# EXTREME HEAT AND KIDNEY-RELATED EMERGENCY ROOM USE IN NEVADA

By

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**Extreme Heat and Kidney-Related Emergency Room Use in Nevada**

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Abstract

*Objective:* Since Nevada experiences extreme heat all over the state, this study examined whether there was a correlation between emergency department visits for kidney-related illnesses and increasing temperature as signified by the wet bulb globe temperature (WBGT) for the January 1, 2016- December 31, 2019 period. *Background:* Public health institutions at international and federal levels have identified anthropogenic climate change as a public health threat, particularly for vulnerable populations. One result of climate change that impacts health is extreme heat. Research shows that extreme heat may lead to negative health outcomes for kidney health. *Methods:* The primary methodologies were a correlation analysis and linear regression. Additionally, a geospatial analysis was conducted using a heatmap to identify the geographic areas where Nevadans are at the highest level of risk for kidney-related illness as temperatures rise. Based on the literature review, a public policy analysis focused on whether climate-health adaptation including kidney-related illnesses are addressing the human health risks adequately. One limitation of the study was that there was no weather data available for Storey County. There also were limitations on the granularity of data due to the HIPAA minimum cell size standard. *Results:* The results of the analyses showed a strong relationship between the WBGT and emergency department visits for kidney-related illness, that urban areas of Nevada are most at-risk, and that public policy does not address the risk sufficiently today. In conclusion, this research indicates that Nevada should focus climate-adaptation and mitigation policies for kidney-related illness on Clark County and Washoe County. Future studies should incorporate geospatial analyses using smaller geographic subdivisions such as census tracts.
Keywords: climate change and health, extreme heat, kidney disease, nephrology, emergency visits, Nevada.

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Dedications

I would like to dedicate this to my father, the Reverend Arthur A. Robinson, Jr. who instilled in me the value of persistence. One of his quotes, “when you’ve done your best, you can always do better” was my first campaign slogan (in elementary school) and continues to guide me.

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# INTRODUCTION

## Statement of the Problem

Scientists agree that anthropogenic climate change is presenting significant global challenges due to burning fossil fuels and deforestation.[1] Some indications of climate change include: increased heat waves, extreme weather events, changes in precipitation, increased humidity, and a warmer ocean.[2] A byproduct of climate change and the associated weather is a negative impact on human health.[3] Specifically, this research will focus on the impact of extreme heat on kidney disease.

The intersection of climate change and human health is a problem with implications in three components: clinical impact from a purely scientific perspective, supporting public policy that enables additional scientific exploration and interpretation, and climate adaptation action planning. Although this is a global issue, the political, financial resources, and knowledge/scientific inquiry create a need to understand the real-life impacts of climate change at the political sub-division level. Understanding what is occurring at state and local levels regarding climate change is critical to evaluating the effectiveness of international and country-level responses because these high-level policies are implemented at state and local levels.

In this case, the state of Nevada has experienced climate change, and looking at the state's response speaks to its overall preparedness for climate change health impacts. "Over the last century, the average temperature in Elko, Nevada, has increased 0.6°F, and precipitation has increased by up to 20% in many parts of the state".[4] Currently, Nevada has two of the nation's 25 fastest warming cities – Reno and Las Vegas.[5]

It is important to know how to identify people at the highest level of risk to experience health consequences related to climate change. One indicator is the presence of a chronic disease, a condition lasting one or more years and necessitates ongoing care. "Chronic diseases such as

heart disease, cancer, and diabetes are the leading causes of death and disability in the United States."[6] Further, chronic diseases are more prevalent among groups of people experiencing social vulnerability.[7] Another example of a chronic disease is Chronic Kidney Disease (CKD). According to the National Institute of Diabetes and Digestive and Kidney Diseases (NIDDK), CKD is "*chronic* because the damage to…kidneys happens over a long period of time."[8] People with kidney disease are at a particularly high risk when exposed to extreme heat because dehydration can decrease kidney function, and heat illness causes an overall shutdown of metabolic function, including the kidneys.[9]

Extreme weather events stemming from climate change may have a disparate impact on vulnerable populations because of the challenges that medical professionals and facilities face in the aftermath.[10] The World Health Organization defines *vulnerability* as "the degree to which a population, individual or organization is unable to anticipate, cope with, resist and recover from the impacts of disasters."[11] This impact on health systems leads people with kidney disease to be more vulnerable due to their chronic disease status.

