2-21-2025

Hurricane Irma's Impact on Mortality Among the Chronically Ill Populations in Florida

Cody Ray Thornton
Walden University

Walden University

College of Health Sciences and Public Policy

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Cody Ray Thornton

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Review Committee
Dr. Chinaro Kennedy, Committee Chairperson, Public Health Faculty
Dr. Patrick Dunn, Committee Member, Public Health Faculty

Chief Academic Officer and Provost
Sue Subocz, Ph.D.

Walden University
2025

Abstract

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by

Cody Ray Thornton

MPH, Touro University, 2008

BSHS, Touro University, 2007

Dissertation Submitted in Partial Fulfillment

of the Requirements for the Degree of

Doctor of Philosophy

Public Health—Epidemiology

Walden University

February 2025

Abstract

Natural disasters pose significant risks to individuals with chronic diseases, exacerbating health disparities through disruptions in healthcare access and systemic vulnerabilities. This study investigated the association between chronic disease-related mortality occurring within 2 months of Hurricane Irma, and whether demographic variables, including age, sex, race, Hispanic ethnicity, poverty, urbanicity, and educational attainment, modified this relationship. This cross-sectional study used the social-ecological model to analyze secondary mortality data from the National Vital Statistics System. Bivariate and multivariate logistic regression revealed that deaths from chronic illnesses, occurring between September 2017 and October 2017, were 2.694 times higher, compared to the same period in 2016 (95% CI: 1.682–4.316, $p < .001$); this association remained significant even after controlling for demographic factors (OR = 2.240, 95% CI: 1.342–3.739, $p = .002$). This study also found significant interactions between age, poverty, and urban residence and chronic disease-related mortality within two months following Hurricane Irma, compared to the same time period in 2016. These findings suggest the need for targeted disaster preparedness strategies for high-risk populations. The emphasis should be placed on prioritizing timely access to care in the wake of disasters for low-income older individuals, in urban areas, who are living with chronic illnesses. The implications for positive social change include the potential for policymakers, emergency response personnel, and healthcare organizations to use these insights to enhance emergency response frameworks, improve healthcare accessibility, and implement interventions to reduce unwarranted mortality.

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February 6, 2025

Dedication

To my mother who passed away in 2020, you are loved and missed very much.

To my dear wife, your unwavering belief in my abilities has been a beacon throughout this academic pursuit. Your patience, understanding, and sacrifices to allow me to focus on my education in addition to a demanding professional career have been extraordinary. To my precious children, you are my inspiration and reason I strive to be the best version of myself. You are the reasons I persevered through the challenges and the moments of self-doubt. It is with immeasurable love and heartfelt appreciation that I dedicate this dissertation to my family.

Acknowledgments

Many people have supported me through my journey, and I would like to take this opportunity to thank them for their support.

First, my dissertation committee has my sincere appreciation for all the support through the challenges with my completing this dissertation. I could not have asked for a better committee during this process. Thank you to Dr. Shields, my initial committee chair, and Dr. Dunn, my second committee member, who helped me orient and not boil the ocean! An incredibly special thanks to Dr. Kennedy, who took over as my committee chair and provided invaluable support with clarifying and strengthening my work and completing Chapters 4 and 5. I made it over the finish line due to her knowledge, experience, and guidance.

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Chapter 1: Introduction to the Study

Introduction

This dissertation examined the impact of Hurricane Irma on the mortality of chronically ill populations, with a focus on demographic and socioeconomic factors that may influence mortality rates. Hurricane Irma, one of the deadliest hurricanes in U.S. and Atlantic history, struck Florida on September 10, 2017, affecting millions of people across the region and leaving a trail of destruction and death (Kapucu et al., 2021; Wingard et al., 2020). Classified as a Category 4 storm with maximum sustained winds of 130 mph, Hurricane Irma was the sixth most powerful hurricane in the region since 1888 (Pinelli et al., 2018; Wingard et al., 2020). The storm caused both direct and indirect deaths, with its effects particularly felt among vulnerable populations. Among these at-risk groups were individuals with chronic illnesses, who are often dependent on ongoing medical care and social support.

In this study, I examined the impact of Hurricane Irma on mortality in the 2 months following the storm (September and October 2017) among chronically ill populations in Florida. The socioecological model (SEM) served as the theoretical framework to contextualize study variables in exploring their impact on chronic illness mortality through the interaction between individual, community, and environmental factors. Through the findings of this cross-sectional study, I aim to build on existing literature by providing quantifiable insights into the impact of hurricanes on the mortality of individuals with chronic illnesses. This information will be valuable to policymakers, emergency responders, and individuals with chronic conditions, helping them better prepare for, respond to, and recover from natural disasters.

This section will present the background of the study, the statement of the problem, and the purpose of the study. It will also outline the research questions and hypotheses, introduce the theoretical framework, and describe the nature of this study. Other areas addressed include definitions, assumptions, scope and delimitations, limitations, and the significance of the study.

Background

Natural disasters, including heat waves, droughts, floods, hurricanes, earthquakes, and pandemics, increasingly impact global health security. These events can lead to devastating effects on health, resulting in significant losses, destruction, and death, while also disrupting medical systems and essential services that depend on them (Kapucu et al., 2021). Disasters such as Hurricane Irma have a disproportionate impact on public health, particularly among vulnerable groups, including individuals with chronic illnesses, the elderly, pregnant women, and children (Lafarga Previdi et al., 2022). The risks faced by these populations are exacerbated by challenges such as limited mobility and dependence on medical supplies, equipment, and services that may be severely disrupted during a disaster (Schoon, 2021).

Vulnerable populations, in particular chronically ill individuals, form a significant and vulnerable population that requires special attention, whether or not disasters occur (Mosby et al., 2021). These individuals include those with heart conditions, diabetes, respiratory disorders, and other long-term health conditions (Babaie et al., 2021).

According to Mosby et al. (2021), 80% of older adults have at least one chronic health condition, and 50% have two or more, making them more vulnerable to the effects of disasters.

Given the increased risks, chronically ill patients may face unique challenges during and after disasters. Natural disasters can exacerbate adverse health outcomes among these individuals, particularly those with cardiovascular diseases and metabolic syndrome (including diabetes; Babaie et al., 2021; Gohardehi et al., 2020; Jiao et al., 2012; Moscona et al., 2019; Murakami et al., 2018). Previous studies have linked hurricane exposure to an increase in emergency room visits and hospitalizations, especially for individuals with diabetes or those requiring dialysis (Dosa et al., 2020). Additionally, Dosa et al. (2020) noted that mortality associated with natural disasters like Hurricane Irma is often underreported due to delayed effects and challenges in documentation.

Understanding the effects of Hurricane Irma on chronically ill populations is crucial for improving disaster preparedness and response strategies (Ghazanchaei et al., 2021). Through this cross-sectional study, I aimed to examine the association between demographic characteristics—such as age, sex, race, Hispanic ethnicity, poverty level, rural–urban continuum, and educational attainment—and mortality within the 2 months following Hurricane Irma's landfall. By doing so, I aimed to enhance decision-making in disaster preparedness, response, and recovery, with the goal of preventing or mitigating disparate health outcomes in vulnerable populations exposed to large-scale disasters.

Problem Statement

Chronic diseases pose a significant global health challenge, accounting for approximately 40 million deaths annually, which represent about 60% of all deaths worldwide (Saha & Alleyne, 2018). The impact of natural disasters on individuals with chronic diseases is profound, as such events can exacerbate existing health conditions and lead to adverse outcomes, particularly in cases of cardiovascular diseases (CVD) and metabolic syndromes such as diabetes (Babaie et al., 2021; Gohardehi et al., 2020; Jiao et al., 2012; Moscona et al., 2019; Murakami et al., 2018). While some studies highlight the association between natural disasters and the exacerbation of specific chronic conditions, there is limited research quantifying the broader impacts of large-scale disasters on chronic disease populations in the United States, particularly in the context of delayed or secondary morbidity and mortality outcomes (Chowdhury, 2019; Hassan et al., 2020; Kishore, 2018; Paul et al., 2018).

Natural disasters, such as hurricanes, often lead to significant disruptions in healthcare access and delivery, disproportionately affecting vulnerable populations, including those with chronic diseases. The literature has focused predominantly on effects of disasters on cardiovascular and metabolic diseases, leaving a notable gap in understanding the delayed health outcomes for the broader range of chronic conditions (Dosa et al., 2020; Ghazanchaei et al., 2021). This gap underscores the need to examine and quantify the extended impact of large-scale disasters on morbidity and mortality among individuals with chronic illnesses in the United States, with a particular focus on the months following such events.

Hurricane Irma, which struck Florida in September 2017, provided a pertinent case study for exploring these delayed health impacts. The hurricane caused widespread disruption, including power outages, displacement, and limited access to medical care, which may have disproportionately affected individuals with chronic diseases. Understanding the specific demographic factors that influence mortality rates among this population postdisaster can inform disaster preparedness and response strategies to mitigate adverse outcomes in future events.

In this study, the dependent variable was mortality, measured using deaths (number of deaths per 100 individuals) in 2 months (September and October 2017) from landfall. Independent variables included chronic disease diagnosis. The specific chronic diseases examined were derived from the International Classification of Diseases (ICD) -10 113 groups, which is an ICD-10 code that refers to a list of 113 selected causes of death. These 113 causes of death were then used to inform three broad causes of death categories for analysis in this study by: CVD, metabolic disease, and non-CVD/metabolic. The covariates examined for effect modification included age, sex, race, Hispanic ethnicity, poverty level rate, rural–urban continuum code, and educational attainment rate.

Despite the global burden of chronic diseases and their exacerbation during disasters, research addressing the delayed morbidity and mortality outcomes of chronic disease populations following natural disasters in the U.S. remains scarce. Through this study, I aimed to address this critical gap by examining the association between demographic characteristics—including age, sex, race, Hispanic ethnicity, poverty level, rural–urban continuum, and educational attainment—and mortality within 2 months post-Hurricane Irma among individuals with chronic diseases in Florida. Through this study, I intend to contribute to evidence-based decision-making in disaster preparedness, response, and recovery efforts that ultimately enhance health outcomes for at-risk/vulnerable chronically ill populations.

Purpose of the Study

The purpose of this quantitative cross-sectional study was to examine the association between deaths occurring within 2 months (September and October 2017) following Hurricane Irma's landfall in Florida and chronic disease–related deaths. I also aimed to investigate whether the primary association is modified by demographic characteristics, including age, sex, race, Hispanic ethnicity, poverty level, rural–urban continuum, and educational attainment rate.

Research Question(s) and Hypotheses

The following research questions were developed to address the research problem. These questions align with the study's purpose and incorporate the variables associated with the theoretical framework.

RQ1. Is there an association between deaths among chronically ill individuals and exposure to Hurricane Irma 2 months after landfall?

H1o: There is no association between deaths among chronically ill individuals and exposure to Hurricane Irma 2 months after landfall among impacted individuals.

H1a: There is an association between deaths among chronically ill individuals and exposure to Hurricane Irma 2 months after landfall among impacted individuals.

RQ2. Is the association between deaths among chronically ill individuals and exposure to Hurricane Irma 2 months after landfall modified by demographic characteristics including age, sex, race, Hispanic ethnicity, poverty level rate, rural–urban continuum code, and educational attainment rate?

H2o: The association between deaths among chronically ill individuals and exposure to Hurricane Irma 2 months after landfall is not modified by demographic characteristics including age, sex, race, Hispanic ethnicity, poverty level rate, rural–urban continuum code, and educational attainment rate.

H2a: The association between deaths among chronically ill individuals and exposure to Hurricane Irma 2 months after landfall is modified by demographic characteristics including age, sex, race, Hispanic ethnicity, poverty level rate, rural–urban continuum code, and educational attainment rate.

Theoretical Framework for the Study

The social-ecological model (SEM) was the theoretical framework used to frame this study, which was conceptualized by Urie Bronfenbrenner (1977). The SEM framework provides an elaborate explanation of relationship between an individual and their environment in terms of different systems, which include the microsystem, mesosystem, exosystem, macrosystem, and chronosystem (Schoon, 2021). According to Bronfenbrenner, the construct of systems that influence health behaviors is framed as follows:

- intrapersonal/individual factors,
- interpersonal factors,
- institutional and organizational factors,
- community factors, and
- public policy factors.

The SEM framework was chosen for the current study considering its successful applications in academic works related to community engagement, health, and risk factors that contribute to positive or negative health behaviors (Caperon et al., 2022; Kemp et al., 2021). Notably, the current adaptation of the socioecological conceptual framework by the Centers for Disease Control and Prevention (CDC) has been used extensively to understand and determine major contributors that affect health through interaction between the characteristics of the individual, the community, and the environment, with consideration of physical, social, and political components (Salmon et al., 2020).

This research study focused on the concepts of socioecological systems as they relate to natural disasters, Hurricane Irma specifically, and the quantifiable association with mortality rates among individuals with chronic diseases. For instance, intrapersonal or individual factors are personal characteristics that influence behavior, choices, and outcomes, such as demographic variables like age, gender, race/ethnicity, income, and education level, as well as biological factors like genetics, physical health, and neurological conditions. Interpersonal factors involve relationships and social interactions that shape individual behavior, including family dynamics such as parenting styles and family support, social networks of friends and peers, emotional and practical support systems, and cultural expectations shared within social circles. Institutional and organizational factors pertain to the policies, practices, and environments within organizations and institutions, such as school environments, curricula, healthcare systems, and the availability of resources and infrastructure. Community factors encompass broader social, physical, and cultural environments, including community networks that foster social cohesion and local support, cultural norms, economic conditions, and the physical environment, including access to transportation and exposure to hazards. Lastly, public policy factors include societal and governmental influences like health policies (e.g., tobacco regulations and vaccination mandates), education policies (e.g., school funding and accessibility), economic policies (e.g., minimum wage laws and tax regulations), and environmental policies that regulate pollution, conservation, and urban planning. Each of these levels highlights the interplay of influences shaping behaviors and outcomes. In this context, the SEM framework provides sound framing and explanation, and thus its application for the specific variables in this study is justified.

The SEM framework was appropriate for achieving the purpose of the study by facilitating a systematic investigation of the multilevel influences on death rates among people with chronic illnesses and modifying effects of age, sex, race, Hispanic ethnicity, poverty level rate, rural–urban continuum code, and educational attainment rate following Hurricane Irma. This approach helps inform targeted interventions and policy strategies to mitigate the adverse health effects of such events by facilitating a better understanding of how individual, interpersonal, institutional, community, and societal factors interact within the socioecological systems affected by natural disasters.

Nature of the Study

A cross-sectional study was conducted to examine the association between chronic disease-related deaths and recorded deaths 2 months after Hurricane Irma's landfall in in Florida. In this instance, the exposure was the time period of September and October in 2017, wherein Irma's landfall was the disaster exposure of interest, and September and October of 2016 was the comparison period where no hurricane occurred. The risk factor in the population was being diagnosed with a chronic condition versus not being diagnosed with a chronic condition documented in death certificate data. The population was individuals who died within the two time periods The main outcome variable, recorded deaths 2 months after Hurricane Irma's landfall, was also well established. A quantitative research methodology supported statistical examination of the association between variables in a natural setting (Patel, 2009). For instance, it was the appropriate approach to examine the association between death 2 months post a large-scale natural disaster, Hurricane Irma, in Florida and chronic disease diagnosis. Quantitative methods also supported statistical examination of the main effects association and possible effect modification between demographic covariates including age, sex, race, Hispanic ethnicity, poverty level rate, rural–urban continuum code, and educational attainment rate. The objective of this study was not aligned to lived experiences, or to the perceptions and opinions of the participants; therefore, qualitative methods were not appropriate and thus were not selected (Creswell, 2013).

Definitions

Independent Variables

Demographics: Include age, sex, race, Hispanic ethnicity, poverty level rate, rural–urban continuum code, and educational attainment rate.

Poverty: The measure includes indicators of high poverty areas, extreme poverty areas, persistent poverty areas, and enduring poverty areas for Decennial Census years 1960–2000 and for American Community Survey (ACS) 5-year periods spanning 2007–2011, 2015–2019, and 2017–2021. People and families are classified as being in poverty if their income is less than their poverty threshold (U.S. Department of Agriculture, n.d.).

Rural Urban Code: A classification scheme distinguishing U.S. counties based on the size of the metropolitan area, degree of urbanization, and adjacency to a metro area. This framework supports finer distinctions beyond the metro and nonmetro dichotomy (U.S. Department of Agriculture, n.d.).

Educational attainment rate: Educational attainment refers to the highest level of education that an individual has completed. This is distinct from the level of schooling that an individual is attending.

Chronic illness: A long-term health condition that persists over an extended period and often progresses slowly. These conditions typically require ongoing management and may have significant impacts on an individual's quality of life (Lafarga Previdi et al., 2022).

Dependent Variable

Death in 2 months: Death of an individual within 2 months, September and October 2017, of Hurricane Irma’s impact.

Additional Terms

Hurricane: A powerful and large-scale tropical cyclone characterized by sustained winds speed greater than or equal to 119 kilometers per hour (Fea et al., 2015).

Morbidity: The state of disease or ill health within a population, including the prevalence or incidence of illnesses, injuries, or diseases.

Mortality: The state of being subject to death. In the context of research or epidemiology, mortality often refers to the number of deaths within a specific population or during a particular period.

Natural disaster: A catastrophic event arising from natural processes of the Earth including hurricanes, cyclones, pandemics, and fire (Wingard et al., 2020).

Assumptions

This study operated under several key assumptions to ensure the validity and reliability of its findings. First, it was assumed that the data collected, including demographic variables, mortality, and chronic illness diagnoses, were accurate and reliable. Any inconsistencies or errors in the data could compromise the validity of the results and lead to incorrect conclusions about the impact of Hurricane Irma on mortality rates among individuals with chronic diseases. Second, the representativeness of the sample was assumed, with the expectation that the analyzed decedents reflect the broader population affected by Hurricane Irma in Florida. While sampling techniques were used with the aim to enhance representativeness, it was acknowledged that the sample may not perfectly capture the diversity and characteristics of the entire impacted population. Third, the study assumed the absence of systematic biases in the measurement of variables such as chronic disease diagnoses and demographic characteristics. Although efforts were made to minimize measurement bias, the potential for bias impacting results could not be entirely eliminated. Lastly, it was assumed that no unmeasured confounding variables or extraneous factors significantly influenced the observed relationships between chronic disease diagnoses, demographic variables, and mortality rates. This assumption was critical for ensuring the validity of the statistical associations identified in the study.

Scope and Delimitations

The aspect of this study that addressed the research problem most directly was the examination of mortality outcomes (death in the 2 months following storm impact) in individuals with chronic diseases after a large-scale natural disaster—more specifically, the quantifiable association of chronic disease–related underlying and additional causes of death among individuals in an area impacted by a hurricane. This aspect of the research problem was chosen because of the significant proportion of individuals with chronic diseases (Centers for Medicare and Medicaid Services, n.d.) coupled with the extensive and detailed mortality vital statistics data available before and after hurricanes in Florida. The sample population for this study included decedents in the continental

United States. Exclusion criteria included individuals with traumatic causes of death or other acute or nonchronic disease–related causes, as these were not indicative of chronic disease–influenced mortality.

The health belief model (HBM) and social cognitive theory (SCT) are other theoretical frameworks related to but not considered in this study. HBM focuses on an individual's course of action and depends on the person's perceptions of the benefits and barriers related to health behavior; however, it does not directly account for environmental or economic factors that influence or deter individual decisions or actions (Bandura, 1986). The SCT focuses on social influence, emphasizing social underpinnings (external and internal), including the social environment; however, the loose organization of the theory made it difficult to assign influence in the dynamic interplay between person, behavior, and environment. The principles of the social-ecological model, which are consistent with concepts of the HBM and SCT assertion of the importance that an environment or creation of an environment, set forth that a favorable environment is essential for the adoption of healthy behaviors and thus outcomes (Gehlert & Ward, 2019).

The results of this study are generalizable to individuals with chronic diseases in storm-impacted areas. Additionally, the socioecological model concepts applied in this study by using county-level data help in inferring individual-level socioecological dynamics, such as infrastructure (rural vs. urban), poverty level rate, educational attainment rate, and rural–urban continuum code, which can provide potential generalizability to populations living with chronic diseases within those socioecological constructs.

