implications

The results of this study have implications for areas which are prone to, or have recently experienced, a hurricane or tornado disaster. The findings of this investigation could be used to inform public health policy and to engender social change. Evidence from this research show pregnant women and their developing fetus, are vulnerable to the adverse effects of hurricane and tornado natural disasters. In Alabama, these effects included increased odds of exposed mothers delivering a preterm or low birth weight infant. In Mississippi, the results show there was potential risk for exposed mothers to have a low birth weight infant; and among both hurricane and tornado disasters, a potential marginal risk for infant mortality. These findings could be used by healthcare providers and public health practitioners, to promote public health policies that will improve disaster preparedness plans and programs essential to maternal and infant health preparedness for public health emergencies.

Knowledge from this research could advance social change by fostering the development and application of various community-level programs, which are necessary to meet the social and public health preparedness needs of maternal and neonatal populations, prior to, during, and in the wake of natural disasters. In geographical areas predisposed to the frequent occurrence of hurricanes and tornadoes, emergency management agencies and their public health counterparts, could use this information to advance public health and disaster preparedness in communities. Moreover, emergency management agencies in these communities should provide healthcare providers with disaster preparedness information (such as stocking drinking water, food and supplies, and planning for a place to evacuate), to assist pregnant women under their care, with preparing for disaster hazards. Thereafter, healthcare providers could offer regular disaster preparedness discussions to pregnant women as part of their care. These deliberations could be informed by this research and other relevant materials, to advise pregnant women of the associated exposure risks.

The results of this research may be used to make important contributions to policymakers, public health agencies, and non-governmental organizations. Findings from this study could help inform and educate officials and stakeholders, of the risk factors which may contribute to adverse pregnancy outcomes. Moreover, the results of this study could also enable the development of policies designating specific hospitals and clinics in local communities as special shelters for pregnant women during public health emergencies; and mandate access to healthcare services for pregnant and postpartum women, and the neonate irrespective of socioeconomic status, particularly in the wake of disasters. The findings of this study could also help enact legislation to improve preparedness for, response to, and recovery from public health emergencies involving a hurricane or tornado; and reduce the multitude of adverse effects of maternal prenatal exposure to natural disasters, among pregnant women and their unborn child. Positive social change could then originate with the establishment and implementation of relevant public health strategies and programs, to appropriately mitigate and amend these undesirable impacts.

Conclusion

This population-based study provides information which could help healthcare providers and public health practitioners in realizing the Healthy People 2020 goal of improving the health and well-being of women, infants, children, and families (HHS, 2015). Targeted objectives designed to realize this national public health goal include reducing the rates of low birth weights, preterm births, and infant mortality. Achieving the Healthy People 2020 aims for maternal and infant health requires an awareness of the factors which may influence adverse maternal and infant health outcomes, and thus could be exploited to mitigate risk and help advance population health.

The results of this study support previous evidence associating maternal prenatal exposure to hurricanes and tornadoes with an increased risk for adverse pregnancy outcomes. These findings are consistent with several investigators positing that pregnant women are susceptible to the deleterious effects of natural disaster storms. Previous research have shown a correlation between maternal prenatal exposure to a hurricane and preterm birth (Antipova & Curtis, 2015; Harville et al., 2009; Simeonova, 2011; Xiong et al., 2008), and low birth weight outcomes (Harville et al., 2009; Simeonova, 2011; Xiong et al., 2008). Similarly, a significant association has been observed between maternal prenatal exposure to a tornado and preterm birth and low birth weight (Simeonova, 2011). Researchers have postulated these influences could be credited to environmental issues, which could contribute to maternal stress (Callaghan et al., 2007; Harville et al., 2009; Sastry & Gregory, 2013; Zotti et al., 2013).

Given there is no evidence suggesting a relationship between maternal prenatal exposure to a hurricane and preterm birth or low birth weight (Currie & Rossin-Slater, 2013; Hamilton et al., 2009; Harville et al., 2009; Harville, Tran et al., 2010; Xiong et al., 2008), the findings of this study lends some confirmation roughly supporting these assertions. In the multivariate analysis examining the influence of maternal exposure to a hurricane on low birth weight and preterm birth, the unadjusted odds ratios showed mothers with hurricane exposure had a risk for delivering a low birth weight infant. However, a positive and consistent statistically significant association was not detected upon adjusting for other covariates. A significant association between maternal exposure to a hurricane and low birth weight was also observed in the bivariate analyses. Although it would seem encouraging to conclude that maternal prenatal exposure to a hurricane does not homogenously influence preterm birth and low birth weight, the limited bivariate and multivariate data provided in this study, coupled with the findings of previous research offering evidence to the contrary, strongly suggest this inquiry requires further examination.