Hurricane Katrina is one example of extreme weather resulting from climate change. People impacted by Hurricane Katrina may be similar to those impacted by other extreme weather events. The research of Flanagan et. al. shows that most deaths from Hurricane Katrina occurred among those with high *vulnerability*.[12] "Among the most vulnerable victims [of Hurricane Katrina] were the [New Orleans] area's nearly 2500 dialysis patients who received care at 43 facilities in the city and surrounding area."[13(p815)]

Although Hurricane Katrina is a different type of extreme weather event than extreme heat, this case study establishes that individuals with high vulnerability struggle to adapt to a sudden weather-related change. It also establishes that people with kidney disease, "especially those who were receiving dialysis or [transplants are] particularly vulnerable."[13(p814)] Therefore, vulnerability in the geographic area of focus should be included in any study related to the health impacts of climate change; in this case, Nevada.

Nevada is a destination for tourism and residence for singles, families with children, and retirees alike. The magnetism of Nevada stems from economic opportunities, a dry and warm

climate, outdoor recreation from Red Rock Canyon National Conservation Area to Lake Tahoe, and attractions like the Las Vegas Strip, Burning Man, and the National Cowboy Poetry Gathering. Residential population growth has been consistently explosive over the course of the past five decades. Overall, Nevada's population at any given time is a diverse mixture of people from all over the US, international visitors, indigenous groups, ultra-wealthy, impoverished, and people across the full age spectrum.

Another note about Nevada's demographics is that it is one of the most racially and ethnically diverse in the US, with a significant portion of residents that are 54% non-white. All of these dynamics mean that Nevada has a preponderance of vulnerable populations.[14] Already, Nevada's most densely-populated region, Clark County, is majority-minority; the rest of the state is projected to become majority-minority by 2023.[15] This majority-minority status speaks to other vulnerability characteristics - people with Limited English Proficiency (LEP); people who may have risky occupations; and people who are uninsured or underinsured.

In addition to the high number of communities of color, linguistically diverse people, tribal communities, and large rural areas, Nevada's population is over 22% children.[14] The state also boasts the 5th largest school district in the nation, the Clark County School District.[16] This large population of children is another illustration of the predominance of vulnerability in Nevada. The American Public Health Association (APHA) has established conclusively that "children are especially vulnerable to climate change because of their physical and cognitive immaturity".[17] Understanding the multifaceted nature of vulnerability for the Nevadan population is critical to any public health preparedness efforts and should be integral to any effective underlying public policy.[18]

The US Global Change Research Program (USGCP) has identified a comprehensive list of groups of people who are acutely vulnerable to the health impacts of climate change. Instead of using the term *vulnerable* or *vulnerability*, USGCP groups terms them *populations of concern*. The factors that contribute to the vulnerability or concern include socioeconomic status, disability, infrastructure, occupation, time spent in risky locations, and responses to extreme events (such as choosing to remain in-residence during an evacuation). These factors may be compounded

with demographic characteristics like LEP, non-white people, and lacking adequate health insurance.[19] Such demographic characteristics are prevalent in Nevada.

When it comes to kidney disease, racial and ethnic health disparities in the incidence of End Stage Renal Disease were established in the literature in the 1980's. Racial and ethnic health disparities in the incidence of CKD were established only since 2015.[20] The intersection of racial and ethnic health disparities and other social vulnerabilities converge in Nevada because of its high number of populations of concern for health impacts of climate change.[7,14,21]

Further, the CDC identifies people with mental illness as having the highest level of risk for health impacts related to extreme heat.[22] Approximately 25% of people with chronic kidney disease also have depression, and people on dialysis are at an even higher risk of depression.[23] This is particularly relevant to Nevada, as Mental Health America ranks Nevada as 51st in the US for adult and youth mental health in its annual publication, *The State of Mental Health in America 2020*.[24] People with mental illness may not be able to cope with the stress of extreme heat nor make decisions about responses to extreme heat exposure.