Limitations

A thorough assessment of potential limitations was conducted, identifying several constraints inherent to the design and methodology of this study. One key limitation was the cross-sectional design, which provided a snapshot of associations between chronic disease–related mortality and Hurricane Irma's impact but limited the ability to infer causation, as exposure and outcomes were measured at a single point in time. Additionally, the study's geographic focus on Florida introduced limitations to generalizability, as demographic, environmental, and socioeconomic factors unique to the state may not reflect conditions in other regions affected by hurricanes or natural disasters.

The study also faced challenges related to secondary data constraints, as it relied on the National Vital Statistics System (NVSS). While the dataset offered valuable county-level demographic information, it lacked individual-level granularity, and data masking or anonymization may have restricted the depth of the analysis. Furthermore, potential coding and documentation errors, such as misclassification of death records or incomplete documentation, could have introduced measurement bias, affecting internal validity. Sampling bias was another limitation, as the purposive sampling approach may have reduced the representativeness of the study population, restricting the generalizability of findings.

Additional challenges included the movement of individuals, as displacement during or after Hurricane Irma may have affected the dataset, introducing biases related to migration patterns or unrecorded mortality outside the studied geographic area. Lastly, operationalizing the SEM posed difficulties, as its broad-reaching nature made it challenging to fully analyze certain variables, particularly intrapersonal and organizational attributes. Despite these limitations, the study provides important insights into the relationship between chronic disease–related mortality and disaster-related vulnerabilities.

Despite these limitations, this study provides valuable insights into the relationship between chronic disease mortality and natural disasters, contributing to disaster preparedness and response strategies. Future research should aim to address these limitations by incorporating more granular, longitudinal, and individually attributed data, and by extending analysis to multiple geographic locations for enhanced generalizability.

Significance

The findings from this study provide valuable insights into the health impacts of natural disasters, particularly hurricanes, on individuals with chronic diseases in storm-affected areas of the United States. By examining the quantifiable change in mortality outcomes (deaths within 2 months post-Hurricane Irma), this research highlights the vulnerabilities of chronically ill populations during and after natural disasters.

The research has significant implications for disaster preparedness, response, and recovery strategies. It contributes to positive social change by informing key stakeholders, including policymakers, healthcare providers, and emergency responders, on how to better support individuals with chronic diseases. Specifically, the study highlights the need for the following:

- Preparedness: Tailored communication and targeted evacuation plans for at-risk populations, such as individuals with cardiovascular and metabolic diseases.
- Response: Immediate access to uninterrupted healthcare services and medications for chronically ill individuals during disaster recovery efforts.
- Recovery: Long-term support to reduce postdisaster mortality risks associated with chronic illnesses.

Additionally, the application of the SEM allowed for a nuanced understanding of how various socioecological factors—such as poverty, education, and rural–urban differences—influence health outcomes in disaster-affected areas. The study findings are expected to help guide the development of equitable health policies and targeted interventions to mitigate the impacts of hurricanes on vulnerable populations.

Finally, this research underscores the importance of incorporating chronic disease management into disaster risk reduction frameworks. By identifying the specific challenges faced by individuals with chronic illnesses, it enables a more informed approach to safeguarding public health during future large-scale disasters.

Summary

This introductory chapter provided a foundation for the study, focusing on the impact of Hurricane Irma on mortality among chronically ill populations in Florida. The chapter introduced the background of the study, highlighting the risks natural disasters pose to vulnerable populations, particularly those with chronic illnesses. The research problem identified the lack of understanding regarding the association between chronic disease-related mortality and hurricane exposure, specifically 2 months post-Hurricane Irma's landfall in September 2017.

The purpose of this cross-sectional study was to examine the association between chronic disease diagnoses and mortality within 2 months following Hurricane Irma. The theoretical framework, the SEM, was used to explore how individual, community, and systemic factors interact to influence health outcomes during natural disasters.

The chapter outlined the study's significance to addressing gaps in disaster preparedness and response, particularly for vulnerable populations, by examining the association between deaths among chronically ill individuals and exposure to Hurricane Irma and demographic and socioeconomic influences on any chronic disease-related mortality. Moreover, the findings from this study could provide insights regarding natural disaster–affected areas in the United States through a unique examination of quantifiable change in mortality outcomes.

Additionally, definitions of key terms, assumptions, scope and delimitations, and study limitations were discussed. These components established the context and boundaries for the research, ensuring a comprehensive approach to understanding the impact of hurricanes on chronic disease populations.

Chapter 2 will present a literature review, providing a comprehensive discussion of key study variables, the SEM framework, and existing research addressing chronic disease management during natural disasters.

Chapter 2: Literature Review

Introduction

The purpose of this quantitative study was to examine the association between death within 2 months (September and October 2017) from landfall among individuals impacted by a large-scale natural disaster, Hurricane Irma, in Florida, while controlling for a number of demographic variables (age, sex, race, Hispanic ethnicity, poverty level rate, rural–urban continuum code, and educational attainment rate). Chapter 2 provides a comprehensive discussion of existing literature on the relationships between demographics among persons with chronic diseases following large-scale natural disasters such as Hurricane Irma. The literature review is divided into several key sections. The literature search strategy is outlined, which includes keywords used for the literature search as well as the types of databases that were employed. Second, the chosen theoretical foundation for the study, the SEM, is discussed, and its implementation is rationalized through existing literature (Bronfenbrenner, 1997). In the main literature review body, I discuss academic publications tied to persons with chronic diseases following natural disasters in accordance with different variables outlined in both the problem and purpose statements. Finally, a summary and conclusions section highlights the key elements discussed in the review, as well as how current literature attempted to address the gap in the study, followed by a transition to Chapter 3.

Literature Search Strategy

The literature review focused on academic sources no older than 2020, except for a minority of foundational or theoretical texts. The databases used for the study included

Google Scholar, EBSCOHost, JSTOR, Taylor & Francis Online, Elsevier, ScienceDirect, Walden Library, and PubMed. The literature review's search criteria comprised the following keywords or phrases: *mortality, mortality rate, death rate, morbidity, secondary morbidity, adverse effects, death, chronic disease, chronic disease complications, non-communicable diseases (NCDs), long-term conditions, chronic complications, long-term complications, natural disasters, tsunami, floods, storms, floods, hurricanes, tornado, hurricane, snowstorms, drought, crises, emergencies,* and *Hurricane Irma*.

Exclusion criteria for the study's literature review included papers that did not pertain to the impact of large-scale disasters or crises on acute, chronic, and noncommunicable illnesses. Another exclusion criterion for the literature review was the exclusion of academic publications published before the year 2020. However, included in the literature are some historical publications that are linked to the problem statement and the chosen theoretical foundation.

The following section will provide an overview of the theoretical foundation for the study: the SEM.

Theoretical Foundation

The theory that guided and framed the study was the SEM, which was conceptualized by Urie Bronfenbrenner (1977). As a framework, the SEM originated from theories that were rooted in Bronfenbrenner's desire to better understand dynamic interactions between both personal and environmental elements. Bronfenbrenner first formulated the SEM as a framework before it was further refined as a theory in the

1980s. Bronfenbrenner continued to refine and revise the SEM up until he died in 2005, and the SEM continues to be used in academic publications that focus on human-oriented behavior dynamics (Schoon, 2021).

The SEM theory was chosen for this study because of the framework's capacity to frame the relationship between an individual and their environment in terms of systems. SEM includes five systems of influence: microsystem, mesosystem, exosystem, macrosystem, and chronosystem (Bronfenbrenner, 1997). The microsystem refers to elements tied to the life of an individual, which include examples like friends, family, work, school, relationships, and neighbors that surround them. The mesosystem mediates the relationship between the microsystem and the exosystem, the latter of which includes aspects such as parents, friends, local governments, mass media, and extended family. The macrosystem contains a wider dimension of societal norms, cultural norms, social norms, and political systems. Finally, chronosystems embody time, which govern the other systems of the SEM theory.

The SEM framework has found usage in contemporary times in academic works centered around community engagement, health, and risk factors that contribute to positive or negative health behaviors (Caperon et al., 2022; Kemp et al., 2021). The evolution of the SEM framework encompasses the origination from a more psychological and interpersonal perspective to understand human development, to that of a framework that focused on understanding the multifaceted and interactive effects of personal and environmental factors from different fields of discipline. The importance of the different fields of discipline that support the SEM framework is pivotal in better understanding the justification regarding its implementation for the study. In contemporary literature, the SEM framework is mostly used in publications that focus on qualities tied to human resilience as well as works tied to psychological support of disadvantaged or disabled persons (Akoto et al., 2022; Schoon, 2021). In addition, the SEM is prevalent in research focused on the resilience and behaviors of persons with noncommunicable diseases (Bickel et al., 2023; Henderson et al., 2020). Furthermore, as a theoretical framework, the SEM is widely used in publications centered around the resilience and mistreatment of youths from different environments (Yoon et al., 2021). Resilience is a significant aspect considered in relation to the study's problem statement due to the roles of resilience and response in how different demographics with noncommunicable or chronic illnesses may respond to the circumstances of a disaster after it has occurred.

Through the CDC adaptation, the SEM construct of health focuses on the major contributors that affect health through interaction between the characteristics of the individual, the community, and the environment, considering physical, social, and political components (Salmon et al., 2020). The construct of systems that influence health behaviors is framed as follows: intrapersonal/individual factors, interpersonal factors, institutional and organizational factors, community factors, and public policy factors. Intrapersonal/individual factors refer to the knowledge in individual belief that is influenced by upbringing based on biological sex. Interpersonal factors refer to the relationships that individuals form with others. Institutional and organizational factors may refer to how the attainment of education is predicted by rules, regulations, policies, and informal structures that facilitate either healthy behaviors or the knowledge of how to respond in the event of an emergency. Community factors refer to how individuals aid each other on a communal level in the event of an emergency or how they may respond to persons in need of special medical attention following a crisis. Public policy factors are significant to consider because policymakers and decisionmakers impact the ways that relevant stakeholders and shareholders may act during emergencies (e.g., emergency health response teams, supplies during emergencies, and health-related infrastructures).

There is a scarcity of recent literature that has successfully applied the SEM in the context of how people with chronic illnesses and noncommunicable diseases respond to the aftermath of natural disasters. However, the importance of the usage of the SEM for the study and, by extension, its inclusion in the literature review is embodied by how the construct of systems that influence health behaviors may impact how people are more likely to respond in the event of large-scale natural disasters. Both the SEM construct of health through CDC adaptation and the framework that covers the relationship between an individual and their environment have the potential to contribute substantially to the problem and purpose statements of the study. The following section will comprise scholarly efforts by different researchers in the field to adequately address the problem of the study as well as the gap in knowledge.

Literature Review Related to Key Variables and/or Concepts

The purpose of this section is to provide a comprehensive discussion of available literature surrounding the different aspects of the study problem. The literature review will be divided into different sections that highlight the key variables and concepts of the study. The first section addresses how natural disasters or emergencies, which include

Hurricane Irma, predict the morbidity and mortality from chronic illnesses such as CVD, asthma, or diabetes. The second variable that will be discussed focuses on the ways that specific natural disasters and environment impact the chronic illness rates of patients. The third area of literature will focus on the long-term effects of natural disasters on chronic illness conditions years after they occurred. Following the literature review will be a comprehensive discussion, a synthesis of the literature, and a conclusion that highlights the key factors that were discussed in the study.

Natural Disasters as Predictors of Chronic illness Morbidity and Mortality

The following section is a comprehensive discussion of academic sources that highlight the role played by chronic illnesses in predicting morbidity and exacerbation of symptoms following large-scale natural disasters. Ghazanchaei et al. (2021) published a study that focused on developing a systematic review protocol for chronic illnesses during natural disasters. Chronic illnesses often require continuous management for optimal outcomes, which is challenged during emergency situations. Natural disasters disrupt healthcare systems and infrastructure, exacerbating chronic illness morbidity and limiting access to essential care (Ghazanchaei et al., 2021). As part of a systematic review, Ghazanchaei et al. identified three dimensions of disaster impacts on chronic illnesses: predisaster, during disaster, and postdisaster phases. Although the importance of a chronic illness management response after natural disasters was underscored, authors highlighted the need for better humanitarian response and chronic illness management during natural disasters and other emergencies (Ghazanchaei et al., 2021).

Ngaruiya et al. (2022) published a systematic review that focused on chronic illnesses in the context of disaster and emergency settings. The systematic review was carried out in the context of how chronic illnesses constitute the leading cause of mortality on a global scale. Ngaruiya et al. (2022) outlined how low and middle-income countries (LMICs) experience the largest burden of humanitarian crises and are also the most impacted by chronic illnesses, but primary focus on the topic has fallen behind (Ngaruiya et al., 2022). The authors conducted a systematic review of the effect of humanitarian disasters on chronic illnesses in LMICs, which addressed epidemiology, interventions, and treatment (Ngaruiya et al., 2022). A systematic search narrowed the review down to 85 included publications where almost half of the articles covered the Eastern Mediterranean Region (EMRO) with a minority of studies that covered the African and Americas regions (Ngaruiya et al., 2022). Most of the studies in the systematic review highlighted evidence for the burden of chronic illnesses on the impact of natural disasters, while there was a notable gap in studies that focused on clinical management and intervention delivery (Ngaruiya et al., 2022). The most commonly cited barriers to healthcare access that contributed to morbidity and exacerbation of chronic illnesses included lack of education, financial difficulties, displacement, illiteracy, lack of medication access, healthcare affordability, and centralized healthcare infrastructures (Ngaruiya et al., 2022). The systematic review highlighted the need to further research contributing factors, interventions, and better chronic illness management during humanitarian emergencies (Ngaruiya et al., 2022).

Ghazanchaei et al. (2021) and Ngaruiya et al. (2022) both carried out insightful systematic reviews that focused on the importance of healthcare response to natural emergencies. Ghazanchaei et al. had less focus on a specific geographical representation, while the systematic review of Ngaruiya et al. found focus in low- and middle-income countries in how infrastructures dealt with medical complications that followed crises. Both Ghazanchaei et al. and Ngaruiya et al. not only stressed the importance of the causes of chronic illness morbidity, but also pressed for further research that focused on better chronic illness control, humanitarian responses, and better chronic illness responses or interventions in the middle of a crisis.

Another systematic review by Ghazanchaei et al. (2022) focused on how quickly the status of persons with chronic illnesses could be established during an emergency. Ghazanchaei et al. published their systematic review to ascertain the response and status times of NC patients before, during, and after a natural disaster or emergency. The systematic review included 42 relevant articles that were published between 1997 and 2019 and mainly focused on the conditions of patients during and after disasters, while articles focused on chronic illness patients before disasters were relatively underrepresented (Ghazanchaei et al., 2022). Ghanzanchaei et al. concluded that the formulation of stronger countermeasures against treatment interruption and surveillance systems to ascertain chronic illness needs were instrumental in preparing patients or susceptible persons for future disasters (Ghazanchaei et al., 2022). Benjamin (2022) published a literature review focused on the integration of health and coordination services following a natural disaster or emergency. According to Benjamin, developing countries are the most affected in terms of chronic illness patients during natural disasters compared to their higher income counterparts. In addition, Benjamin underscored the importance of more refined integration and coordination of health services during emergency contexts. The article concluded with Benjamin calling for further research on the exploration of barriers that interfere with consistent communication and collaborative strategies at an organizational level vis-à-vis disaster preparedness and chronic illness management.

Both Benjamin (2022) and Ghazanchaei et al. (2022) came to the same conclusion regarding the need to further optimize disaster response procedures, especially considering chronic illness management. While Ghazanchaei et al. focused on all areas—before, during, and after—Benjamin mostly centered their focus on disaster response time following the event of a disaster. A weakness in Benjamin’s research is the limited scope in his work, which focused more on four specific diseases: cancer, diabetes, CVD, and respiratory. Ghazanchaei et al. used a more varied sample because of their overall systematic review.

Leff et al. (2022) carried out a systematic review focused on NCD responses in low- to middle-income countries following a natural disaster. According to Leff et al. LMICs experience the largest burden of humanitarian emergencies alongside experiencing the largest burden associated with chronic illness impact. Leff et al. analyzed 85 articles and found that there were no sources that discussed in detail the means by which chronic illness mitigation was carried out during the preparation or prevention stages. Leff et al. concluded their systematic review by outlining the significance of improved collaboration between humanitarian and developmental actors alongside improved training and capacity building for chronic illness response. Dhimal et al. (2021) published a literature review aimed at reviewing contemporary evidence on the environmental risk factors of chronic illnesses as well as the methods that were used to establish a connection between chronic illnesses and environmental risk factors. According to Dhimal et al., climate change is linked to natural disasters such as wildfires and hurricanes, all of which contribute to loss of land and disruption and damage to key infrastructure. The damage to infrastructure and land disruption lead to food insecurity, which increases chronic illnesses that are tied to mental health such as depression, anxiety, and suicidal symptoms (Dhimal et al., 2021). The study's conclusions outlined that some of the study designs that could link the risks between chronic illnesses and environmental factors were descriptive, analytical designs and meta-analyses (Dhimal et al., 2021). Both Dhimal et al. and Leff et al. placed significance on the role played by infrastructure that is damaged by both climate change and the natural disasters that follow. There is a wide availability of academic sources and publications that discuss the dynamics of NCDs in crisis or emergency contexts depending on the sickness or the conditions with examples including hypertension, CVD, diabetes, and mental health.

Impact of Natural Disasters and Environment on Chronic Illness

There are several examples of academic studies that address the impact of natural disasters in the area of hypertension. Keasley et al. (2020) carried out a systematic review focused on the hypertension burden, access to hypertension care, and views of hypertension from patients during humanitarian crisis settings. The study was carried out because worldwide, a record number of people are impacted by humanitarian crises caused by conflict and natural disasters. Following the United Nations high-level meeting on chronic illnesses, the global commitment to universal health coverage and the needs expressed by humanitarian stakeholders means that efforts to manage hypertension during critical emergency settings have risen (Keasley et al., 2020). For the literature review and narrative synthesis, I searched for articles from five databases, which included a population of interest that comprised nonpregnant adults living in any country who had been exposed to a natural disaster or crisis since 1999. Of the 61 studies that were included in the analysis, there was an overrepresentation of studies focused on the Iraq War, the Syria Civil War, the 2011 Great East Japan Earthquake, Hurricane Katrina, and Palestinian refugees in the Israeli–Palestinian conflict. (Keasley et al., 2020). The study's authors concluded that the impact of hypertension was noticeable in disaster settings and that there needed to be stronger efforts to better accurately estimate the hypertension in crisis-impacted populations worldwide and that further understanding of both patient demographic knowledge and hypertension would prove invaluable to the study field (Keasley et al., 2020).

Yousuf et al. (2020) published a systematic review that focused on the dynamics of acute myocardial infarctions and natural disasters. The study was published by Yousuf et al. under the context of multiple reports that were linked to a significant rise in the incidence of acute coronary syndromes (ACS) alongside the occurrence of natural disasters. Yousuf et al. stressed that each event was linked with similar mechanisms, which increased the overall CVD mortality and morbidity. The systematic review indicates that the ways natural disasters or crises impact CVD symptoms varies but there was a consistency in how stress and psychological factors following a natural disaster contributed to hypertension, hypercoagulability, and tachyarrhythmia. Yousuf et al. concluded by stating that increased healthcare demand after disasters that is accompanied by reduced availability and treatment delays were subject to potential increases in both morbidity and mortality.

Ghosh et al. (2022) carried out a scoping review centered around the impact of extreme weather and hurricanes on cardiovascular health. Climate change has contributed to extreme weather, which in turn suggests a growing body of evidence that hurricane victims have an increased likelihood of CVD due to the stress and trauma associated with being exposed to hurricanes and storms (Ghosh et al., 2022). A comprehensive literature search involved population-level and cohort studies that were linked to CVD outcomes across several databases, where 48 out of 1,103 studies met the scoping review's criteria (Ghosh et al., 2022). Ghosh et al. outlined that even if there were significant amounts of literature that linked the adverse effects of hurricanes with an increased likelihood of CVDs, there was still an overall gap, which included the following: a) lack of rigorous long-term exposure to hurricanes, b) scarcity of hurricane exposure investigations on the most vulnerable populations, c) shortage of research focused on exposure of multiple populations to hurricanes, and d) absence of mechanisms that lead to worsened CVD outcomes. Ghosh et al. outlined the importance of future studies to fill the aforementioned research gaps.