This study contributes to the burgeoning body of evidence documenting the sensitivity of pregnancy outcomes to the adverse effects of hurricanes and tornadoes. The evidence reported in this study show that pregnant women with exposure experiences to the April 2011 Alabama tornadoes were at an increased risk of delivering a newborn with a low birth weight, and the neonates of mothers exposed to this incident had shorter gestations. Whereas the findings of this investigation showed a weak correlation between maternal prenatal exposure to hurricanes and tornadoes and infant mortality, this study helps bridge a gap in the existing literature by contributing evidence on the influence of exposure to these storms and infant mortality. The findings of this study reinforce evidence of a relationship between maternal prenatal exposure to hurricanes and tornadoes, and adverse pregnancy outcomes. However, these results are not generalized to populations beyond Alabama and Mississippi, or to other disaster incidents.

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Appendix A: IRB Study Approval

Kenneth Christopher

From:	IRB <irb@waldenu.edu>
Sent:	Thursday, December 10, 2015 6:59 PM
To:	Kenneth Christopher (kenneth.christopher@waldenu.edu)
Cc:	'Joseph F. Robare'
Subject:	IRB Materials Approved - Kenneth Christopher

Dear Mr. Christopher,

This email is to notify you that the Institutional Review Board (IRB) confirms that your study entitled, "The Effects of Hurricane and Tornado Disasters on Pregnancy Outcomes," meets Walden University's ethical standards. Our records indicate that you will be analyzing data provided to you by the National Center for Health Statistics as collected under its oversight. Since this study will serve as a Walden doctoral capstone, the Walden IRB will oversee your capstone data analysis and results reporting. The IRB approval number for this study is 12-10-15-0408759.

This confirmation is contingent upon your adherence to the exact procedures described in the final version of the documents that have been submitted to IRB@waldenu.edu as of this date. This includes maintaining your current status with the university and the oversight relationship is only valid while you are an actively enrolled student at Walden University. If you need to take a leave of absence or are otherwise unable to remain actively enrolled, this is suspended.

If you need to make any changes to your research staff or procedures, you must obtain IRB approval by submitting the IRB Request for Change in Procedures Form. You will receive confirmation with a status update of the request within 1 week of submitting the change request form and are not permitted to implement changes prior to receiving approval. Please note that Walden University does not accept responsibility or liability for research activities conducted without the IRB's approval, and the University will not accept or grant credit for student work that fails to comply with the policies and procedures related to ethical standards in research.

When you submitted your IRB materials, you made a commitment to communicate both discrete adverse events and general problems to the IRB within 1 week of their occurrence/realization. Failure to do so may result in invalidation of data, loss of academic credit, and/or loss of legal protections otherwise available to the researcher.

Both the Adverse Event Reporting form and Request for Change in Procedures form can be obtained at the IRB section of the Walden website: http://academicguides.waldenu.edu/researchcenter/orec

Researchers are expected to keep detailed records of their research activities (i.e., participant log sheets, completed consent forms, etc.) for the same period of time they retain the original data. If, in the future, you require copies of the originally submitted IRB materials, you may request them from Institutional Review Board.

Both students and faculty are invited to provide feedback on this IRB experience at the link below:

http://www.surveymonkey.com/s.aspx?sm=qHBJzkJMUx43pZegKlmdiQ_3d_3d

Sincerely,
Libby Munson
Research Ethics Support Specialist
Office of Research Ethics and Compliance
Email: irb@waldenu.edu
Fax: 626-605-0472

Appendix B: Data Use Agreement

National Center for Health Statistics
Data Use Agreement (DUA) for Vital Statistics Data Files

Requesting Organization: Kenneth Christopher, Walden University, School of Health Sciences

Requested Data File(s): County-level (All county) linked Births/Infant deaths for the following states only: Florida (for period 1 January 1997 to 31 December 2009); Mississippi (for period 1 January 2004 to 31 December 2006); Alabama (for period 1 January 2010 to 31 December 2012), and Oklahoma (for period 1 January 1997 to 31 December 2010).

Proposed Use(s): Secondary analysis of birth outcomes utilizing county-level linked birth and infant death files, to examine effects of prenatal exposure to a hurricane and/or tornado disaster on birth outcomes: birth weight, infant mortality and mode of delivery, controlling for socio-demographic factors, health behaviors, pregnancy history, and maternal health status.

Vital statistics data are provided to NCHS by vital statistics jurisdictions with the understanding that the data are protected under the provisions of the Public Health Services Act (42 U.S.C. 242m(d), and that any file released under a data use agreement requires both NAPHSIS and NCHS review and approval of proposed use.