Additionally, the research of Nerbass et al showed a relationship between people subjected to indoor and outdoor occupational heat exposure and the incidence of kidney disease, which also aligns with vulnerable populations. An example of an outdoor heat exposure occupation is construction work, and an example of indoor occupational heat exposure is factory work near boilers. Typically, people who are low-income with minimal education, poor access to health care, and few job options are in these types of occupations.

Often, work is evaluated by productivity, which may lead to working beyond safe limits to maintain job and financial security.[21] Mix et al observed the occupational risk of acute kidney injury and overall reduced kidney function (CKD) in the *Girasoles (Sunflower) Study*. The study was done in collaboration with the Farmworker Association of Florida on the heavily Latino immigrant population of Floridian farm workers.[25]

This type of occupational or daily living heat exposure can trigger the kidney disease process, as described in Figure 1. There are multiple mechanisms implicated in the development of CKD associated with heat, from De Lorenzo and Liaño.[26] Hopp and Bobb noted that "kidney failure has

also been associated with several factors that could induce hospital admissions during heat waves".[27(p4)] Due to the physiological process that occurs due to dehydration and heat, extreme heat also is associated with Acute Kidney Injury & Failure “when…kidneys suddenly become unable to filter blood.”[28]

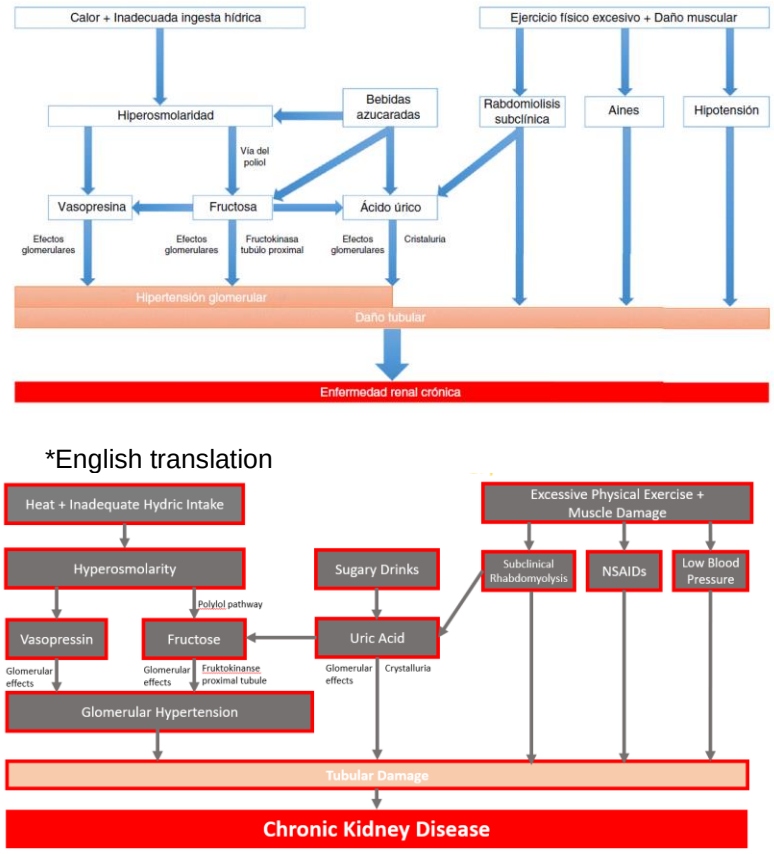


**Figure 1.** Kidney Disease process[26]

Additionally, Figure 1 shows that the metabolism of fructose can lead to Chronic Kidney Disease. [26] This was substantiated by Johnson et al, who discussed the physiological processes that occur when fructose is in the body and how that can result in kidney disease. Johnson et al also specifically discussed sugar-sweetened drinks as related to elevated blood pressure and Diabetes, both of which lead to kidney disease.[29] This reference to sugary drinks is significant because “sugary beverages and snacks are often widely available in low resource communities” and have high consumption among racial and ethnic minorities, all of which are vulnerable populations.[30(p6)]