De Vita et al. (2024) published a comprehensive examination of environmental exposures linked with climate change and its intricate relationships. In their publication, De Vita et al. examined the consequences of air pollution, extreme temperatures, and severe weather conditions on CVD to define the subpopulations that are the most vulnerable to CVD induced by climate change. De Vita et al. described how climate change, particularly the increased frequency of natural disasters, including hurricanes and coastal flooding, undeniably affects people and upholds the identified linkage between CVD exacerbation.

Both De Vita et al. (2024) alongside Ghosh et al. highlight the significance of extreme weather, climate change, and hurricanes on the cardiovascular health of individuals who are affected the most by natural disasters. However, De Vita et al. indicated that the significance of climate change and by extension, the impact brought about by hurricanes and extreme weather natural disasters were dependent on demographic factors. De Vita et al. outlined those regions with coastal and low-lying geography, in addition to densely populated cities that lack proper infrastructure, are less protected from potential health risks linked with extreme climate-related events such as hurricanes. Keasley et al. supported this assertion by outlining the roles played by different geographical circumstances when natural disasters impact different types of vulnerable populations.

Khraishah et al. (2022) publish a similar study to that of De Vita et al. and Ghosh et al.. Khraishah et al. mostly focused on the links and relationships between CVD and climate change, especially the natural disasters that result from it. According to

Khraishah et al. , climate change is the most dangerous existential challenge to planetary and human well-being, which is dictated by a shift in the Earth's weather and air conditions that is owed to anthropogenic activity. Climate change has led not only in extreme climates, but also to a rise in droughts, wildfires, dust storms, coastal flooding, storm surges, and hurricanes, in addition to multiple compound and cascading events (Khraishah et al., 2022). In a systematic review, the authors aimed to provide an overview of climate change's potential consequences on cardiovascular health, which include sudden shifts to ambient temperatures, forest fires, desert storms, direct exposure pathways, and extreme weather events (Khraishah et al., 2022). The study findings provided some indication that mitigation strategies can be formulated based off data on populations who are the most susceptible and vulnerable to natural disaster aftermaths that impact CVD.

The implications brought by the findings of Khraishah et al. is that climate change acts as a core predictor of natural disasters that impact CVD health, which range from either sudden or sharp increases in temperature or the conditions of climate change that can result in disastrous consequences for the environment as well as implications regarding future natural disasters. In addition to wildfires, climate change has also resulted in catastrophic rainfall events that eventually become hurricanes, which impact cardiovascular health. Peirce et al. (2022) carried out a systematic literature review that focused on characterizing the state of research vis-à-vis flooding and noncommunicable respiratory diseases (NCRDs), which included 16 papers for the review following a sweep of 200 articles that were initially included. The evidence for the associations between NCRDs and extreme weather events were low as only one out of the 16 papers that were analyzed found a significant correlation between either of the aspects. Peirce et al. provided some final recommendations, which included more efforts to collect further granular data on the health status of patients following any extreme weather events linked with natural disasters.

Burrows et al. (2023) in another study found that there was a strong health disparity for people with CVD living in Florida during the hurricane seasons. According to Burrows et al. , Tropical cyclones (TCs) are a significant threat to human health, and further research is needed to ascertain high-risk subpopulations. Burrows et al. investigated whether hospitalization risks from TCs in Florida varied across individuals and communities. The authors modeled the associations between all Florida storms that took place from 1999 to 2016 and over 3.5 million Medicare hospitalizations for respiratory diseases (RD) and CVDs. The authors identified an association between RDs and tropical cyclones when stratifying by neighborhood-level features, finding that more urban areas (based on percent urban or population density) had an elevated risk of RD hospitalizations during TC periods as opposed to less urban areas.

Burrows et al. indicated that hospitalizations linked to RD during TC periods were linked to the geography of certain neighborhoods within Florida. When it came to the risk factors that were linked with CVDs, Burrows et al. did not report any significant changes during the 10-day TC period but they outlined that they reported fewer CVD hospitalizations during the TC-exposed day and the day that followed the storm. The implications of these findings are that conditions that are created by storms make it more unsafe to travel than usual, which may mean delays for patients who suffer from a type of CVD.

Another Florida-based study explored the factors that contributed the most to Congestive Heart Failure discharges in Florida following a natural disaster cyclone (Kim et al., 2023). The study aimed to analyze congestive heart failures (CHF) in a Floridan context post-tropical cyclones from 2007 to 2017. The study utilized a retrospective longitudinal time series analysis that comprised CHF quarterly discharges across Florida. The study identified roughly 3.3 million patients in the sample, where the average range of CHF discharges were people aged 72-73 with the mortality rate sliding between 4-6% (Kim et al., 2023).

The key takeaways from Kim et al. (2023) as well as Burrows et al. are that not only does the storms play a role in terms of both hospitalizations and discharges but there are also demographical elements that need to be considered when observing the immediately available data. However, Kim et al. outline that there was not a significant increase in CHF discharges following cyclone or hurricane cycles. While Kim et al. failed to note any increases in CHF discharges during cyclone-seasons, Burrows et al. identified the opposite, which indicated that people with CVD were not going to the hospital or checking in enough due to the damages brought about by storms during the more turbulent seasons.

Mattei et al. (2022) published another study that was linked to a Puerto Rican population following Hurricane Maria and the associated risk factors that followed the storm. In the study performed by Mattei et al., the chronic diseases and associated risk factors were identified among adults in Puerto Rico following Hurricane Maria using a cross-sectional study that derived data from participants (n=825) across two different studies that were carried out between 2015 and 2019. Mattei et al. also found lower depressive symptom and stress scores but higher social support scores, reaffirming that while mental and emotional health can be worsened after natural disasters, there is evidence that increases in protective factors, including resilience and coping strategies is occurring.

The implications presented by Mattei et al. are that mental and emotional health are key predictors of the CVD risk factors that face Puerto Ricans following Hurricane Maria. CVD risk factors were also shown to vary between different geographies, ethnicities, and circumstances.

The points outlined by Mattei et al. indicated that in addition to mental health, demographics, and socioeconomic factors play a role in how different crises or disasters impact the CVD health of different groups of individuals. Other numerous studies have considered the role played by CVD and other factors in the context of natural disasters or other types of emergencies. The works of authors McCann and Szaflarski (2023) reinforce the works of Mattei et al. , by outlining the county-level differences between how various demographics susceptible to CVD are affected because of hurricanes or other tropical storms.

Another study by Andrade et al. (2022) also focused on the impact brought about by Hurricane Maria towards Puerto Rico. The qualitative study involved Andrade et al. carrying out interviews with stakeholders (n=40) that were tied to mayors, first responders, faith leaders, community leaders, and municipal employees who all came from 10 Puerto Rican municipalities (Andrade et al., 2022). Andrade et al. stressed the importance of protecting populations with NCDs and especially CVDs from environmental burdens and hazards that had the capacity to endanger people's lives. It was observed by Puerto Rican locals that a lack of access to key medical facilities was seen as the biggest threat against the survivability of persons with NCDs and CVDs during an emergency (Andrade et al., 2022).

Another correspondent in the study performed by Andrade et al. recalled how unreliable electric power contingencies raised the likelihood of patients and NCD vulnerable persons were during Hurricane Maria, validating the significantly compromised infrastructure causing the availability and access to be scarce and difficult to obtain for many days and even up to a week, respectively.

Andrade et al. observed problems within 10 Puerto Rican municipalities that were tied not only to the increased status of morbidity for people with CVD or other chronic illnesses but also the augmented likelihood of fatalities because of a lack of solid infrastructure during the event of high-level emergencies. The findings of Andrade et al. vis-à-vis infrastructure have some parallels with the study carried out by Yamaoka-Tojo and Tojo (2024). Yamaoka-Tojo and Tojo stated that natural disasters like floods and landslides caused by heavy rainfall, earthquakes, and tsunamis could potentially lead to induced stress, which may in turn lead to the onset and aggravation of different CVDs. According to Yamaoka-Tojo and Tojo, the circulatory system is most vulnerable to the effects of stress, and stress-related cardiovascular diseases, which includes examples like the following: Takotsubo cardiomyopathy, pulmonary thromboembolism, hypertension, stroke triggered by heightened blood pressure, and acute myocardial infarction. Yamaoka-Tojo and Tojo all indicated that these were CVDs that could potentially be triggered by an onset of stress-induced experiences from hurricanes. Yamaoka-Tojo and Tojo also reported on the importance of ensuring evacuation centers are staffed and equipped properly, even in resource constrained environments, when to prevent CVD deaths within evacuation centers during hurricanes and cyclones:

Yamaoka-Tojo and Tojo reported that on the part of health and infrastructure-related stakeholders, they could formulate key infrastructures that could play a role in helping reduce morbidity and fatality from hurricanes and other natural disasters. Key strategies and recommendations identified by Yamaoka-Tojo and Tojo Included ensuring knowledgeable healthcare providers, healthcare educators and communicators, prioritizing patient education, securing proficient leadership focused on establishing and implementing/disseminating preventive measures against cardiovascular diseases during emergencies,

In their study, McCann and Szaflarski observed the links between county-level hurricane damage and CVD mortality rates following Hurricane Matthew, and the moderating effect of different aspects of social capital and hurricane damage. McCann and Szaflarski carried their study out in the context of the increased frequency of hurricanes due to the warming climates. The study used yearly county-level sociodemographic and epidemiological data (n=183) that was used between 2013 and 2018. Findings of the study indicated that CVD mortality means increased in both low-and high-damaged counties while associations with social capital were null. Although McCann and Szaflarski identified the role of hurricane damage increasing CVD morbidity and mortality, there was still a gap in information as to the role it played alongside social and epidemiological capital.

In another publication, Parks et al. (2022) published a retrospective observational study to evaluate the association of county-level tropical cyclone exposure and death rates from different cases within the United States. Monthly cause-specific county-level death rates were characterized by six different factors: CVD, cancers, infectious diseases, neuropsychiatric conditions, and respiratory diseases (Parks et al., 2022). The study concluded by stating that among US counties that experienced at least one tropical cyclone between 1988-2018, each additional cyclone day per month was linked with higher death rates in the months that followed the cyclone for several causes of death, which included injuries from the cyclone, infectious and parasitic sicknesses, CVDs, neuropsychiatric illnesses, and respiratory diseases (Parks et al., 2022).

Both Parks et al. in addition to McCann and Szaflarski observed the significance played by hurricane and cyclone level damage on a county level. However, while McCann and Szaflarski focused more on sociodemographic predictors, Parks et al. focused on the more direct causes of morbidity and fatality during cyclones that took place between 1988 and 2018. Parks et al. as well as McCann and Szaflarski provided both researchers and learners some decent understanding on the level of county damage from natural disasters in conjunction with causes of death from CVD conditions.

However, there are still other examples of studies that consider a wider range on the topic of tropical cyclones and CVD conditions.

In another related study, Parks et al. aimed to observe some of the key elements that contributed the most to short-term excess mortality that followed tropical cyclone cycles within the United States. The study was carried out in the context of excess fatalities after tropical cyclones and researchers needing to better understand critical impacts directly crucial to policies on preparedness and mitigation on part of health stakeholders (Parks et al., 2023). The researchers applied an ensemble of 16 Bayesian models to 40.7 million U.S. deaths, which comprised a record of 179 tropical cyclones over a period of 32 years between 1988 and 2019 as an estimate for the short-term cause of excess deaths (Parks et al., 2023). Parks et al. identified cardiovascular diseases as some of the key immediate causes of deaths that followed a cyclone.

Similarly, Hassan and Evans (2023) observed how disasters such as hurricanes and cyclones had the potential to worsen the disparities among the most vulnerable NCD populations. Hassan and Evans used the SEM Framework to describe the effect that contributed to disasters on chronic illnesses and CVDs as well as the disproportionate impact of natural disasters on the most historically marginalized groups. In another similar study, Chang et al. (2022) observed how older adults, and their cardiovascular health were at far more hazard due to hurricanes and cyclones stirred by climate change. Chang et al. examined how climate change manifested itself in multiple environmental hazards to the health of people, namely advanced age adults and CVD patients are vulnerable to poor outcomes of cyclones and hurricanes because of unique social, economic, and physiologic vulnerabilities that come with age, CVD, and other chronic illnesses (Chang et al., 2022). This review summarized the vulnerabilities of older adults and CVD patients where the resultant impacts of climate-mediated disasters impact the hearts of aging older adults (Chang et al., 2022). People of advanced age were the most susceptible to being impacted by cyclones and other natural disasters the most after the fact due to the complications that come with their condition after a disaster.

Chang et al. impliedthat some of the key factors that contribute the most to the vulnerabilities of CVD patients are both internal and external. Internal due to the advanced ages of older adults and external because of differing environmental factors brought about by global warming such as pollution, wildfires, heat waves, and other natural crises. According to Spatz et al. (2024), mindfulness towards the impact of hurricanes and droughts i.e., environmental burdens that stakeholders need to consider vis-à-vis natural disasters when reducing the exposure of the most vulnerable to predictors that could potentially harm them.

Yan et al. (2021) carried out their study to explore tropical cyclones' impacts on noninjury morbidity, which could be triggered via pathways that consist of psychosocial stress or interruption in medical treatments. The study utilized secondary data that was drawn from daily emergency Medicare hospitalizations (1999–2010) in 180 US counties, which draws on an existing cohort of high-population counties. Yan et al. classified counties that were exposed to tropical cyclones when storm-associated peak sustained winds were at ≥21 m/s in the county center. The secondary analyses considered different wind thresholds and hazards where Yan et al. aligned storm-exposed days to unexposed days through county and seasonality. Findings highlighted that 175 county studies between 1990-2010 had at least one tropical cyclone exposure and that while CVD hospitalizations decreased during the storm, they would increase again following the storm. The findings of Yan et al. align with that of Burrows et al. , who observed that hospitalization decreased during storm or hurricanes due to inability to access travel or medical care to hospitals during storms.

The observations of both Burrows et al. and Yan et al. provide some academic value but there are still gaps in academic literature and information. Even though both authors could provide both researchers and learners further insight on the pattern of hospitalization of CVD patients during storms, there is still a gap information as to what it means for how different ages and demographics react to various types of hospitalization or storms.

Another study by Shih et al. (2020) discussed increased mortality and medical visits from adults with CVD in Severely Affected Areas following Typhoon Morakot. Shih et al. (2020) reported that disasters have negative health effects on chronic diseases in impacted populations. Heavily affected areas usually comprise rural sectors with limited basic infrastructure and a population that has limited access to optimal healthcare post disaster (Shih et al., 2020). Patients with CVD need to maintain quality care, even following crises. Shih et al. carried out a population-based case-control study that observed enrolled adults from the National Health Insurance Registry diagnosed with ischemic heart disease and cerebrovascular disease who all lived in the area affected by Typhoon Morakot in 2009 (Shih et al., 2020). The key methodology for the study was comprised of a survival analysis during the two years after the typhoon, which was defined by an increase in CVD-related mortalities, especially among elderly with comorbidities, and areas severely affected by the disaster (Shih et al., 2020).

The key indications from Shih et al. are that the health statuses of patients with CVD prior to the typhoon were due to a combination of elderly demographical aspects and factors that predicted morbidities within the area. Shih et al. reported that areas affected by Typhoon Morakot were already becoming significantly impacted by typhoons and cyclones, especially vis-à-vis the population in those areas that were already becoming affected with CVD-related morbidity.

A commentary publication by Magdy et al. (2023) discussed the cardiovascular impact of natural disasters such as floods and wildfires from a South Wales perspective. The study was carried out in the context of Australia experiencing extreme weather consecutively because of climate change (Magdy et al., 2023). The publication outlined the role of cardiovascular conditions being exacerbated by natural disasters and extreme weather, especially for the most vulnerable populations in the country (Magdy et al., 2023). An ecological study by Huang et al. (2021) discussed and conducted an estimate of the changes in ischemic heart disease (IHD) mortality and years of life lost (YLL) rates among a mostly female sample through multiple linear regression analysis. The analysis found that both males and females were equally susceptible not only to natural disasters but also with its independent associations with heart diseases and other CVDs (Huang et al., 2021).

Another study by Chaseling et al. (2023) examined the role of extreme heat vis-à-vis CVD and other similar conditions. The study was carried out in the context of Australia's extreme heat temperatures. Even though Australia has implemented regional and state heat warning infrastructures, most of the personal heat–health protective advice available on public health policy documents are lacking, not grounded in, scientific evidence, and/or fails to consider clinical factors such as age or co-morbidities that are linked with CVDs and other chronic illnesses (Chaseling et al., 2023). Chaseling et al. concluded by outlining the risks that were associated with prolonged exposure to heat, which could lead to CVD morbidity in turn and advised future researchers to develop and disseminate evidence-based heat-health advice that can be best tailored for vulnerable populations who have been exposed to CVD.

A study by Hessami et al. (2021) discussed the role of CVD burden during the COVID-19 pandemic using both a systematic review and meta-analysis methodology. Context of the study was linked to the high rate of CVD reported by patients diagnosed with COVID-19 while there were controversies among different studies vis-a-vis CVD burden in COVID-19 patients. Therefore, Hessami et al. aimed to study CVD burden among in the context of the pandemic as a crisis scenario. The study findings indicated that in general, there was a high number of CVD burden from patients who suffered COVID-19. However, a key weakness in Hessami et al. and their study is COVID-19's status as an infectious disease rather than a chronic illness or a chronic condition.

Long-Term Effects of Natural Disasters on Chronic Illness Conditions: Diabetes and Obesity

There is a variety of academic literature that consider the impact of emergencies and natural disasters on persons with both diabetes and obesity. A study by Martínez-Lozano et al. (2023) discusses Hurricane Irma and Maria in relation to the presence of diabetes in Puerto Rico vis-à-vis survivability. The researchers evaluated the impact of Hurricane Irma and Maria in relation to the incidence of diabetes in Puerto Rico through the San Juan Overweight Adult Longitudinal Study (SOALS), which comprised a sample of adults aged 40 to 65 who complete the three year follow up and were free of any diabetic symptoms afterwards (Martínez-Lozano et al, 2023). The study highlights the predisposition for medical decision making and resources to be focused on acute injury and illness, few resources are available/prioritized for chronic condition management and prevention. This is a concerning dynamic given Martínez-Lozano et al found that when adjusting for age, hurricanes increased diabetes incidence, which heightens the critical need for individuals with prediabetes to be prepared for natural disasters to sustain healthy levels of HbA1c; a critical preparedness and response consideration for implementation into medical and public health response prior to, during, and after disasters. Joshipura et al. (2022) published another article that was related to preparedness and health vis-à-vis the island's most vulnerable diabetic populations in wake of both Hurricane Irma and Maria. Puerto Rico has had an extensive history with hurricanes but 59% of the population, especially the most vulnerable populations such as diabetics and other groups with chronic illnesses, were considered ill-prepared (Joshipura et al., 2022). Furthermore, Joshipura et al. outlined how low preparedness for hurricanes contributes to the most detrimental health side effects for Puerto Rican populations in addition. In addition, elements that are caused by hurricanes such as a massive disruption of drinking water and other power outages were linked to a change in people's diets and a greater level of urgency in terms of how they were impacted during storms. The article highlighted detrimental dietary changes (resulting from poor food preparedness and access) could exacerbate chronic conditions, such as hypertension and diabetes. (Joshipura et al., 2022). Notably, the study performed by Joshipura et al. found that the associations between duration the stored food lasted, and diet changes were not significant, suggesting that other aspects, such as alternative cooking means and receiving help from government or other sources, may have mitigated the impact.