The Public Health Service Act (42 U.S.C. 242m(d) provides that the data collected by the National Center for Health Statistics (NCHS) may be used only for the purpose for which they were obtained; any effort to determine the identity of any reported cases, or to use the information for any purpose other than for health statistical reporting and analysis, would violate this statutory restriction and the conditions of this data use agreement. NCHS does all it can to assure that the identity of data subjects cannot be disclosed; all direct identifiers, as well as characteristics that might lead to identification, are omitted from the data set. Nevertheless it may be possible in rare instances, through complex analysis and with outside information to ascertain from the data set the identity of particular persons or establishments. Considerable harm could ensue if this were done.

Therefore, the undersigned gives the following assurances with respect to all NCHS data sets:

- I will not use nor permit others to use the data in these data sets in any way except for statistical reporting and analysis and for the purposes described in the data request.

- I will not release nor permit others to release the data sets or any part of them to any person who is not a member of this organization, except with the approval of NCHS. Under section 308(d) of the Public Health Service Act, the only persons to be allowed access to these data sets will be staff members of this organization or its contractor(s) who have been authorized to work with the data and have, prior to being granted access to the data, read and signed this DUA Statement in the space provided below.

- I will not attempt to link nor permit others to attempt to link the data set with individually identifiable records from any other NCHS or non-NCHS data set;

Data Use Agreement (DUA) for Vital Statistics Data Files—Cont.

- I will not attempt to use the data sets nor permit others to use them to learn the identity of any person or establishment included in any data set;

- If I should inadvertently discover the identity of any person or establishment, then (a) I will make no use of this knowledge, (b) I will immediately advise the Director of the Division of Vital Statistics of the incident, (c) I will safeguard or destroy the information that would identify an individual or establishment, as requested by NCHS, and (d) I will inform no one else of the discovered identity.

In addition, I will make every effort to release all statistical information in such a way as to avoid inadvertent disclosure. For example:

- **No figure, including totals, should be less than 10 in tabulations for sub-national geographic areas, regardless of number of years combined.**
- No data on an identifiable case should be derivable through subtraction or other calculation from the combination of tables in a given publication.
- No data should permit disclosure when used in combination with other known data.

I will secure identical written assurances from every individual within this organization who will have access to this data set.

My signature below indicates my agreement to comply with the above-stated statutorily-based requirements with the knowledge that deliberately making a false statement in any matter within the jurisdiction of any department or agency of the Federal Government violates 18 USC 1001 and is punishable by a fine of up to $10,000 or up to 5 years in prison.

Further conditions for data use:

NAPHSIS and NCHS have reviewed and approved the use of the data provided under this agreement for purposes described in the requestor's application for one year from the date of receipt of the data. The data files listed under "Requested Data Files" above are the property of the National Center for Health Statistics (NCHS), Division of Vital Statistics (DVS). Permission is granted to use these data files for one year from the date of receipt. At the expiration of the one year period, the data files and any copies of the data files must be destroyed. Users must notify DVS in writing that the file(s) have been destroyed. This policy will be strictly enforced; however, extension of this usage period will be given consideration under appropriate circumstances, when requested in writing. Requests for extensions must be sent to the Director, Division of Vital Statistics, 3311, Room 7311 Toledo Road, Hyattsville, MD, 20782.

Citation of NCHS: Users of these data are asked to acknowledge NCHS and the vital statistics jurisdictions as the data source in published reports and studies for which the files were used. NCHS and the vital statistics jurisdictions should also be cited in reports, articles, and news releases in electronic and print media describing the studies or results of the studies. The following is the recommended citation:

National Center for Health Statistics. [*Name of data file(s)*] (*[year(s)*]), as compiled from data provided by the 57 vital statistics jurisdictions through the Vital Statistics Cooperative Program.

Return completed and signed form:
Joyce Arbertha
Division of Vital Statistics
National Center for Health Statistics
3311 Toledo Road - Room 7324
Hyattsville, MD 20782

Print Name of Official authorized to execute agreements*, or Faculty Advisor (If applicable): Joseph F. Robare
Title: Faculty Advisor/Lead Contributing Faculty
Organization: College of Health Sciences, Walden University
Signature: Dr. Joseph F. Robare Date: 4/8/15

*The type of "official authorized to execute agreements" will, of course, vary among organizations. Whenever possible, this official should be at a higher level of authority than the principal investigator or other person responsible for the study or project; for example, the dean of a college, a vice president of a company, or the director of a government division or bureau.

Under section 308(d) of the Public Health Service Act, the only persons to be allowed access to these data sets will be staff members of the above organization or its contractor(s) who have been authorized to work with the data and have, prior to being granted access to the data, read and agreed to the data-use requirements specified above in this DUA. By their signatures below, the following individuals affirm that they have read the DUA and will abide by the specified DUA data-use requirements:

Print: Kenneth E. Christopher Signature [signature] Date 4/7/15

Print: Joseph F. Robare Signature Dr. Joseph F. Robare Date 4/8/15

Print: _____ Signature _____ Date _____

Appendix C: Elsevier Copyrights Clearance License

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Dec 04, 2015

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