Background of the Problem

The National Aeronautics and Space Administration (NASA) defines *climate change* as an extensive breadth of climate-related transformations including: “rising sea levels, shrinking mountain glaciers, accelerating ice melt in Greenland, Antarctica and the Arctic, and shifts in flower/plant blooming times…caused mainly by people burning fossil fuels and putting out heat-trapping gases into the air”.[31] There is broad scientific consensus that the rapid change in climate that the planet is experiencing currently is anthropogenic in nature. Cook et al confirmed that among papers expressing a position on AGW [Anthropogenic, or human-caused, Global Warming], an overwhelming percentage (97.2% based on self-ratings, 97.1% based on abstract ratings) endorses the scientific consensus on AGW.[32]

Although climate change has its consequences in nature, the downstream impacts of those changes to our natural environment can include negative health outcomes. Health outcomes are a change in health status based on interventions or variables. In this case, the interventions or variables are the physiological and environmental responses to climate change.

Specifically, the Centers for Disease Control and Prevention (CDC) Climate Change and Health Program delineates climate change-related health risks in the following categories: air pollution, allergens, wildfires, temperature extremes, precipitation extremes, diseases carried by vectors, food and waterborne diarrheal disease, food security, and mental health and stress-related disorders.[33] This categorical list of health impacts demonstrates the various ways in which climate change can impact human health. For example, under the category of *precipitation extremes*, buildings in areas that have been flooded can have poor indoor health quality due to mold, which can lead to increased asthma episodes, upper respiratory symptoms and lower respiratory symptoms including pneumonia.[34]

The CDC links extreme heat to deaths from heat stroke, cardiovascular disease, respiratory disease, and cerebrovascular disease. This is in addition to increased hospitalization for cardiovascular disease, kidney disease, and respiratory disorders during heat waves. More indirect health impacts of extreme heat include: wildfires, water and food scarcity, vector-borne diseases, and allergens.[33]

To respond to these potential health impacts, the CDC developed the CDC Climate and Public Health Framework in 2006. The CDC Climate and Public Health Framework was a precursor to existing, more robust programming related to climate change and health. The Framework laid the foundation for what was needed from a national program to address the intersection of climate change and human health.[33]

After moving forward with the Framework, subsequently, in 2009, the CDC launched the Climate and Health Program. The Climate and Health Program has three core functions: (1) informing states, local health departments and communities of the climate change science, (2) creating decision-support tools for public health preparedness, and (3) establishing the CDC as a leader for public health planning related to climate change. Each core function has a set of *Priority Actions* and *Projects/Activities* to carry-out each core function.[35]

Today, the CDC has a formal *Policy on Climate Change and Health*. The Policy is divided into two parts. The first is called the *Scientific Framework;* the second is called the *Public Health Approach*. The *Scientific Framework* is a combination of an overview of the need for a scientific understanding of climate change in the public health sector and a listing of specific weather events, associated health impacts, and populations most vulnerable to those negative health impacts.[36]

While the CDC was establishing its Climate and Health Program in 2009, the same year, the World Health Organization (WHO) Executive Board approved a workplan to address preventive measures against the potential health effects of climate change.[37] The WHO Climate Change and Health Workplan is designed to work in tandem with a set of policy documents from the World Health Assembly. These documents include a Climate Change and Health Resolution passed in 2008, Secretariat Report to the World Assembly, the WHO Workplan, and a Progress Report to the Executive Board.[38] The WHO Workplan establishes a set of four objectives and corresponding actions along with a commitment to implementing these objectives and taking the actions. Through these initiatives, WHO can advocate for non-industrialized countries and low-income people, conduct surveillance and monitoring, create evidence-based models, and share best practices.[37]