Rivera-Hernandez et al. (2022) also observed some of the key elements that contributed to the exacerbation of NCDs such as obesity and the implications that it brought about for patients with kidney failure. Rivera-Hernandez et al. examined whether migration and mortality rates in Puerto Rico changed following Hurricane Maria. The study design involved a cross-sectional study used an interrupted time-series design of 6-month mortality rates and migration of 11,652 patients, all of whom were given hemodialysis or peritoneal dialysis care in Puerto Rico prior to Hurricane Maria and/or during and after the hurricane had occurred. Rivera-Hernandez et al. (2022) reported their data analyses, which were performed from February 12, 2019, to June 16, 2022. The cross-sectional study found a substantial migration (or evacuation) of dialysis patients after Hurricane Maria based on the significant increase in the number of patients receiving dialysis outside of Puerto Rico after the hurricane, as well as a significant decline in the number of unique persons receiving dialysis in Puerto Rico. Interestingly and contrary to other studies and reports for the general population, Rivera-Hernandez et al. found no evidence of increased mortality among patients with kidney failure after Hurricane Maria. Among the acknowledged limitations in this study was the potential to have missed patients being treated with dialysis in Puerto Rico.

Although kidney failure is loosely related to the effects of obesity, it is still an important aspect to consider for the literature review as it is a disease that is connected to either obesity or diabetes. Huang et al. (2023) observed the health-related outcomes of cyclones, especially when it came to the impact brought about by diabetes and other chronic illnesses during Hurricane Maria. Huang et al. carried out a systematic review with a meta-analysis on the risks of all health-related outcomes vis-à-vis cyclones as a means of better identifying gaps in research for future discussion. Huang et al. studied the findings of 71 studies across eight countries with a majority of them being from the United States. The studies included in their investigation mostly considered only one cyclone (with many assessing Hurricane Katrina or Hurricane Sandy) and mental disorders morbidity and all-cause mortality and hospitalizations within 1.5 years after cyclone exposure. The risk of mental health-related morbidity and PTSD and all-cause mortality or hospitalizations was found to be elevated after cyclone exposures. Most notably were the findings that there was limited or mixed evidence for other outcomes. Huang et al. in addition to the findings of Joshipura et al. indicate that the key issues behind health morbidity tied to diabetes following Hurricanes is due to a combination of logistical issues, an overall lack of proper infrastructure planning, and several averse factors from other NCDs such as cancer and other mental disorders. Martínez-Lozano et al. (2023) provide another perspective that is more tied to a lengthy history of demographic ages and other crucial factors that pertain to the survivability of individuals that follows a major natural disaster. In another similar study, Lukowsky et al. (2023) examined the impact of Hurricane Irma and Hurricane Maria for American veterans' access to dialysis care in Puerto Rico using a longitudinal cohort study. Although there was an increase of dialysis services in Puerto Rico during the Hurricanes, there was a notable decrease of accessibility for American veterans who wished to access services.

Another study by Mizelle Jr (2020) examined the resiliency of diabetics during the entirety of Hurricane Katrina. Mizelle Jr wrote their essay with the intention of focusing on the most vulnerable groups during Hurricane Katrina, namely diabetic evacuees whose physical and mental fortitude were the most affected. The essay was written due to mounting evidence from Hurricane Katrina and other natural disasters that showcased the impact that natural disasters had on the most vulnerable populations suffering from some form of Chronic illness, which included diabetes and obesity. Furthermore, Mizelle Jr outlined how African American diabetic evacuees in New Orleans after the Hurricane were among the most affected.

The study highlights the necessity for understanding the system and environment that affects vulnerability to and health outcomes resulting from intense weather events and disasters. Objectively, this study validates need to operationalize the social-ecological model in assessment and mitigation decision making. For example, the study stresses that rapid urbanization, persistent social stratification, and climate change and the absence of adequate planning to support vulnerable populations and manage chronic diseases in degraded environments, such disruptive events can and will become costly and deadly. Both Mizelle Jr as well as Martínez-Lozano et al. considered the gravity that was brought about by the most vulnerable populations suffering from chronic illnesses. Obesity is especially a key element that numerous populations from vulnerable sectors suffer from because of the numerous medical complications that are the most associated, which also include the field of obesity.

Summary and Conclusions

To conclude, there is a growing body of academic studies that observed and considered the different circumstances behind natural disasters, hurricanes, and their dynamics with persons with CVDs and metabolic syndrome-related chronic illnesses, but not other chronic diseases. There was a notable overrepresentation of recent publications that resorted to the use of systematic reviews as a means of identifying gaps in information or areas where literature was lacking. There was also an increase in recent years of academic sources that were centered around the role of CVDs and metabolic syndrome-related chronic illnesses (mainly diabetes and kidney disease/failure) and how they were impacted by hurricanes and other natural disasters, however. not other chronic diseases.

A commonality found in the academic literature from practitioner’s conclusions are that most problems and aspects that were identified in the literature were infrastructural and rooted in flaws that were tied to logistics. Researchers and authors in the literature review identified aspects that were tied to ill-preparedness and a lack of fortified infrastructure when it came to mitigating morbidity or fatalities for people with CVD or metabolic disease, are a broad generalization of chronic illness during an emergency. A common conclusion drawn by authors of systematic reviews is that there was not enough emphasis on timely responses to emergencies or not enough prioritization for people with chronic illnesses, which was focused on CVD and metabolic diseases primarily and did not address unique considerations for other chronic diseases.

Another commonality that was observed in the literature was a demographic perspective, which focused on more vulnerable and marginalized populations. These examples are geographical, with some systematic reviews that focused on secondary county-data within the United States. Some studies have considered racial and ethnic groups from certain areas that were in much more vulnerable and problematic states. For example, diabetic patients of African American origin in New Orleans were more vulnerable following their respective hurricanes.

A gap or weakness found in existing studies is that there is not a uniform or standardized population that has been observed. Studies in recent years have centered on various different demographics and populations. Authors of different disciplines and practices have made different suggestions vis-à-vis medical suggestions or a means for more research to be carried out to better identify the specific predictors of morbidity and mortality among people with CVDs or metabolic diseases, with minimal acknowledgment of other chronic illnesses impacted by a natural disaster. This is where the purpose of this cross-sectional study was focused, to provide additional quantifiable evidence, using multiple regressions and contingency tables with Pearson's chi-square, to examine the associations, ultimately enhancing the understanding of the impact hurricanes have on individuals with chronic illnesses, including those beyond CVD and metabolic diseases.

Chapter 3: Research Method

Introduction

Chapter 3 details the methodology adopted to execute the study. It includes the setting, research design and rationale, methodology (population, sampling, instrumentation, data collection, and data analysis), threats to validity, and ethical procedures. The methods chosen were aligned with the study's purpose: to examine the association between deaths among individuals with chronic diseases and exposure to Hurricane Irma 2 months postlandfall in Florida.

Research Design and Rationale

A cross-sectional design was selected given that the aim of the study was to collect data at a single point in time to examine the variable relationships (Spector, 2019). This examination would be achieved through a comparison of two time periods, the 2 months post-Irma landfall and a similar time period in 2016, and the deaths that occurred during that period that were chronic disease related. The study's geographic location was Florida, which was severely impacted by Hurricane Irma in September 2017 (Wingard et al., 2020). The study was focused on the immediate aftermath of the storm and its possible associative effects on the mortality of people with chronic conditions.

The outcome variable was mortality, measured using deaths per 100 individuals. The exposure variable was Hurricane Irma 2 months after landfall. The exposure variable, which was the time period 2 months after Hurricane Irma made landfall, was important because it made it possible to capture what the prevalence of mortality would have been during that time period. The specific chronic disease–related deaths examined included diabetes mellitus, major cardiovascular diseases, and chronic respiratory disease, as well as cancers.

The covariates examined included age defined as a categorical variable, 85 and older or younger than 85; sex defined a biologically born male or female; race, defined as Black, non-Hispanic, White, non-Hispanic, Asian, Hispanic ethnicity, defined as Yes or No; poverty level rate, defined as percentage of people in an area living in (at or below) poverty categories of high poverty, extreme poverty, persistent poverty, and enduring poverty, rural–urban continuum code, defined as metro area and nonmetropolitan; and educational attainment rate, defined as completing college, not completing high school, completing high school, and completing some college. Underlying cause of death (UCD) was coded using the UCD 113, which is an International Classification of Diseases (ICD)-10 code that refers to a list of 113 selected causes of death. The National Center for Health Statistics (NCHS) created the UCD 113 list to provide a consistent standard for ranking causes of death. The list includes 50 of the NCHS's leading causes of death, including codes for diabetes mellitus, major cardiovascular diseases, and other causes of death.

Demographic characteristics in relation to mortality included age, sex, race, Hispanic ethnicity, and education. Age was measured by groups ranging from under 1 month to 100 years and over. Sex was measured as either male or female. Education rate was defined using four levels of educational attainment rates, with Levels 1–4 being did not complete high school, completed high school, completed some college (including associate’s degree), and completed college, respectively. Poverty uses the U.S.

Department of Agriculture (USDA) Economic Research Service (ERS) categorical coding associated with four levels of poverty rates: high poverty, extreme poverty, persistent poverty, and enduring poverty. Regarding urbanicity, rural–urban continuum codes were stratified across a six-level urban–rural classification scheme for U.S. counties and county-equivalent entities. Educational attainment rate, poverty level rate, and rural–urban continuum codes all served as socioeconomic indicators in this study.

A cross-sectional study was the appropriate approach considering the data set available because it supported assessment of the sample population during a set period of time to observe an outcome before and after a defined exposure and then make a comparison over two different points in time. Specifically, this design enabled assessment of the mortality among individuals with chronic diseases (outcome) who were impacted by Hurricane Irma (exposure) in the study population during the same time. The participants in this cross-sectional study were selected based on the inclusion and exclusion criteria set for the study. The subject characteristics were individuals who died from a chronic disease–related cause of death within 2 months from landfall of Hurricane Irma, based on the identified independent variables (Lau, 2017), and exposure was determined given the geographical location (counties in Florida) of the individual's death after the impact of the storm (Song et al., 2013).

This cross-sectional study design capitalized on existing data sources with sufficient data on the sample population in Florida to examine for association between deaths among chronically ill individuals and exposure to Hurricane Irma 2 months after landfall, as well as assess for modification by key demographics. This design choice allowed for a more time-efficient utilization of available resources and avoided the need for extensive primary data collection.

The use of a quantitative cross-sectional study design aligned with the requirement to produce solid empirical information on the effect of Hurricane Irma on the mortality rates of people with chronic illnesses to further the field's understanding. This research design informs public health policies and initiatives targeted at minimizing the effects of natural disasters and advances scientific understanding of the health repercussions of such events through systematic data analysis and statistical modeling.

Methodology

A cross-sectional study was used to examine the association between deaths occurring among chronically ill individuals and exposure to Hurricane Irma 2 months after landfall. The cross-sectional study design was used to examine the broad relationship between deaths among chronically ill individuals and exposure to hurricanes. It is an ideal observational study design when a researcher hopes to gain a snapshot of the health conditions among certain populations. Additionally, because data were collected at some point in the past, there was no way to conduct an analytic study because information on both exposure and outcome were examined and assessed at the same point in time. Because the objective of this study was not aligned to the lived experiences, perceptions, and opinions of the participants (Creswell, 2013), qualitative methods were not appropriate and thus not selected.

Population

The number of individuals with at least one chronic illness residing in Florida when it was impacted by Hurricane Irma is estimated to be around 13.1 million (Florida Department of Health, 2018). The population for this study included all individuals who died in Florida 2 months after Hurricane Irma's landfall in 2017. There were approximately 203,000 deaths in 2017 in Florida and approximately 33,000 total deaths in Florida during September 2017 and October 2017 based on data from the NCHS.

Sampling and Sampling Procedures

The sample was comprised of a subset of this population, specifically those individuals who experienced mortality within 2 months following the Hurricane Irma's landfall. This sample was selected to investigate the associations between deaths among individuals living with chronic illness and exposure to the aftermath of Hurricane Irma.

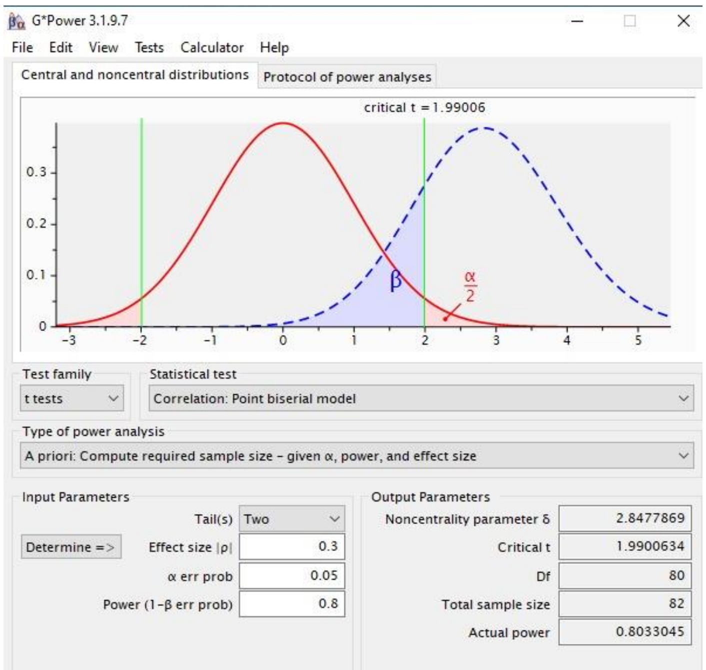
The study data were a sample from all chronically ill individuals living in Florida who were directly impacted by Hurricane Irma and died during the months of September and October 2017. A comparable time period in 2016 was used as comparison to examine the effects of Hurricane Irma's aftermath among chronically ill individuals. Purposive sampling was used to collect data for analysis from a database that included individuals with chronic illness. Purposive sampling allows the selection of study units that bear the characteristic of interest in a sample (Creswell, 2013). The sample comprised a population of individuals in Florida who were chronically ill (determined via chronic disease–related deaths on death certificate) and experienced mortality within 2 months following Hurricane Irma landfall. Data from entries that had chronical illness were included in the study while data with other types of illnesses and causes of death were excluded. Only decedent data from September 2017 to October 2017 were included in the study as the exposure cohort comprised all mortality cases in Florida starting in September 2017 and were assessed using mortality data for 2 months after Hurricane Irma's impact.

A power analysis was performed to determine the appropriate sample size for the study, and a sample size of 82 or greater was necessary, which was calculated using G*power statistical software. Power analysis refers to the estimation of the smallest sample size needed in a study under a preset sample effect size, a required significance level, and the statistical power. Power analysis helps in determining whether the findings in a study are due to chance or if they are significant and reliable. A correlational model was used to examine the relationship between demographic characteristics (age, sex, race, Hispanic ethnicity, poverty level rate, rural–urban continuum code, and educational attainment rate) and death in 2 months from landfall among individuals with chronic disease following a large-scale natural disaster, Hurricane Irma, in Florida.

The statistical power of the hypothesis test was defined by *p*-value, which is the probability (*p*-value) of seeing an effect. A higher statistical power represents a case where one should reject the alternative hypothesis when the null hypothesis is true. Often, statistical power must be 80% or more in order to accept the results (Creswell, 2013). A sample greater than 82 data records was necessary for analysis. The sample size was obtained from the G*power statistical software with a power of 0.8, effect size of 0.3, and a confidence interval of 0.05 (Figure 1).

Figure 1

Power Analysis Using GPower Statistical Software



Note. This was the power analysis performed for this study using G*Power statistical software.

The choice of these parameters ensured that the hypothesis testing procedure would have an 80% or greater chance of finding a statistically significant difference when there is one in the study variables. The higher the statistical power, the lesser the likelihood of giving a false negative or type II error.

In addition to the G*Power analysis, according to Peduzzi et al. (1996), the concept of events per variable (EPV) of 10 is acceptable for both logistic regression and Cox regression determination of sample size sufficiency. There were nine variables in this study, demographic variables including age, sex, race, Hispanic ethnicity, poverty level rate, rural–urban continuum code, and educational attainment rate, and chronic disease cause of death , which meant a sample size of 82 also met the requirement of an EPV of 10.

Archival Data Use

Secondary data were utilized in this study. The data were downloaded freely from the NCHS Vital Statistics CDC Wonder public website and from the USDA ERS public website. Data required for this study were publicly available on the CDC Wonder website with no permission or request requirement, and a general data user agreement notice was accepted when accessing the data. After the dataset files were downloaded, the data were ready for aggregation and analysis. The pooled data were then transformed and cleaned, which involved selecting only the relevant data for analysis, which comprised only data that met the eligibility requirements. For example, only individuals with chronic illnesses during the months of September and October of 2016 and 2017 were included in the analysis.

Due to the size limitations of data pulls from the NCHS CDC Wonder website, three mortality data sets had to be pulled from NCHS's CDC Wonder site and then combined: Data Set 1: Florida, September and October 2017, Male_ grouped by Hispanic origin, race, UCD-ICD 113, county, 10-year age group; Data Set 2: Florida, September and October 2017, Female_ grouped by Hispanic origin, race, UCD-ICD 113, county, 10-year age group; and Data Set 3: Florida, September and October 2017, grouped by state, county, and 2013 urbanization. These three data sets provided all data for the variables age, sex, race, Hispanic ethnicity, rural–urban continuum code, and chronic disease–related deaths among people who died in Florida 2 months after the impact of Hurricane

Irma. Additionally, the USDA ERS county-level data sets provided poverty level rate and educational attainment rate at the county level in Florida for the study time period.

Instrumentation and Operationalization of Constructs

Instrumentation

The secondary data set for this study was the "Mortality Multiple Cause-of-Death" data retrieved from the CDC NCHS NVSS data, on CDC Wonder. These data are publicly available on the CDC’s NVSS website and via CDC Wonder with no permission or request requirement. This secondary data include the mortality variable (underlying condition of death and date of death [month and year], and state/county), as well as demographic data (age, sex, race, Hispanic ethnicity). Within the deidentified individual mortality data, the chronic conditions/diseases coding for underlying cause of death is critical; this enabled examination of underlying cause of death and provided information for researchers and policymakers to have a better understanding of the burden of chronic conditions among decedents.

Mortality data were from death certificates for U.S. residents. Each death certificate contains a single underlying cause of death, up to 20 additional multiple causes, and demographic data. NCHS mortality data, which are publicly available via CDC Wonder, were used to provide the number of deaths by place of death (U.S. state and county), age group, race, Hispanic ethnicity, gender, year and month of death, and underlying and multiple causes of death (4-digit ICD-10 codes associated with the 113 selected causes of death for infants, injury causes, or drug/alcohol-induced causes of death).

The reliability and validity of NCHS NVSS mortality data are well established and documented, particularly greater than 1 year after death, which allows for death certificates to be processed and information to be received and validated by NCHS (Ahmad et al., 2022; CDC, 1989). Quality assurance of NCHS mortality data is promoted during each phase of data collection and data processing; and states submitting records are encouraged and supported in the scrutinization of records and questionable entries with guidance and tools to enable more effective and efficient provision of quality records. It was noted, however, that the potential exists for misclassification of certain categories of race and ethnicity reported on death certificates (Arias & Heron, 2016), which could impact death rates slightly for some groups. Nevertheless, the "Mortality Multiple Cause-of-Death" data from the CDC's NCHS NVSS data were very relevant and specifically valid and reliable for use in this study.

Additionally, educational attainment rate, poverty level rate, and rural–urban continuum codes, which are socioeconomic indicators that vary across U.S. states and their county and county equivalents, were downloaded from the USDA ERS public website and the NCHS Vital Statistics CDC Wonder site, respectively. USDA ERS compiles the latest statistics on these measures and provides maps and data for U.S. states and counties/county equivalents, including Puerto Rico when available. The NCHS data systems are often used to study the associations between urbanization level of residence and health and to monitor the health of urban and rural residents, and as a result, NCHS has developed a six-level urban–rural classification scheme for U.S. counties and county-equivalent entities leveraging Office of Management and Budget parameters, similar to USDA ERS (NCHS, n.d.).

The USDA ERS Educational attainment data leverages the American Community Survey (ACS) Educational attainment data. ACS data is reported annually. These data provide estimates of educational attainment from 2000 to present, and are available for the U.S., states, metropolitan area, and more specific geographic areas that meet minimum population sizes for the given survey year. Five-year estimates for census groups and larger are available beginning in 2010 (for data years 2005-9). The USDA ERS educations attainment data set for all counties in Florida for the 2018-2022 period was used to populate the Educational attainment rate variable for this study.

The USDA ERS Poverty estimates are model-based estimates from the U.S. Census Bureau's Small Area Income and Poverty Estimate (SAIPE) program. Detailed documentation and information about the (SAIPE) program methodology used to generate the estimates for individuals living in (at or below) povertycan be found on the Census Bureau's Small Area Income and Poverty Estimates web page.

Operationalization of Variables

The dependent variable, death occurring 2 months after storm impact was calculated by using the date of death and its proximity to the date of impact for Hurricane Irma, which was September 10, 2017. This variable was coded as 0 for did not die in 30-60 days after storms impact from chronic health disease and 1 for died in 30-60 days after storms impact from chronic disease.

The independent variable was exposure to Hurricane Irma. This exposure was defined as anyone with a chronic health condition who was alive during Hurricane Irma's landfall. As a comparison to this exposure, a time-period between Hurricane Irma's landfall and 2 months after was used as the unexposed time period.

Covariates included demographic data which were age, sex, race, Hispanic ethnicity, poverty level rate, and rural–urban continuum code, and educational attainment rate.

Demographic information for the decedents was coded within the dataset using specific identifiers. The month of death coded as September of October indicates the month in which the individual passed away. Sex was coded as "M" for male or "F" for female. Race was categorized by codes are provided white or Black or African American, distinguishing the racial background of the decedent. Age at the time of death was represented by coding for ten-year age groups. Hispanic origin was identified by codes for Latino or Hispanic and Not Hispanic or Latino whether the individual is of Hispanic ethnicity.

The poverty estimates used in this study are model-based estimates from the U.S. Census Bureau's Small Area Income and Poverty Estimate (SAIPE) program. People and families are classified as being in poverty if their income is less than their poverty threshold. The Census Bureau's definition of poverty uses money income before taxes and does not include capital gains or noncash benefits (such as public housing, Medicaid, and food stamps) (U.S. Department of Agriculture, n.d.). For this study, the USDA ERS definitions for the specific poverty measures were:

- High poverty: areas with a poverty rate of 20.0 percent or more in a single time period.
- Extreme poverty: areas with a poverty rate of 40.0 percent or more in a single time period.
- Persistent poverty: areas with a poverty rate of 20.0 percent or more for four consecutive time periods, about 10 years apart, spanning approximately 30 years (baseline time period plus 3 evaluation time periods).
- Enduring poverty: areas with a poverty rate of 20.0 percent or more for at least five consecutive time periods, about 10 years apart, spanning approximately 40 years or more (baseline time period plus four or more evaluation time periods).

The 2023 Rural–Urban Continuum Codes distinguish U.S. metropolitan (metro) counties by the population size of their metro area, and nonmetropolitan (nonmetro) counties by their degree of urbanization and adjacency to a metro area. The codes allow researchers, policy makers, and others to view county-level data by finer residential groups—beyond metro and nonmetro—when analyzing trends related to population density and metro influence.

The Rural Urban Code is a classification scheme that distinguishes metropolitan counties by the population size of their metro area, and nonmetropolitan counties by degree of urbanization and adjacency to a metro area (U.S. Department of Agriculture, n.d.). The Rural–Urban Continuum (RUC) codes are a system used to categorize counties in the United States as either metropolitan (metro) or nonmetropolitan (nonmetro). The codes are based on the population size of metro areas and the degree of urbanization and adjacency to a metro area for nonmetro counties. Each county and census-designated county-equivalent is assigned one of six codes:

1. Metropolitan counties: Large central metro counties in MSA of 1 million population that: 1) contain the entire population of the largest principal city of the MSA, or 2) are completely contained within the largest principal city of the MSA, or 3) contain at least 250,000 residents of any principal city in the MSA.
2. Large fringe metro counties in MSA of 1 million or more population that do not qualify as large central.
3. Medium metro counties in MSA of 250,000-999,999 population.
4. Small metro counties are counties in MSAs of less than 250,000 population.
5. Nonmetropolitan counties: Micropolitan counties in micropolitan statistical area.
6. Noncore counties not in micropolitan statistical areas data access website.

Education rate is the educational attainment of the decedent, specifically level of education received (using 2003 education coding revision). The education rate coded across four levels with level 1-4 being, Not completing high school, Completing high school, Completing some college (including associates degree), Completing college, respectively. USDA ERS leverages the Census Bureau's American Community Survey estimates, which are derived from survey data collected over a 5-year period. 60 months of collected data Example: 2018-2022 ACS 5-year estimates Date collected between:

January 1, 2018, and December 31, 2022. This data includes data for all areas, is the largest sampling of education reporting by individuals, and is the most reliable data set for education rates, based on aggregation of individual reporting, collected by the 2018-2022 American Community Survey.

Data Analysis Plan

The statistical plan included both descriptive and inferential statistics. Descriptive statistics were used to describe demographic data as well as the distribution of the exposure and outcome variables. Inferential statistics were used to examine possible associations between the main independent and dependent variables. In terms of visualization, tables were used to support readability of the summarized descriptive data, leveraging the underlying cause of death (UCD) 113 code, which is an ICD-10 code that refers to a list of 113 selected causes of death. The NCHS created the UCD 113 list to provide a consistent standard for ranking causes of death.

Data Cleaning

Data analysis was performed using statistical package for social sciences (SPSS) software, version 29. The procedure started with data cleaning process. Procedures for data cleaning and screening are essential to guaranteeing the dataset's dependability and integrity (Rangineni et al., 2023). Demographic data and death certificate data was gathered from the official website. The approach entailed validation and verification to ensure accuracy and completeness. Once the important variables were discovered, the data was reviewed and cleaned to remove duplicate entries, formatting errors, and inconsistencies. These variables included mortality rates, diagnoses for chronic diseases, and demographic aspects. Outliers were located and assessed for their influence on study conclusions, while missing data will be managed with suitable methods such as imputation techniques or removal from analysis depending on the severity of the issue.

Analysis of Research Questions

RQ1. Is there an association between deaths among chronically ill individuals and (dependent variable) exposure to Hurricane Irma 2 months after landfall (dependent variable)?

H1o: There is no association between deaths among chronically ill individuals and exposure to Hurricane Irma's 2 months after landfall among impacted individuals.

H1a: There is an association between deaths among chronically ill individuals and exposure to Hurricane Irma 2 months after landfall among impacted individuals.

RQ2. Is the association between deaths among chronically ill individuals and exposure to Hurricane Irma 2 months landfall modified by demographic characteristics including age, sex, race, Hispanic ethnicity, poverty level rate, and rural–urban continuum code, and educational attainment rate?

H2o: The association between deaths among chronically ill individuals and exposure to Hurricane Irma 2 months after landfall is not modified by demographic characteristics including age, sex, race, Hispanic ethnicity, poverty level rate, and rural–urban continuum code, and educational attainment rate.

H2a: The association between deaths among chronically ill individuals and exposure to Hurricane Irma 2 months after landfall is modified by demographic characteristics including age, sex, race, Hispanic ethnicity, poverty level rate, and rural–urban continuum code, and educational attainment rate.

The following sections cover the descriptive and inferential statistical approaches adopted for analysis of the RQs.

Descriptive Statistics

Descriptive analysis was performed conceptual groupings of independent variables including, individual demographics (age, race, Hispanic ethnicity, and sex) and socioeconomic (education and poverty) variables, to discern potential effect on mortality of individuals with chronic diseases after a hurricane. Additionally, a descriptive analysis was performed on deaths in 2 months after a hurricane of decedents with underlying chronic diseases to discern potential effect chronic diseases has on mortality of individuals after a hurricane.

Inferential Statistics

The study employed appropriate statistical analyses, such as multiple regressions and contingency tables with Pearson's chi-square, to examine the associations among demographics, chronic disease-related death, and death within 2 months. Logistic regressions allow for examining a series of predictor variables to determine those that best predict a specific outcome, wherein the predictor variables may be of any data level (categorical, ordinal, or continuous). Contingency tables were used with the chi-square test for independence to display the distribution of categorical variables and examine relationships between them.

Given the data set includes all deaths for September and October 2017, monthly all-cause mortality for decedents with and without chronic disease was calculated. In addition, attributable risks, attributable fractions, and relative risks (RRs) were calculated to assess the impact and strength of associations between exposure to Hurricane Irma and chronic diseases, the nature of the research questions and the types of variables involved. For hypothesis testing, appropriate statistical tests were employed. For example, utilize contingency tables with Pearson's chi-square tests for the analyses considering the association between chronic disease-related deaths (a binary variable) and categorical independent variables like age, sex, race, Hispanic ethnicity, poverty level rate, and rural–urban continuum code, and educational attainment rate, chronic disease status.

Given the living population was not assessed, the reference group for the dependent variable consisted of those individuals who died within 2 months and did not have chronic disease implicated in the cause of death. Also, for county level data, in mixed regression models, clustering among individuals by zip code is likely and could possibly elicit “random effects” within the data.

Threats to Validity

Changes in the characteristics of the participants or the environment in various locations or periods may interact differently with the experimental variables (such as Hurricane Irma exposure) and affect the results. Subgroup analyses was used in this study to investigate possible correlations between participant characteristics (such as age and socioeconomic status) and the hurricane's impact on fatality rates to counteract this threat.

The generalizability of the study's findings may be limited by the variables (such as demographic traits and diagnoses for chronic diseases) that may have different impacts in other situations or populations. Diversity across populations and situations relating to the disaster was considered. It was assumed that the data set used captured a wide range of demographic and clinical characteristics to help counteract this threat.

Other than Hurricane Irma, there could be other factors influencing the study results, such other natural disasters happening at the same time or treatments carried out during the study period. To mitigate this threat, isolation of the impact of Hurricane Irma on death rates while taking other possible affects into account by using regression modeling was performed, to account for confounding variables.

Threat due to internal validity may present since the study data was not randomly selected which might lead to selection bias as purposive sampling was used for the study. There could have been other interventions occurring during the study period that could affect mortality rates other than the chronically ill individuals that could act as confounding factors. The participants' data health conditions over the 30-day period could be mistaken for the effects of Hurricane Irma thus making the wrongly attribution to the hurricane. Threats to external validity are possible since Florida's population may differ significantly from other regions in terms of demographics, healthcare infrastructure, or disaster preparedness, thus the findings may not apply elsewhere (Creswell, 2013). Finally, the study is conducted years after Hurricane Irma, therefore the variables utilized now, and thus impact and response to the disaster might now have changed due to factors like improved disaster preparedness or changes in community and healthcare infrastructure, to include associated data.

Ethical Procedures

All ethical procedures were followed. Submission to and approval from the university IRB was obtained for the study as a deidentified retrospective study; No unique IRB requirements were imposed. IRB approval number is 07-09-24-0991235. However, the data used, while already deidentified by CDC, could be sensitive and so adherence to the general public data users' agreement from CDC ensured protection and proper handling of the information as well as an assurance to utilize it only for the intended reasons for conducting this research. The dataset was not shared with third parties, even though third parties can download the data set directly from the NCHS public website. Confidentiality of the data was ensured by keeping it out of access to unauthorized individuals. Since the procedure did not involve collecting data from human subjects, there were no consent forms required or risks of personal data being exposed (Chowdhury et al., 2019). All materials utilized in the process of this research were dully acknowledged and cited.

There was full adherence to the Vital Statistics [public] Data Release Policy. The policy outlines guidelines and procedures for accessing and using mortality data collected by the CDC. This policy ensures the protection of individual privacy and confidentiality while promoting the responsible and ethical use of mortality data for public health research and policymaking (NVSS - data release policy for Vital Statistics, 2019).

In this study, measures were implemented to safeguard the confidentiality of collected data. All data, including mortality records and demographic information, were securely stored using encryption and password protection on restricted-access servers. Physical storage devices were encrypted and stored in secure facilities to prevent unauthorized access. Data dissemination was strictly controlled, and no data was shared with other researchers or individuals beyond the researchers committee members. All data was downloaded from CDC and anonymization, or aggregation was already performed by CDC to protect individuals' privacy. Access to confidential data was limited to approved team members who have undergone training in data security, and data destruction was carried out in compliance with regulations and guidelines once the study was complete.

Summary

This chapter described the methods used in data collection and analysis. It highlighted the dependent variable will be the outcome or mortality, measured by presence or absence of death within the first 2 months following the exposure to the disaster, while independent variables were cause of death and demographic data. The study setting was Florida, USA, where Hurricane Irma struck in 2017. The study design was a cross-sectional research, and justification was presented. The primary data set for this study was the "Mortality Multiple Cause-of-Death" data from the CDC’s NCHS NVSS, retrieved via CDC Wonder. Data was analyzed quantitatively using SPSS (version 29). The study employed appropriate statistical analyses, such as multiple regressions and contingency tables with Pearson’s chi-square, to examine the associations among demographics, chronic disease diagnosis, and death within 2 months. Chapter 4 presents the study findings after data analysis.

Chapter 4: Results and Findings

Introduction

The purpose of this cross-sectional study was to examine the association between death within 2 months following a large-scale natural catastrophe, Hurricane Irma in Florida, and chronic disease–related deaths among individuals. This was accomplished by examining variable relationships in a comparison of two time periods, the 2 months post Irma and a similar time period in 2016, and the deaths that occurred among those diagnosed with chronic conditions. The specific research issue addressed by this study was that it is unknown what influence hurricanes had on the mortality of individuals with chronic disease, based on death within 2 months of landfall in Florida. Hurricane Irma provided a vital case study and an important chance to analyze the mortality outcomes for individuals with chronic conditions when confronted with extreme weather due to its unprecedented intensity and widespread effects on Florida. This study's findings provide insights to natural disaster–affected areas in the United States by conducting a unique examination of the quantifiable change in mortality outcomes (death within 2 months of September 2017 and October 2017) of chronic disease patients following natural disasters, specifically Hurricane Irma, in Florida.

RQ1. Is there an association between deaths among chronically ill individuals and (dependent variable) exposure to Hurricane Irma 2 months after landfall (independent variable)?

H1o: No association exists.

H1a: An association exists.

RQ2. Is the association between deaths among chronically ill individuals and exposure to Hurricane Irma 2 months after landfall modified by demographic characteristics including age, sex, race, Hispanic ethnicity, poverty level rate, rural–urban continuum code, and educational attainment rate?

H2o: The association is not modified.

H2a: The association is modified.

This chapter presents the findings, organized into overarching sections. The Data Collection section provides an overview of the time frames, response rates, and any discrepancies encountered compared to the original data collection plan. It also provides the Baseline Characteristics section, which contains a description of the sample demographics, an assessment of the representativeness of the data, and an overview of univariate or assumption analysis. The results section details the results of descriptive statistics, a thorough assumption analysis, univariate and multivariate analyses, as well as effect modification analysis. Finally, the Summary section highlights the key findings and conclusions drawn from the analyses, offering a comprehensive overview of the study's outcomes.

Data Collection

Time Frame and Recruitment

Data were collected using secondary datasets, primarily the Mortality Multiple Cause-of-Death dataset from the CDC’s NVSS. The data covered deaths occurring in Florida during September and October of 2016 and 2017. This period was selected to compare mortality outcomes during a 2-month window post-Hurricane Irma (2017) with a comparable period in 2016.

The study population consisted of approximately 33,000 total deaths in Florida during the 2-month period in 2017. A subset of this population included individuals with chronic illnesses, representing the primary focus of the analysis.

Discrepancies in Data Collection

There were no significant discrepancies between the data collection process and the methodology outlined in Chapter 3. However, potential misclassification of certain demographic categories (e.g., race, ethnicity) was noted as a limitation due to the reliance on death certificate data.

Baseline Characteristics

The majority of deaths in the study sample occurred among individuals aged 65 years and older, with the largest subgroup being those aged 85 and above, accounting for approximately 44.8% of total deaths post-Hurricane Irma. The sample had a relatively balanced distribution between males and females. Most decedents were White (92.3%), while Hispanic individuals comprised about 9.8% of the sample. Socioeconomic indicators revealed disparities in mortality rates, with higher rates observed among individuals residing in high-poverty areas. Mortality was also disproportionately higher in urban regions compared to rural settings. Educational attainment levels varied, with a significant portion of the sample having lower levels of education. Chronic diseases such as CVD and diabetes accounted for a substantial proportion of deaths, highlighting the vulnerability of individuals with chronic illnesses during disasters. Geographic representation focused on Florida counties, with demographic diversity aligning closely with statewide data for populations affected by Hurricane Irma.

Representativeness

The sample was representative of Florida's population of individuals with chronic illnesses. The demographic and geographic diversity of the sample aligns closely with state-level data for individuals impacted by Hurricane Irma, providing external validity.

Univariate (Assumption) Analysis

Key statistical assumptions for logistic regression were tested and validated. The evaluation of assumptions included linearity in the logit, avoidance of multicollinearity, and no significant outliers. For linearity in the logit, the Box-Tidwell procedure confirmed no significant violations, indicating linear relationships between continuous predictors and the logit of the dependent variable. For multicollinearity, variance inflation factors (VIFs) were below 10 for all predictors, confirming no multicollinearity issues. For outlier analysis, Cook's distance identified no influential data points, and residual analyses showed no significant outliers. These results ensure the robustness and reliability of the logistic regression models.

Results

Descriptive Statistics

The study population comprised individuals who died from chronic diseases during the months of September and October in 2016 and 2017. The demographic characteristics were as shown in Table 1. The majority of the study population was White (95.7%), with a similar distribution in both years (2016: 95.7%; 2017: 95.7%). Black or

African American individuals comprised 4.3% of the population in both years. Regarding Hispanic origin, 90.2% of the population were not Hispanic or Latino (2016: 90.9%; 2017: 89.4%), while 9.8% were Hispanic or Latino (2016: 9.1%; 2017: 10.6%). The age distribution showed that the largest group was individuals aged 85 and above, representing 44.8% of the population (2016: 39.2%; 2017: 50.9%). This was followed by individuals aged 75–84, comprising 27.4% of the population (2016: 27.5%; 2017: 27.2%). Those aged 65–74 made up 17.1% (2016: 18.7%; 2017: 15.3%), while the 55–64 age group accounted for 7.6% (2016: 9.1%; 2017: 5.9%). The smallest group was those below 55 years, comprising 3.2% (2016: 5.4%; 2017: .8%).

The study population was distributed across various urbanization categories. Large Central Metro areas accounted for 7.6% of the population (2016: 7.5%; 2017: 7.8%), while Large Fringe Metro areas comprised 16.8% (2016: 16.4%; 2017: 17.2%). Medium Metro areas included 29.0% of the population (2016: 28.4%; 2017: 29.7%). Micropolitan (Nonmetro) areas accounted for 10.7% (2016: 10.4%; 2017: 10.9%), Non-Core (Nonmetro) areas for 22.1% (2016: 23.9%; 2017: 20.3%), and Small Metro areas for 13.7% (2016: 13.4%; 2017: 14.1%).

Table 1

Demographic Characteristics

	Total	2016	2017
Race			
White	2,414 (95.7)	1,266 (95.7)	1,148 (95.7)
Black or African American	108 (4.3)	57 (4.3)	51 (4.3)
Hispanic origin			
Not Hispanic or Latino	2,274 (90.2)	1,202 (90.9)	1,072 (89.4)
Hispanic or Latino	248 (9.8)	121 (9.1)	127 (10.6)
Age Groups			
85 & above	1,129 (44.8)	519 (39.2)	610 (50.9)
75–84	690 (27.4)	364 (27.5)	326 (27.2)
65–74	431 (17.1)	248 (18.7)	183 (15.3)
55–64	192 (7.6)	121 (9.1)	71 (5.9)
Below 55	80 (3.2)	71 (5.4)	9 (.8)
Urbanization			
Large Central Metro	10 (7.6)	5 (7.5)	5 (7.8)
Large Fringe Metro	22 (16.8)	11 (16.4)	11 (17.2)
Medium Metro	38 (29.0)	19 (28.4)	19 (29.7)
Micropolitan (Nonmetro)	14 (10.7)	7 (10.4)	7 (10.9)
NonCore (Nonmetro)	29 (22.1)	16 (23.9)	13 (20.3)
Small Metro	18 (13.7)	9 (13.4)	9 (14.1)
Chronic diseases			
No	93 (3.7)	69 (5.2)	24 (2.0)
Yes	2,429 (96.3)	1,254 (94.8)	1,175 (98.0)
		M [*SD*]	
Estimated percent of people in poverty (2021)	13.0 [2.5]	13.1 [2.7]	13.0 [2.4]
Education level (percent)			
Not completing high school	10.6 [3.4]	10.6 [3.5]	10.5 [3.3]
Completing high school	28.2 [4.2]	28.4 [4.4]	28.1 [3.9]
Completing some college	29.6 [3.4]	29.6 [3.4]	29.6 [3.4]
Completing college	31.7 [6.5]	31.5 [6.8]	31.9 [6.2]

Note. In round brackets are the column percentages; square brackets are the standard deviation. *M* = mean; *SD* = standard deviation.

A vast majority of the population (96.3%) had chronic diseases (2016: 94.8%; 2017: 98.0%), while only 3.7% did not have chronic diseases (2016: 5.2%; 2017: 2.0%). The estimated percentage of people in poverty was consistent between the 2 years, with an overall mean of 13.0% (*SD* = 2.5; 2016: *M* = 13.1%, *SD* = 2.7; 2017: *M* = 13.0%, *SD* = 2.4). Regarding education level, 10.6% of the population did not complete high school (2016: 10.6%, *SD* = 3.5; 2017: 10.5%, *SD* = 3.3). Those completing high school made up 28.2% (2016: 28.4%, *SD* = 4.4; 2017: 28.1%, *SD* = 3.9). Individuals completing some college comprised 29.6% (2016: 29.6%, *SD* = 3.4; 2017: 29.6%, *SD* = 3.4). Finally, those who completed college represented 31.7% (2016: 31.5%, *SD* = 6.8; 2017: 31.9%, *SD* = 6.2). Hurricane Irma was used in this study as the independent variable, and death occurring 2 months after landfall among individuals with chronic health conditions was the dependent variable. For comparison, the deaths occurring at the same point in time 1 year prior to Hurricane Irma were used. Thus, data were collected during the months of September and October of the years 2017 and 2016 and were used to compare difference in mortality prevalence among chronically ill individuals in Florida. The dependent variable mortality was defined as death occurring within 60 days of touchdown. The chronic health conditions of particular focus included cardiovascular conditions, including major cardiovascular diseases, ischemic heart disease, and various forms of heart disease. Respiratory illnesses, such as chronic lower respiratory diseases, were also included, alongside cerebrovascular diseases and Alzheimer’s disease. Malignant neoplasms, particularly in the trachea, bronchus, lung, and other unspecified sites, were also included. Other notable chronic conditions included diabetes, chronic liver disease, hypertension, nephritis, and renal failure. Individuals' age, race, and level of education were all considered independent factors. The estimated percentage of people in poverty from the USDA ERS county-level data was also included as one of the independent variables.

Summary of Cause of Death Data for September and October of 2016 and 2017—Chronic Diseases

The data in Table 2 include the causes of death among individuals with chronic diseases for the years 2016 and 2017. The data were categorized into two groups: those who died from chronic diseases and those who did not. The most common cause of death among individuals with chronic diseases was major cardiovascular diseases, accounting for a total of 466 deaths (2016: 231; 2017: 235). This was followed by diseases of the heart, with a total of 356 deaths (2016: 177; 2017: 179), and malignant neoplasms, with a total of 396 deaths (2016: 200; 2017: 196). Ischemic heart diseases were also a significant cause of death, totaling 217 deaths (2016: 121; 2017: 96), along with other forms of chronic ischemic heart disease, which accounted for 148 deaths (2016: 86; 2017: 62). Other heart diseases contributed to 77 deaths (2016: 40; 2017: 37), and cerebrovascular diseases resulted in 79 deaths (2016: 37; 2017: 42).

Other categories with minimal deaths included nephritis, nephrotic syndrome, and nephrosis (1 death in 2017), renal failure (1 death in 2017), malignant neoplasm of pancreas (1 death in 2016), and malignant neoplasms of colon, rectum, and anus (1 death in 2016).

Comparing the 2 years, there were several notable trends. There was no significant increase in deaths due to chronic lower respiratory diseases from 2016 (37 deaths) to 2017 (39 deaths), resulting in a total of 76 deaths over the 2 years. The number of deaths due to major cardiovascular diseases remained relatively consistent between the two years, with 231 deaths in 2016 and 235 deaths in 2017.There was a decline in deaths due to ischemic heart diseases from 121 in 2016 to 96 in 2017. Notably, deaths due to chronic liver disease and cirrhosis increased from two in 2016 to 39 in 2017. The number of deaths due to diseases of the heart remained stable, with 177 deaths in 2016 and 179 deaths in 2017. Deaths due to malignant neoplasms showed a slight decrease from 200 in 2016 to 196 in 2017.

These findings highlighted the persistence of cardiovascular diseases and malignant neoplasms as leading causes of death among individuals with chronic diseases, with some slight variations (increases and decreases) in specific categories such as chronic lower respiratory diseases and chronic liver disease and cirrhosis between the 2 years.

Table 2

Summary of Causes of Death Occurring September-October 2016 and 2017

	2016 Chronic disease			2017 Chronic disease			Total Chronic disease		
	No	Yes	Total	No	Yes	Total	No	Yes	Total
Acute myocardial infarction	0	11	11	0	11	11	0	22	22
All other and unspecified malignant neoplasms	0	1	1	0	1	1	0	2	2
All other diseases (residual)	0	86	86	0	93	93	0	179	179
All other forms of chronic ischemic heart disease	0	69	69	0	47	47	0	116	116
All other forms of heart disease	0	20	20	0	25	25	0	45	45
Alzheimer’s disease	0	25	25	0	28	28	0	53	53
Atherosclerotic cardiovascular disease, so described	0	6	6	0	4	4	0	10	10
Cerebrovascular diseases	0	37	37	0	42	42	0	79	79
Chronic liver disease and cirrhosis	0	2	2	0	39	39	0	2	2
Chronic lower respiratory diseases	0	37	37	0	0	0	0	76	76
Diabetes mellitus	0	2	2	0	2	2	0	4	4
Diseases of heart	0	177	177	0	179	179	0	356	356
Essential hypertension and hypertensive renal disease	0	0	0	0	2	2	0	2	2
Heart failure	0	6	6	0	7	7	0	13	13
Hypertensive heart disease	0	3	3	0	3	3	0	6	6
Ischemic heart diseases	0	121	121	0	96	96	0	217	217
Major cardiovascular diseases	0	231	231	0	235	235	0	466	466
Malignant neoplasm of breast	0	2	2	0	1	1	0	3	3
Malignant neoplasm of pancreas	0	1	1	0	0	0	0	1	1
Malignant neoplasm of prostate	0	2	2	0	0	0	0	2	2
Malignant neoplasms	0	200	200	0	196	196	0	396	396
Malignant neoplasms of colon, rectum, and anus	0	1	1	0	0	0	0	1	1
Malignant neoplasms of lymphoid, hematopoietic, and related tissue	0	2	2	0	2	2	0	4	4
Malignant neoplasms of trachea, bronchus, and lung	0	39	39	0	18	18	0	57	57
Nephritis, nephrotic syndrome, and nephrosis	0	0	0	0	1	1	0	1	1
Nontransport accidents	20	0	20	8	0	8	28	0	28
Other chronic lower respiratory diseases	0	39	39	0	36	36	0	75	75
Other forms of chronic ischemic heart disease	0	86	86	0	62	62	0	148	148
Other heart diseases	0	40	40	0	37	37	0	77	77
Parkinson’s disease	0	3	3	0	1	1	0	4	4
Pneumonia	1	0	1	0	0	0	0	1	1
Renal failure	0	0	0	0	1	1	1	0	1
Symptoms, signs, and abnormal clinical and laboratory findings, not elsewhere classified	0	5	5	0	6	6	0	11	11
Total	*69*	*1,254*	*1,323*	*24*	*1,175*	*1,199*	*93*	*2,429*	*2,522*

Summary of Cause of Death Data for 2016 and 2017 Categorized by Cardiovascular Diseases, Metabolic Disease, and Non-Cardiovascular Disease/Metabolic Causes

The summary of the data in Table 3 categorizes the causes of death among individuals for the years 2016 and 2017 into three categories: Cardiovascular Disease (CVD) related, Metabolic Disease related, and Non-CVD or Metabolic Disease related. In 2016, the most frequent cause of death within the CVD category was major cardiovascular diseases, accounting for 231 cases. In the metabolic category, diabetes mellitus was the most frequent cause, with two cases. For non-CVD/nonmetabolic diseases, malignant neoplasms were the leading cause of death, with 200 cases. The least frequent causes of death in the CVD category in 2016 were hypertensive heart disease, heart failure, and atherosclerotic cardiovascular disease, each with three cases. In the metabolic category, both chronic liver disease and cirrhosis and diabetes mellitus had two cases each. Among non-CVD/nonmetabolic diseases, influenza and pneumonia, malignant neoplasm of the colon, rectum, and anus, malignant neoplasm of the pancreas, and accidental poisoning and exposure to noxious substances each accounted for one case.

Table 3

CVD or Metabolic Disease Related Causes of Death

	2016				2017				Total			
	CVD	Metabolic	Non-CVD or non-metabolic	Total	CVD	Metabolic	Non-CVD or non-metabolic	Total	CVD	Metabolic	Non-CVD or non-metabolic	Total
Alzheimer disease	25	0	0	25	28	0	0	28	53	0	0	53
Cerebrovascular diseases	37	0	0	37	42	0	0	42	79	0	0	79
Chronic liver disease and cirrhosis	0	2	0	2	0	0	0	0	0	2	0	2
Chronic lower respiratory diseases	0	0	37	37	0	0	39	39	0	0	76	76
Diabetes mellitus	0	2	0	2	0	2	0	2	0	4	0	4
Diseases of heart	177	0	0	177	179	0	0	179	356	0	0	356
Essential hypertension and hypertensive renal disease	0	0	0	0	2	0	0	2	2	0	0	2
Influenza and pneumonia	0	0	1	1	0	0	1	1	0	0	2	2
Malignant neoplasms	0	0	200	200	0	0	196	196	0	0	396	396
Nephritis, nephrotic syndrome, and nephrosis	0	0	0	0	0	1	0	1	0	1	0	1
Parkinson disease	0	0	3	3	0	0	1	1	0	0	4	4
Acute myocardial infarction	11	0	0	11	11	0	0	11	22	0	0	22
All other and unspecified malignant neoplasms	0	0	1	1	0	0	1	1	0	0	2	2
All other diseases (Residual)	0	0	86	86	0	0	93	93	0	0	179	179
All other forms of chronic ischemic heart disease	69	0	0	69	47	0	0	47	116	0	0	116
All other forms of heart disease	20	0	0	20	25	0	0	25	45	0	0	45
Atherosclerotic cardiovascular disease, so described	6	0	0	6	4	0	0	4	10	0	0	10
Heart failure	6	0	0	6	7	0	0	7	13	0	0	13
Hypertensive heart disease	3	0	0	3	3	0	0	3	6	0	0	6
Ischemic heart diseases	121	0	0	121	96	0	0	96	217	0	0	217

	2016				2017				Total			
	CVD	Metabolic	Non-CVD or non-metabolic	Total	CVD	Metabolic	Non-CVD or non-metabolic	Total	CVD	Metabolic	Non-CVD or non-metabolic	Total
Major cardiovascular diseases	231	0	0	231	235	0	0	235	466	0	0	466
Malignant neoplasm of breast	0	0	2	2	0	0	1	1	0	0	3	3
Malignant neoplasm of pancreas	0	0	1	1	0	0	0	0	0	0	1	1
Malignant neoplasm of prostate	0	0	2	2	0	0	0	0	0	0	2	2
Malignant neoplasms of colon, rectum, and anus	0	0	1	1	0	0	0	0	0	0	1	1
Malignant neoplasms of lymphoid, hematopoietic	0	0	2	2	0	0	2	2	0	0	4	4
Malignant neoplasms of trachea, bronchus, and lung	0	0	39	39	0	0	18	18	0	0	57	57
Nontransport accidents	0	0	20	20	0	0	8	8	0	0	28	28
Other chronic lower respiratory diseases	0	0	39	39	0	0	36	36	0	0	75	75
Other forms of chronic ischemic heart disease	86	0	0	86	62	0	0	62	148	0	0	148
Other heart diseases	40	0	0	40	37	0	0	37	77	0	0	77
Renal failure	0	0	0	0	0	0	1	1	0	0	1	1
Total	*832*	*4*	*487*	*1323*	*778*	*3*	*418*	*1199*	*1610*	*7*	*905*	*2522*

In 2017, major cardiovascular diseases again were the most frequent cause of death within the CVD category, with 235 cases. Diabetes mellitus remained the most frequent cause in the metabolic category, with two cases. Malignant neoplasms continued to be the leading cause of death among non-CVD/nonmetabolic diseases, with 196 cases. The least frequent causes of death in the CVD category in 2017 were hypertensive heart disease, atherosclerotic cardiovascular disease, and heart failure, each with three cases. In the metabolic category, diabetes mellitus accounted for two cases. For non-CVD/nonmetabolic diseases, renal failure was the least frequent cause of death, with one case.

Overall, combining the data from both years, the most frequent causes of death were major cardiovascular diseases (466 cases) in the CVD category, diabetes mellitus (4 cases) in the metabolic category, and malignant neoplasms (396 cases) in the non-CVD/nonmetabolic category. The least frequent causes of death were hypertensive heart disease and atherosclerotic cardiovascular disease, each with six cases in the CVD category; chronic liver disease and cirrhosis, with two cases in the metabolic category; and renal failure, with 1 case in the non-CVD/nonmetabolic category.

When comparing the two years, the total number of CVD-related deaths decreased slightly from 832 in 2016 to 778 in 2017. Major cardiovascular diseases remained the most frequent cause within this category, increasing slightly from 231 cases in 2016 to 235 cases in 2017. Metabolic disease-related deaths remained very low, with a slight decrease from 4 in 2016 to 3 in 2017, and diabetes mellitus was consistently the most common cause within this category, with 2 cases each year. Non-

CVD/nonmetabolic disease-related deaths decreased from 487 in 2016 to 418 in 2017, with malignant neoplasms remaining the most frequent cause within this category, decreasing slightly from 200 cases in 2016 to 196 cases in 2017. Overall, there was a decrease in total deaths across all categories from 2016 to 2017, from 1323 to 1199, with the most significant reduction seen in non-CVD/nonmetabolic disease-related deaths. Major cardiovascular diseases consistently represented the highest number of deaths in both years, highlighting the prominence of CVD as a leading cause of death.

Assumption Analysis

The assumption analyses conducted ensured the validity and reliability of the statistical models used to examine the relationship between Hurricane Irma exposure and chronic disease-related mortality. The Box-Tidwell procedure confirmed no significant violations of the linearity in the logit assumption for continuous predictors. Variance inflation factors (VIFs) were calculated to assess multicollinearity among independent variables, and all values were within acceptable thresholds (less than 10), indicating no multicollinearity issues. The independence of observations was verified, ensuring that each observation in the dataset was independent. Residual analysis and Cook's Distance were used to identify potential outliers or influential data points, and no significant issues were detected that could affect model stability. Additionally, the sample size was evaluated and determined to be sufficient for the logistic regression models, given the number of predictors and covariates included. These analyses performed below confirmed that the models met all key assumptions, thereby enhancing the robustness and reliability of the study's findings.

To address the potential issue of multicollinearity among interaction terms involving demographic variables and the study period (Year), several variables were centered. This process involved subtracting the mean of each variable from its individual observations. The variables that underwent centering included gender, Hispanic origin, age groups, poverty level rate, and rural–urban continuum code. By centering these variables, we aimed to reduce the correlation between the interaction terms and the main effects, thereby improving the stability and interpretability of the regression model. The centered interaction terms were subsequently employed to investigate the second research question (RQ2), which focused on the modification effects of demographic characteristics on the association between chronic illness and mortality post-Hurricane Irma. By examining these interactions, we sought to identify specific subgroups that might have been disproportionately affected by the disaster.

The logit's linearity principle asserts that each continuous independent variable has a linear relationship with the log odds (logit) of the dependent variable occurring (Schober & Vetter, 2021). This is the most crucial assumption, and the linearity assumption states that every one-unit increment in a continuous independent variable results in a constant increase in the value of the dependent variable's log odds. For example, in this research, for every one-percentage increase in the estimated percentage of people in poverty, the log odds (logit) of mortality due to chronic illnesses should be constant (see Table 4). The Box-Tidwell test was used to evaluate the assumption of linearity, specifically if the relationship between the continuous independent variable (estimated percent of people in poverty in 2021) and the log odds of the dependent variable (mortality) was linear. This was accomplished by multiplying the continuous independent variable (poverty) by its natural logarithm, resulting in an interaction term. A logistic regression model was run, which included the original continuous variable, its interaction term, and the other independent variables (race, gender, age group and rural–urban continuum code). The model was evaluated to determine the coefficient of the interaction term for the continuous variable. If the coefficient is significantly different from zero, it means that the relationship between the variable and log odds is not linear. In the study conducted, the interaction term was not statistically significant ($B = -2.326$, $p = .905$), indicating that the linearity assumption was not violated.

Table 4

Variables in the Equation for the Box-Tidwell Linearity Test

	B	S.E.	Wald	df	P
Hispanic Origin					
Not Hispanic or Latino			Reference		
Hispanic or Latino	.292	.590	.244	1	.621
Race					
White			Reference		
Black or African American	18.348	3923.081	.000	1	.996
Age Groups					
85 & Above			Reference		
Below 85	-.172	.254	.454	1	.500
Age Group X Year	1.792	.541	10.979	1	.001
Gender					
Female			Reference		
Male	-.286	.244	1.379	1	.240
Gender X Year	.594	.507	1.373	1	.241
Estimated % of People in Poverty	37.376	92.387	.164	1	.686
Estimated % of People in Poverty By Logit Estimated % of People in Poverty	*-7.485*	*20.504*	*.133*	*1*	*.715*
Logit Estimated % of People in Poverty	-135.051	249.823	.292	1	.589
Rural–Urban Continuum Code	1.049	.301	12.167	1	.000
Rural–Urban Continuum Code X Year	-.659	.587	1.260	1	.262
Constant	92.502	119.965	.595	1	.441

Note. “X Year” implies the interaction terms of Year with corresponding variables.

The second assumption examined was that the data should not exhibit multicollinearity, which occurs when two or more independent variables are significantly correlated (Kim, 2019). The Variance Inflation Factor (VIF) was used to test the assumption that the data did not show multicollinearity, implying that the two independent variables were unrelated. According to the VIF, multicollinearity increases the variance of the predicted regression coefficient for an independent variable (Kim, 2019). A VIF score of 1 implies no multicollinearity between the variables, but a value of 10 or above indicates strong multicollinearity, and the assumption is violated (Kim, 2019). The study's VIF for all the independent variables were within the allowed ranges, showing that this assumption was not violated (see Table ***5***).

Table 5

Collinearity Statistics

	Tolerance	VIF
Hispanic Origin	.825	1.213
Hispanic Origin X Year	.589	1.698
Race	.920	1.087
Age Groups	.968	1.033
Age Groups X Year	.976	1.024
Gender	.971	1.030
Gender X Year	.968	1.033
Estimated % of People in Poverty	.871	1.149
Estimated % of People in Poverty X Year	.391	2.561
Rural–Urban Continuum Code	.876	1.141
Rural–Urban Continuum Code X Year	.589	1.697

Note. “X Year” implies the interaction terms of Year with corresponding variables.

The third and last assumption was that there would be no significant outliers. Outliers are detected using casewise diagnostics, resulting in a list table displaying cases with standardized residuals larger than ±2.5 standard deviations (Jones, 2019). Table 6 displays many cases with standardized residuals greater than ±2.5. Cook's distance was utilized in conjunction with casewise diagnostics to see if outliers had a significant impact on the logistic regression. Cook's distance can be used in logistic regression to find influential observations with a significant impact on the model's estimated coefficients. Cook's distance measures how much the model's predictions differ when a given observation is removed from the analysis (Baba et al., 2021). The Cook's distance in the logistic regression model ranged from .000 to .195, which fell short of the problematic threshold of 1.0 or higher (Baba et al., 2021). This indicated that, despite the presence of outliers in the data, the assumption had not been violated because their impact on the study was insignificant.

Table 6

Cases With Studentized Residuals > 2.5

Case	Selected Status[a]	Observed	Predicted	Predicted Group	Temporary Variable	
		Chronic Disease			Resid	ZResid
46	S	N**	.936	Y	-.936	-3.822
88	S	N**	.937	Y	-.937	-3.87
150	S	N**	.95	Y	-.95	-4.346
165	S	N**	.95	Y	-.95	-4.346
176	S	N**	.989	Y	-.989	-9.534
184	S	N**	.951	Y	-.951	-4.426
195	S	N**	.985	Y	-.985	-8.016
197	S	N**	.936	Y	-.936	-3.822
244	S	N**	.988	Y	-.988	-9.168
250	S	N**	.988	Y	-.988	-9.168
251	S	N**	.937	Y	-.937	-3.87
253	S	N**	.988	Y	-.988	-9.168
282	S	N**	.962	Y	-.962	-5.026
302	S	N**	.936	Y	-.936	-3.822
306	S	N**	.985	Y	-.985	-8.014
331	S	N**	.988	Y	-.988	-9.168
343	S	N**	.962	Y	-.962	-5.026
423	S	N**	.967	Y	-.967	-5.413
579	S	N**	.967	Y	-.967	-5.413
584	S	N**	.967	Y	-.967	-5.413
612	S	N**	.936	Y	-.936	-3.822
615	S	N**	.989	Y	-.989	-9.534
667	S	N**	.888	Y	-.888	-2.822
772	S	N**	.964	Y	-.964	-5.205
793	S	N**	.94	Y	-.94	-3.948
801	S	N**	.909	Y	-.909	-3.17
829	S	N**	.886	Y	-.886	-2.787
834	S	N**	.909	Y	-.909	-3.17
846	S	N**	.972	Y	-.972	-5.846
848	S	N**	.931	Y	-.931	-3.666
849	S	N**	.909	Y	-.909	-3.17
852	S	N**	.909	Y	-.909	-3.17
853	S	N**	.931	Y	-.931	-3.666
876	S	N**	.909	Y	-.909	-3.17
887	S	N**	.888	Y	-.888	-2.822
900	S	N**	.886	Y	-.886	-2.787

Case	Selected Status[a]	Observed	Predicted	Predicted Group	Temporary Variable	
		Chronic Disease			Resid	ZResid
903	S	N**	.909	Y	-.909	-3.17
906	S	N**	.972	Y	-.972	-5.845
917	S	N**	.94	Y	-.94	-3.948
935	S	N**	.98	Y	-.98	-6.954
945	S	N**	.927	Y	-.927	-3.573
955	S	N**	.929	Y	-.929	-3.625
963	S	N**	.929	Y	-.929	-3.625
1029	S	N**	.931	Y	-.931	-3.666
1120	S	N**	.929	Y	-.929	-3.625
1135	S	N**	.909	Y	-.909	-3.17
1157	S	N**	.909	Y	-.909	-3.17
1170	S	N**	.888	Y	-.888	-2.822
1181	S	N**	.888	Y	-.888	-2.822
1185	S	N**	.909	Y	-.909	-3.17
1203	S	N**	.888	Y	-.888	-2.822
1220	S	N**	.888	Y	-.888	-2.822
1221	S	N**	.909	Y	-.909	-3.17
1227	S	N**	.888	Y	-.888	-2.822
1248	S	N**	.886	Y	-.886	-2.787
1260	S	N**	.888	Y	-.888	-2.822
1275	S	N**	.909	Y	-.909	-3.169
1299	S	N**	.888	Y	-.888	-2.822
1306	S	N**	.888	Y	-.888	-2.822
1313	S	N**	.964	Y	-.964	-5.205
1330	S	N**	.981	Y	-.981	-7.151
1365	S	N**	.94	Y	-.94	-3.948
1532	S	N**	.963	Y	-.963	-5.088
1540	S	N**	.978	Y	-.978	-6.691
1562	S	N**	.984	Y	-.984	-7.915
1590	S	N**	.95	Y	-.95	-4.339
1618	S	N**	.943	Y	-.943	-4.078
1631	S	N**	.984	Y	-.984	-7.915
1668	S	N**	.95	Y	-.95	-4.339
1762	S	N**	.95	Y	-.95	-4.339
1772	S	N**	.957	Y	-.957	-4.719
1787	S	N**	.954	Y	-.954	-4.562
1892	S	N**	.954	Y	-.954	-4.562
1947	S	N**	.977	Y	-.977	-6.458
1974	S	N**	.977	Y	-.977	-6.458

Case	Selected Status[a]	Observed	Predicted	Predicted Group	Temporary Variable	
		Chronic Disease			Resid	ZResid
2263	S	N**	.963	Y	-.963	-5.088
2389	S	N**	.941	Y	-.941	-3.999
2496	S	N**	.963	Y	-.963	-5.088
2540	S	N**	.954	Y	-.954	-4.562
2642	S	N**	.941	Y	-.941	-3.999
2664	S	N**	.943	Y	-.943	-4.078
2755	S	N**	.963	Y	-.963	-5.088
2788	S	N**	.943	Y	-.943	-4.078

[a] S = Selected, U = Unselected cases, and ** = Misclassified cases.

Statistical Analysis

The study had two research questions. The dependent variable was deaths occurring among chronically ill individuals. The independent variables included being exposed to Hurricane Irma September and October 2017. A comparable time period in 2016 was used to compare the probability of deaths from a hurricane between September and October. Demographic characteristics of age, gender, race, education, rural urban continuum code, and estimated percentage of people in poverty were used as covariates. Bivariate analysis was conducted to answer RQ1. Multivariable logistic regression was used to control the effect confounding in RQ1. To answer RQ 2, multivariable logistic regression, with an insertion of a product term in the model, was used to examine effect modification. The findings of the model are presented here.

Research Question 1

The first research question examined if there was an association between death occurring among chronically ill individuals (dependent variable) and exposure to Hurricane Irma (dependent variable). Binary logistic regression analyses were conducted to determine if there was an association between deaths occurring 2 months after Irma's landfall and those occurring during a comparable time period during the prior year (represented as 2016 and 2017). In both bivariate and multivariate analyses, the year of death was significantly associated with mortality following Hurricane Irma (See Table 7). In bivariate analysis, the odds of death between September and October 2017 were 2.694 times higher than the comparable time-period in 2016 (95% CI [1.682, 4.316], $p < .001$). This association remained statistically significant in multivariate analyses, where the odds of death in 2017 were 2.240 times higher than the same time-period in 2016 (95% CI [1.342, 3.739], $p = .002$), even after adjusting for demographic factors. The findings therefore led to the rejection of the null hypothesis and acceptance of the alternative hypothesis of an association between recorded deaths and Irma's landfall among chronically ill individuals.

Research Question 2

The second and research question asked whether deaths among chronically ill individuals and exposure to Hurricane Irma was modified by demographic characteristics including age, sex, race, Hispanic ethnicity, poverty level rate, and rural–urban continuum code, and educational attainment rate. Two approaches were used in this study: multivariable analyses (Table 7) and effect modification (interaction – Table 8) analyses to examine if the mortality rate 2 months after Hurricane Irma's landfall among individuals who had chronic health conditions was influenced by predetermined demographic characteristics.

Multivariate Analysis

Individual bivariate analysis was used to examine whether there was an independent association between each demographic risk factor and mortality. The bivariate analysis and multivariate results are presented below., followed by an analysis of effect modification.

In the examining the association between of sex and the odds of death 2 months after Hurricane Irma's landfall the odds ratio (OR) for male compared to female was 1.351 with a 95% confidence interval (CI) of .519 to 3.517. This indicated that men were 1.35 times more likely to experience recorded deaths 2 months after Hurricane Irma compared to women, but the CI included 1, meaning the result was not statistically significant (p = .537). In multivariate analysis, the OR for males versus females was .776 (95% CI: .494, 1.218), which was not statistically significant (p =.270). Additionally, the analysis found age was also not statistically significantly associated with mortality among individuals chronically ill, 2 months after Hurricane Irma's landfall. Individuals under the age of 85 had lower odds of death compared to those aged 85 and older in both bivariate (OR = .736, 95% CI [.480, 1.129], p = .160).

Hispanic individuals had slightly higher odds of death (OR = 1.019, 95% CI [.506, 2.052], p = .959) compared to those not Hispanic or Latino, but this was not statistically significant. Poverty level, measured as the estimated percentage of people living in poverty, showed no significant association with mortality in either analysis. The bivariate analysis indicated an OR of 1.056 (95% CI [.958, 1.164], p = .275). In bivariate analysis, the OR for urban influence code (i.e., the influence of urban vs. rural areas) was

2.961 with a 95% CI of 1.759 to 4.984, and in the multivariate analysis, the OR was 3.218 with a 95% CI of 1.889 to 5.483. Both analyses showed that people living in more urban-influenced areas were significantly more likely to experience recorded deaths following the hurricane. The odds of recorded deaths were about 3.2 times higher in areas with a stronger urban influence, with a highly significant p-value of <. 001 in both analyses.

Lastly, education level yielded highly variable and inflated odds ratios, especially for individuals who did not complete high school (OR = 1.06E+04, 95% CI [.202, 5.52E+08], p = .095) or who completed some college (OR = 3.63E+06, 95% CI [8.675, 1.52E+12], p = .022), suggesting potential data issues. Despite these large odds ratios, education level did not show a significant association with mortality across the categories analyzed.

Table 7

The Association Between Chronic Disease-Related Deaths and Recorded Deaths 2 Months After Hurricane Irma's Landfall in Affected Regions in Florida Modified by Demographic Characteristics

	Univariate Analysis						Multivariate Analysis					
		95% *CI*						95% *CI*				
	OR	Lower	Upper	SE	Wald	*p*	OR	Lower	Upper	SE	Wald	*p*
Year												
Sept-Oct 2016	Reference						Reference					
Sept-Oct 2017	2.694	1.682	4.316	.240	16.988	.000	2.240	1.342	3.739	.261	9.515	.002
Hispanic Origin												
Not Hispanic or Latino	Reference						Reference					
Hispanic or Latino	1.019	.506	2.052	.357	.003	.959	1.206	.541	2.688	.409	.209	.648
Race												
White	Reference											
Black or African American	6.47E+07	.000	.	3867.570	.000	.996						
Age in Years												
85 & Above	Reference						Reference					
Below 85	.736	.480	1.129	.218	1.972	.160	.825	.519	1.311	.236	.663	.415
Estimated % of People in Poverty	1.056	.958	1.164	.050	1.192	.275	1.087	.967	1.223	.060	1.951	.163
Education Level												
Completing College	Reference											
Not Completing High School	1.06E+04	.202	5.52E+08	5.543	2.793	.095						
Completing High School	59.349	.008	4.61E+05	4.570	.798	.372						
Completing Some College	3.63E+06	8.675	1.52E+12	6.605	5.231	.022						
Urban Influence Code	2.961	1.759	4.984	.266	16.691	.000	3.278	1.864	5.763	.288	16.991	.000
Gender												
Female	Reference											
Male	.666	.429	1.034	.224	3.285	.070	.776	.494	1.218	.230	1.218	.270

Note. OR = Odds Ratio; CI = Confidence Interval; SE = Standard Error; Wald = Wald Statistics; *p* = Significance level at .05.

Effect Modification (Interaction)

Five models, one for each for the demographic variables, were analyzed separately. Several variables were centered to address the possible issue of multicollinearity among interaction terms including demographic variables and the study period (Year). To do this, the mean of each variable was deducted from each observation separately. Sex, Hispanic origin, age groups, poverty level rate, and rural–urban continuum code were among the characteristics that were examined. Our goal in centering these variables was to improve the stability and interpretability of the regression model by decreasing the correlation between the main effects and the interaction terms. The second research question (RQ2), which examined the modifying effects of demographic variables on the relationship between chronic illness and death following Hurricane Irma, was then examined using the centered interaction terms. By examining these interactions, we sought to identify specific subgroups that may be disproportionately affected by the disaster (see Table 8).

In Model 1, that included Hispanic origin and year in the model, the main effects showed that individuals in 2017 had 13.674 times higher odds of chronic disease-related deaths compared to those in 2016 (95% CI: .000 to 5.27E+304, p = .994). This was not statistically significant based on the confidence interval that included 1. Hispanic individuals had 2.88E+03 times higher odds of chronic disease related=deaths compared to non-Hispanic individuals p = .996). The 95% confidence interval was extremely large, highlighting the non-significant findings. The interaction between Hispanic origin and year was non-significant (p = .990), suggesting that the effect of being Hispanic on chronic disease-related deaths in the 2 months following Hurricane Irma's landfall was not different between the two years.

Model 2 included age and year, and the results showed that individuals in 2017 had 3.175 times higher odds of chronic disease-related deaths compared to those in 2016 (95% CI: 1.757 to 5.739, $p < .001$). Individuals aged 85 and above had 1.221 times higher odds of chronic disease-related death compared to those below 85 (95% CI: 0.700 to 2.128, $p = .482$), a not significant finding. The interaction between age and year was significant ($p < .001$), indicating that the effect of age on chronic disease-related death changed over time.

Model 3 included poverty level and year in the binary logistic regression and the results indicated that individuals living in Poverty, measured as the estimated percentage of people living in (at or below) poverty, in 2017 had 2.860 times higher odds of chronic disease diagnosis compared to those in 2016 (95% CI: 1.758 to 4.652, $p < .001$). The percentage of people in poverty was associated with a 1.131 times higher odds of chronic disease diagnosis (95% CI: 1.013 to 1.263, $p = .028$). The interaction between poverty level and year was significant ($p < .001$), suggesting that the effect of poverty on chronic disease-related death did change significantly over time, between 2016 and 2017.

Model 4 included urban influence code and year, the main effect results indicated that individuals in 2017 had 2.337 times higher odds of chronic disease-related death compared to those in 2016 (95% CI: 1.323 to 4.128, $p = .003$). Individuals living in more urban areas had 2.721 times higher odds of chronic disease-related death (95% CI: 1.568 to 4.723, $p = .000$). In terms of interaction effect, the interaction between urban influence code and year was not significant (*p* = .377), indicating that the effect of urbanicity on chronic disease-related deaths did not change significantly over time.

Model 5 included sex and year and the findings showed that individuals in 2017 had 2.393 times higher odds of chronic disease-related deaths compared to those in 2016 (95% CI: 1.392 to 4.114, *p* = .002). Males had 0.910 times the odds of chronic disease-related deaths compared to females (95% CI: 0.536 to 1.547, *p* = .728). The interaction between gender and year was not significant (p = .181), suggesting that the effect of sex on chronic disease-related deaths did not change significantly over time.

The last Model 6 included race and year. There were two races for comparison: Whites and Black or African American. This effect modification was largely non-significant, as shown by the large p-values in the model. Compared to 2016, those individuals sampled in 2017 had 2.595 times the odd of chronic disease-related deaths, (95% CI: .000 to --, p = .996). Black or African Americans had a 5.839E+7 odds ratio compared to Whites and this was not statistically significant (p = .996). The interaction between race and year was also not significant (p = 1.000), suggesting that the effect of race on chronic disease-related deaths did not change significantly over time.

Table 8

The Impact of Demographic Factors on Chronic Disease-Related Deaths Recorded 2 Months After the Hurricane's Landfall in Florida's Affected Regions

				95% CI				
			OR	Lower	Upper	SE	Wald	*p*
Model 1								
	Year							
		Sept-Oct 2016			Reference			
		Sept-Oct 2017	13.674	.000	5.27E+304	356.656	.000	.994
	Hispanic Origin							
		Not Hispanic or Latino			Reference			
		Hispanic or Latino	2.88E+03	.000	.	1676.281	.000	.996
	Hispanic Origin X Year		5.66E+07	.000	.	3566.554	.000	.996
	Constant		8.225			167.628	.000	.990
Model 2								
	Year							
		Sept-Oct 2016			Reference			
		Sept-Oct 2017	3.175	1.757	5.739	.302	14.639	.000
	Age in Years							
		85 & Above			Reference			
		Below 85	1.221	.700	2.128	.283	.495	.482
	Age Group X Year		8.331	2.654	26.155	.584	13.190	.000
	Constant		18.174			.232	155.983	.000
Model 3								
	Year							
		Sept-Oct 2016			Reference			
		Sept-Oct 2017	2.860	1.758	4.652	.248	17.910	.000
	Estimated % of People in Poverty		1.131	1.013	1.263	.056	4.823	.028
	Estimated % of People in Poverty X Year		1.000	1.000	1.000	.000	14.025	.000
	Constant		4.037			.718	3.782	.052
Model 4								
	Year							
		Sept-Oct 2016			Reference			
		Sept-Oct 2017	2.337	1.323	4.128	.290	8.545	.003
	Urban Influence Code		2.721	1.568	4.723	.281	12.666	.000
	Urban Influence Code X Year		.602	.195	1.855	.574	.781	.377
	Constant		5.286			.390	18.195	.000
Model 5								
	Year							
		Sept-Oct 2016			Reference			
		Sept-Oct 2017	2.393	1.392	4.114	.276	9.965	.002
	Gender							
		Female			Reference			
		Male	.910	.536	1.547	.271	.121	.728
	Gender X Year		2.108	.706	6.295	.558	1.786	.181
	Constant		19.938			.205	213.952	.000
Model 6								
	Year							
		Sept-Oct 2016			Reference			
		Sept-Oct 2017	2.595	.000	1.542E+26 4	309.884	.000	.998
	Gender							
		Female			Reference			
		Male	5.839E+7	.000	--	3867.609	.000	.996
	Gender X Year		2.108	.370	.000	--	7747.106	.000
	Constant		19.938	17.675			145.646	.000

Note. OR = Odds Ratio; CI = Confidence Interval; SE = Standard Error; Wald = Wald Statistics; p = Significance level at .05; "X Year" implies the interaction terms of Year with corresponding variables.

Summary

This study sought to investigate the relationship between chronic disease diagnoses and death within 2 months of Hurricane Irma's impact in Florida, with a particular emphasis on demographic variables and preexisting medical conditions. Research question 1 (RQ1) sought to determine if there was an association between chronic disease-related deaths and death within 2 months following Hurricane Irma’s landfall. The results from both univariate and multivariate binary logistic regression analyses revealed a significant association between the year of death and mortality, with the odds of death in 2017 (post-Irma) being significantly higher than in 2016. This led to the rejection of the null hypothesis (H1o) and the acceptance of the alternative hypothesis (H1a), confirming that there was a significant association between chronic disease-related deaths and mortality following Hurricane Irma.

Research question 2 (RQ2) examined whether the association between deaths among chronically ill individuals and exposure to Hurricane Irma 2 months landfall was modified by demographic characteristics including age, sex, race, Hispanic ethnicity, poverty level rate, and rural–urban continuum code, and educational attainment rate. The multivariate analysis showed no significant modification of the association by these demographic factors. Age, sex, race, Hispanic ethnicity, and poverty level were not significantly associated with mortality, and education level yielded inconsistent results, possibly due to data issues. Persons living in more urban-influenced areas were significantly more likely to experience recorded deaths following the hurricane. In the effect modification (interaction) analysis two demographic factors were identified that modified this association: Age and estimated % of individuals in poverty. Older individuals, especially those aged 85 and above, were more vulnerable to the increased risk of mortality associated with the hurricane. Poverty was associated with a slightly increased risk of chronic disease-related mortality. Other variables like Hispanic origin, urban influence code, and sex did not significantly modify the association between Hurricane Irma and chronic disease-related mortality.

The results presented in this chapter provide empirical evidence of the heightened mortality risks faced by chronically ill individuals during natural disasters. The significant associations between Hurricane Irma exposure, certain demographic factors, and mortality underscore the vulnerabilities of older adults, individuals living in more urban areas, and economically disadvantaged populations.

These findings form the foundation for the discussion and implications presented in Chapter 5. The next chapter will interpret these results in the context of existing literature, explore their implications for disaster preparedness and public health interventions, and offer recommendations for future research. By addressing the systemic vulnerabilities identified in this study, Chapter 5 will provide actionable strategies to mitigate the health impacts of natural disasters on chronically ill populations.

Chapter 5: Discussion and Conclusions

Introduction

The purpose of this quantitative cross-sectional study was to examine the association between chronic disease-related deaths and mortality within 2 months following Hurricane Irma's landfall in Florida. I also aimed to investigate whether this association was modified by demographic characteristics, including age, sex, race, Hispanic ethnicity, poverty level, rural–urban continuum, and educational attainment rate. Hurricane Irma provided a critical case study for assessing the impact of severe weather events on vulnerable populations, particularly those with chronic illnesses. The study employed the SEM as its theoretical framework, emphasizing the interplay between individual, community, and systemic factors in shaping health outcomes during natural disasters.

The results revealed a significant association between Hurricane Irma exposure and mortality among individuals with chronic diseases, confirming that the hurricane substantially increased mortality risks. Additionally, the findings identified that age (85+ years), rural–urban continuum, and poverty level were key demographic factors that moderated this relationship. Conversely, other demographic variables, such as sex, race, and Hispanic ethnicity, did not significantly influence the association. These insights contribute to understanding how natural disasters exacerbate health disparities among at-risk populations and underscore the importance of targeted interventions for disaster preparedness and response.

The discussion that follows interprets these findings in the context of existing literature, explores their implications for public health practice and policy, and provides recommendations for future research. This chapter builds on the study's results to offer actionable strategies aimed at mitigating the health impacts of natural disasters on chronically ill populations.

Interpretation of the Findings

The findings from this study provide critical insights into the association between chronic disease-related deaths and Hurricane Irma exposure, with an emphasis on how demographic factors influence these relationships. This section interprets the results in the context of existing literature and the SEM, ensuring that the interpretations align with the scope and data of the study.

Confirmation, Contradiction, and Extension of Existing Literature

Relative to the first research question, the results indicated that there were significant differences in chronic disease–related mortality across age groups for each year and when pooled across both years. These findings contrasted with research outcomes by Kim et al. (2023), who found that there was no significant difference in mortality based on age, and overall mortality among people aged 72–73 ranged from 4.3% to 6.4%. The finding that there was an increase in mortality rates among individuals aged 85 and above aligned with findings by Chang et al. (2022), who observed that older adults with cardiovascular health issues faced far more hazards due to hurricanes. This finding also supported research results by Shih et al. (2020), who established that there was an increase in mortality among the elderly after Typhoon Morakot. The results of the current study suggested that older people are more vulnerable to the effects of hurricanes than younger people, leading to more deaths among the elderly.

Further, relative to the first research question, the results indicated that the presence of diabetes and cardiovascular conditions, as well as other non-CVD and metabolic diseases, increased mortality rates after Hurricane Irma. This finding corroborated research findings by Ghazanchaei et al. (2021), who found that emergency situations in times of natural disasters disrupt the continuous management of chronic illnesses and augment the risk of acute chronic illness exacerbations. The current study's findings also supported the research findings of a systematic review by Ngaruiya et al. (2022), which established the impact of natural disasters on chronic illnesses due to barriers to healthcare access, which led to mortality and an exacerbation of chronic illnesses. Having chronic illnesses can lead to higher chances of death after a natural calamity.

This study's result relative to the first research question also corroborated the findings by Yousuf et al. (2020), who noted that natural disasters exacerbated morbidity and mortality rates among cardiovascular disease patients. The current study's findings supported research findings by Burrows et al. (2023) and Kim et al. (2023), who found that mortality rates ranged between 4.3% and 6.4% post-tropical cyclones because people with cardiovascular diseases were not going to hospitals due to the damages caused by storms. Research findings by Andrade et al. (2022) indicated an increased morbidity risk for individuals with cardiovascular diseases and an elevated likelihood of fatalities due to a lack of solid infrastructure during and after high-level emergencies, which agreed with the current study’s findings. Chronic diseases can reduce the survival chances of patients following a natural disaster such as a hurricane.

Research outcomes by McCann and Szaflarski (2023) that identified the role of Hurricane Mathew’s damage in increasing cardiovascular disease mortality and morbidity aligned with the current study’s findings relative to the first research question. The current study’s findings corroborated research by Parks et al. (2022), who concluded that every additional cyclone day per month was linked with higher death rates in the months after a cyclone. Research findings by Parks et al. (2023) that identified cardiovascular diseases as some of the immediate causes of death after a cyclone also agreed with the current study’s results. The current study’s findings also aligned with research findings by Shih et al. (2020), who established that there was an increase in mortality among the elderly after Typhoon Morakot. Research findings by Huang et al. (2021) showed that mortality was associated with cyclone exposures, which agreed with the current study’s findings—Chronic illnesses (in the aggregate) increase the risk of mortality among patients following a natural calamity.

The findings for the first research question also indicated that major cardiovascular diseases were the most frequent causes of death within the CVD category. The number of deaths due to major cardiovascular diseases remained relatively consistent between the 2 years, with 231 deaths in 2016 and 235 deaths in 2017. There was a decrease in the number of CVD-related deaths between 2016 (832) and 2017 (778). Non-CVD/non-metabolic disease–related deaths also decreased from 487 in 2016 to 418 in 2017. These results did not support research outcomes by Burrows et al. (2023), who reported no significant changes in risk factors associated with CVDs during a 10-day tropical cyclone period. The current study's outcomes did not support study findings by McCann and Szaflarski (2023), who found that CVD mortality increased in both low- and high-damaged counties during Hurricane Matthew. Research findings by Parks et al. (2022) indicated that there were higher death rates in the months following a cyclone for several causes of death, including CVDs, which disagreed with the current investigation's results. The current study's findings highlighted the prominence of CVD as a leading cause of death during Hurricane Irma. Still, the results differed from existing research on the significance of CVD in mortality during natural calamities. This contradiction can be attributed to previous studies having focused on demographic variables that were not included in the current research or the current study including variables that were not included in earlier studies, including poverty, urbanization, and education.

The outcomes obtained for the first research question indicated that diabetes mellitus was the most frequent cause of death in the metabolic category during Hurricane Irma, with two deaths each in 2016 and 2017. This finding aligned with research results by Joshipura et al. (2022), who underscored the role of diabetes in health-related morbidity during hurricanes. The current research findings suggested that diabetes mellitus was an important chronic condition that contributed to mortality during times of natural disasters as was the case with Hurricane Irma.

Relative to the second research question, the results of the multivariate analysis revealed that the demographic factors age, sex, race, Hispanic ethnicity, and poverty level did not significantly alter the association between chronic disease diagnosis and death, while living in urban-influenced areas was linked to a significantly increased chance of death following a hurricane. The effect modification analysis showed that the demographic characteristics of Hispanic origin, urban influence, and sex did not significantly alter the relationship between chronic disease diagnosis and mortality while age and estimated percentage of individuals living in poverty modified the association. The findings partially contrasted with research outcomes by De Vita et al. (2024), who established that the impact of hurricanes and extreme weather conditions was dependent on demographic factors. The outcome also contrasted with the findings by Mattei et al. (2022) that demographics played a role in how crises impacted cardiovascular health among people in times of natural disasters. Research findings by Shih et al. (2020) that noted elderly demographic aspects as key pointers of the health status of patients with cardiovascular diseases before a typhoon contradicted the current study’s findings. However, the results showing that living in urban-influenced areas had a significantly increased chance of death following a hurricane while age and estimated percentage of individuals living in poverty modified the association between death and exposure to Hurricane Irma corroborated the findings of De Vita et al., Mattei et al., and Shih et al. This partial corroboration of the findings of the current study from existing literature can be attributed to the unique factors affecting different geographic regions and demographic populations exposed to hurricanes. For instance, the population and health dynamics in cities versus rural areas could be different, which might lead to different outcomes posthurricane (Yousuf et al., 2020).

While the current study did not analyze morbidity, only mortality associated with morbidity, the study brought to light potential questions about the association with research outcomes by Ngaruiya et al. (2022), who noted that a lack of education was a direct barrier to healthcare access, which contributed to morbidity. Research findings by Yamaoka-Tojo and Tojo (2024) indicated that patient education was one of the strategies that could prevent or reduce mortality from hurricanes, which disagreed with the current study's outcomes. Understanding the variables, their individual association, and therefore generalizability in other existing studies could help clarify the exact nature and context that education requires at an individual level to prevent or reduce mortality in a population. However, the findings in this study could also be attributed to the relatively low prevalence rates of poverty (13.0%) and education (where 10.6% of respondents had not completed high school) in the sample population, which might have minimized the impact of the two factors (education and poverty) on mortality.

Theoretical Framework

Using the SEM as the theoretical framework, this study contextualized its findings within the multilayered factors influencing health outcomes during disasters. At the individual level, chronic disease diagnoses and advanced age emerged as critical vulnerabilities, consistent with the SEM's emphasis on personal attributes as key determinants of health outcomes (Kapucu et al., 2021; Salmon et al., 2020). At the community level, the significant association between urban residency and increased mortality risks highlights the role of environmental and infrastructural disparities, emphasizing the need for disaster planning that addresses urban density challenges and resource allocation (Burrows et al., 2023). At the policy level, the interaction between poverty and mortality risk underscores the importance of systemic interventions to address economic disparities. This finding aligns with the SEM's focus on public policy as a critical determinant of health outcomes, reinforcing the need for policies that reduce inequities in resource distribution and access to healthcare (Hassan & Evans, 2023; Martinez-Lozano et al., 2023). Collectively, these findings highlight the utility of SEM in understanding the interconnected factors that influence disaster-related health outcomes and inform targeted interventions at multiple levels.

In conclusion, the study demonstrates that Hurricane Irma's impact on health and mortality among chronically ill populations was shaped by an interplay of factors across all levels of the SEM. Addressing these multilevel influences requires a coordinated approach, including strengthening disaster preparedness, ensuring continuity of care during disasters, and implementing equitable public policies that prioritize the needs of vulnerable populations. This interpretation aligns with both the study’s findings and broader literature, offering critical insights for improving disaster response and mitigating health risks for at-risk groups.

Limitations of the Study

This study faced several limitations regarding generalizability, validity, and reliability, which should be considered when interpreting its findings. First, the geographic focus on Florida inherently limits the generalizability of the results to other regions or populations affected by natural disasters. The demographic and socioeconomic characteristics unique to Florida may not reflect conditions in other states or regions, reducing the applicability of the findings beyond the study area. Additionally, the use of purposive sampling to select data from the NVSS introduced potential sampling bias. While the sampling strategy was tailored to address the research questions, it may not fully represent the broader population affected by Hurricane Irma.

The reliance on secondary data posed further limitations, as variables were available only at the county level, limiting the granularity of the analysis. This constraint precluded the ability to examine individual-level attributes such as personal socioeconomic status or individual disaster responses, potentially masking important nuances in mortality patterns. Furthermore, the cross-sectional design of the study restricted causal inferences, as exposure and outcome data were collected simultaneously. While this design effectively identified associations, it could not establish causation between Hurricane Irma and the observed mortality outcomes.

Data reliability was also a concern, as potential errors in coding, misclassification, or incomplete documentation within the NVSS dataset may have introduced measurement biases. Efforts were made to address this by implementing rigorous data cleaning and analysis protocols, but the possibility of residual bias remains. Additionally, the broad scope of the SEM framework posed challenges in operationalizing certain variables. Factors such as interpersonal and organizational attributes were less granularly analyzed due to limitations in the available data.

Despite these limitations, this study provides valuable insights into the relationship between chronic disease mortality and natural disasters, contributing to disaster preparedness and response strategies. Future research should address these constraints by incorporating longitudinal designs, expanding geographic scope, and utilizing primary, individual-level data to enhance the granularity and applicability of findings.

Recommendations

The results of this study indicated that there were high rates of chronic disease among individuals who died within 2 months of Hurricane Irma. It need not be stated that outright avoidance of disasters can reduce the risk of mortality among people with chronic diseases from a disaster; this is not always possible. Individuals with chronic diseases could also avoid natural disasters through evacuation from the disaster zones after a disaster or sheltering in areas that can sustain services and access to care needed. Future researchers can focus on gaining greater fidelity in individual data and more individually specific SES factors/context to better understand associations and potential causal factors that could inform and enhance the opportunity and ability for people with chronic illnesses to understand their risk and move to (access) safer areas of resources and care during and after a disaster. Researchers could also focus on early warning systems that can alert elderly people about impending storms both broadly and more specifically and individualized risk and emergency communications.

The current study's findings suggested that there were some statistically significant demographic shifts in mortality patterns when comparing pre- and postdisaster data. This implied that Hurricane Irma did disproportionately affect specific demographic groups within the population studied, specifically those over 85 years of age, those in poverty, and those in urban areas. The dataset used in the current study was limited in terms of variables and did not allow an exploration of other demographic factors such as individually reported education level, individual poverty status, and rural–urban coding associated with residence versus location of death, which could provide further insight into potential mediating or moderating variables for mortality among individuals with chronic diseases or other unique outcomes. In future studies, researchers can focus on socioeconomic factors directly associated with the individual versus geographic attribution, such as poverty, education, marital status, rural–urban code, and housing, to determine whether such demographic factors can influence the differences in mortality rates.

The use of purposive sampling was a limitation of this study since it may have minimized generalizability. Purposive sampling enabled the researcher to select data that was most suitable for answering the research questions. However, this technique can be unrepresentative of the general population. To correct this shortcoming, future researchers can consider employing a random sampling technique, which is more likely to end up with a more representative sample. This can be done directly or by purposively selecting data from several randomly selected cohorts.

The use of data from a single state limited this study's generalizability. Different states may have unique demographic characteristics and nuances that could make generalizing findings from Florida informative for study in the context of other states but impractical in terms of direct operationalization. In future studies, investigators can consider conducting their study in different states, which may increase the representativeness of the sample selected and in turn enhance generalizability.

Using secondary data from NVSS was another limitation of this study. Secondary data constrains the researcher's ability to fully address a research problem because the variables used in the secondary data may not necessarily match the variables in the current study (Yan et al., 2021). This was the case in this study whereby socioeconomic variables for poverty rates and educational attainment were attributed (linked) via geographic areas and county prevalence and were not directly associated with individual cases in the NVSS data. This inhibited the ability to respond to the second research question at the individual level directly. In future studies, researchers should consider collecting primary data from the target population whereby all needed data and variables can be collected, directly attributed to the individuals, and analyzed for a more comprehensive answer to the research questions at the individual level across all variables.

A cross-sectional study approach was a major strength of this study. Cross-sectional studies are the best way to determine prevalence and can study the associations of multiple exposures and outcomes, which can contribute to causal inference but they cannot establish cause and effect relationships. Specifically, the design allowed the researcher to study multiple outcomes based on a similar exposure to Hurricane Irma, which enabled the analysis of potential associations between the exposure and the mortality outcomes. However, it can be difficult to measure the impacts of disasters such as hurricanes directly and true causality of exposure would be best understood by comparing individual-level data that existed before the disaster to data that is collected afterward. As such, the findings from this cross-sectional study and others could be used to inform a retrospective cohort research design with time series analysis to investigate and inform or determine causality of the influences and impacts of natural disasters on chronic diseases, beyond CVD and metabolic diseases, on morbidity and mortality, while better understanding and controlling for potential mediating and moderating variables.

The current study employed the SEM framework, which is a broad-reaching theory and challenging to operationalize. Future researchers can consider identifying additional variables to operationalize the framework more fully, in addition to possibly identifying other theoretical frameworks may be less broad when investigating the impacts of natural calamities such as hurricanes on mortality. Some suggested theories include the theory of planned behavior/reasoned action and the extended parallel processing model. The theory of planned behavior/reasoned action states that intentions, attitudes, and norms influence behavior (Schoon, 2021). The extended parallel processing model describes how rational considerations alongside emotional reactions combine to determine the behavioral decisions of people facing calamities (Schoon, 2021). A theoretical triangulation of the two or three theories can enable future researchers to more fittingly explain the behavioral and health outcomes observed post-natural disaster.

Implications

This study offers critical insights into the intersection of chronic disease mortality and disaster impacts, particularly Hurricane Irma, and provides a foundation for recommendations that promote positive social change at individual, family, organizational, and societal levels. By using the Social-Ecological Model (SEM), the study contextualized health outcomes across multiple levels of influence and identified actionable pathways for improvement.

At the individual level, findings emphasize the need for personalized disaster preparedness strategies tailored to the needs of chronically ill populations, such as early evacuation plans and access to essential medications. These strategies empower individuals to mitigate risks during natural disasters and foster resilience, particularly for older adults and those with limited mobility.

At the family level, the study highlights the importance of caregiver support networks in ensuring the well-being of vulnerable populations. Disaster preparedness education for families, particularly those caring for chronically ill individuals, can help mitigate risks and enhance recovery efforts.

At the organizational level, healthcare systems and emergency response organizations must prioritize continuity of care during disasters. The findings underscore the critical role of ensuring uninterrupted access to medical resources and infrastructure, especially in areas with heightened urbanization or economic disparities. The study supports initiatives like enhanced coordination between local healthcare providers and emergency services, as discussed in studies by Yamaoka-Tojo and Tojo (2024), which propose comprehensive disaster response protocols focused on chronic disease management.

At the societal and policy levels, the findings call for targeted interventions to address systemic inequities, particularly those linked to poverty and geographic disparities. Policies that enhance disaster preparedness funding for low-income communities, improve rural healthcare infrastructure, and address urban resource constraints are essential. These align with broader recommendations for equitable healthcare policies and disaster risk reduction frameworks, emphasizing the need for systemic changes to mitigate disaster impacts on at-risk populations.

The implications of this study point to the need for integrating more granular, individual-level data to better understand the nuances of demographic and socioecological modifiers. By complementing county-level analyses with individual-level data, future research can refine causal relationships and intervention strategies. Furthermore, the study's application of the SEM framework demonstrates the importance of multilevel approaches in public health research, providing a theoretical basis for similar studies on disaster impacts.

Finally, recommendations for practice include developing community-based resilience initiatives and leveraging technology for disaster communication and early warning systems. Practical interventions, such as mobile health clinics and telemedicine, can be deployed in disaster-prone regions to ensure continuity of care during and after crises. By addressing gaps in healthcare accessibility and fostering inclusive disaster planning, this study contributes to a broader understanding of how to safeguard public health in the face of increasing natural disasters.

Conclusion

This study investigated the association between chronic disease mortality and Hurricane Irma’s impact in Florida, focusing on demographic factors such as age, poverty level, and rural–urban continuum. Using the Social-Ecological Model (SEM) as a guiding framework, the research revealed that age (85+ years), poverty, and urban residency significantly increased mortality risks among individuals with chronic illnesses during the disaster. These findings emphasize the disproportionate vulnerabilities faced by older adults, low-income populations, and urban residents, making the addressal of potential systemic healthcare and infrastructural disparities a priority.

The results contribute to a growing body of evidence demonstrating how natural disasters exacerbate health inequities by disrupting critical healthcare services and amplifying preexisting social vulnerabilities. For policymakers, these findings underscore the importance of targeted disaster preparedness strategies, including early evacuations for high-risk groups and investments in urban healthcare infrastructure. At the individual and family levels, the findings highlight the need for personalized disaster readiness plans, particularly for chronically ill individuals who are most at risk during extreme weather events.

Methodologically, the use of secondary, county-level data offered valuable insights but also presented limitations in analyzing individual-level factors. Future studies should consider collecting primary data to better capture the nuanced interactions between demographic variables and health outcomes. The application of the SEM framework demonstrated its utility in exploring multilevel influences on disaster-related health outcomes but also highlighted the need for integrating complementary theories to refine the analysis further.

In summary, this study provides actionable insights for improving disaster resilience among vulnerable populations. It calls for a multilevel approach that combines systemic policy interventions, community-based preparedness efforts, and individual-level education to mitigate the health impacts of future natural disasters. By addressing these vulnerabilities, the findings aim to foster a more equitable and effective disaster response framework, safeguarding at-risk populations from preventable mortality.

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