One stark difference between the CDC approach and the WHO approach to public health preparedness for climate change stems from WHO's focus on low- and middle- income States and small island States.[39] Due to this global and developing country emphasis, which is inherent to WHO as an agency of the United Nations, the conceptualization of the impact of climate change on human health also includes a broad explanation of possible health systems impacts. Health systems from a global and developing country perspective includes food security, clean water, sanitation, and the status of women. Due to this distinction, the WHO pledge to share knowledge and best practices takes on a different context than the CDC commitment to create and distribute decision-making tools.[33]

Despite those differences, the formal engagement of the CDC and WHO on the topic of climate change and health signifies the acceptance of climate change as a real health threat and acknowledges the need for proactive climate-related health promotion activities. Since climate change is a global problem with global impacts, the country-level program implementation such as the CDC Climate Change and Health Program is integral to the success of a cohesive and comprehensive international approach such as the WHO Workplan. Both levels are important, with the international engagement facilitating and creating the capacity for the country-level engagement, particularly in countries that are less affluent than the United States (US).

Another aspect of the US country-level response is the US Global Research Program (USGRP) report *The Impacts of Climate Change on Human Health in the United States: A Scientific Assessment.*[19] USGRP is a consortium of the following thirteen federal agencies: Department Agriculture, Department of Commerce, Department of Defense, Department of Energy, Department of Health and Human Services, Department of the Interior, Department of State, Department of Transportation, Environmental Protection Administration, National Aeronautics and Space Administration, National Science Foundation, Smithsonian Institution, and U.S. Agency for International Development. The report aligns with the CDC Climate Change and Health Program and references issues like temperature-related illness, air quality, water-related illness, and vulnerable populations. USGRP also produces a National Climate Assessment periodically.[40]

The most recent National Climate Assessment is comprehensive, covering all areas of climate change, including a section devoted to human health. Other areas covered in the Assessment span from ecosystems and biodiversity to infrastructure and agriculture. One section of the Assessment is concentrated entirely on Indigenous populations. Based on the discussion in the *Indigenous Peoples* section, the effects of climate change on Indigenous Peoples is especially harsh because climate change threatens traditional ways of life including activities as fundamental as food sourcing and access to plants used for medicine.[33] When viewed in totality, climate change could exacerbate the existing health disparities experienced in the indigenous communities of the US.[40]

Indigenous people are not the only vulnerable populations in the US who will have a differential experience with climate change. Due to limited resources and health disparities, the ability for vulnerable populations to combat the health impacts of climate change depends largely on the consensus of the public health professional community. This requires an acceptance of the undergirding scientific basis of climate change and preparedness can be achieved through public policy. Yet, the first step is unanimity about the link between climate change and human health.

One indicator of scientific consensus regarding any public health issue is the extent to which the topic is integrated into public health literacy efforts. The article, *Developing Effective Communication Materials on the Health Effects of Climate Change for Vulnerable Groups: A Mixed Methods Study*, offers insight into the types of health communications materials that should be used to educate populations with low socio-economic status to increase literacy regarding the intersection of health and climate change.[41] The CDC and American Public Health Association (APHA) co-created a series of six fact sheets explaining various climate and health topics along with animated PowerPoints that can be downloaded for use in education efforts in both English and Spanish.[33] Similarly, at the international level, WHO has developed a set of infographics like one called *Who is at Risk for Climate Change*, which uses simple images to describe vulnerable populations.[42]

Medical professionals are becoming increasingly aware, educated, and engaged about climate change and health. The article, *The Climate/Health Nexus at COP21 & Beyond,* provides an

overview of international efforts to address the intersection of climate change and health.[43] In addition to The Paris Agreement on climate change, the article discusses the *Climate and Health Summit 2015: Engaging with Health in a Post-2015 World*, which was convened by the Global Climate and Health Alliance, WHO and other organizations and brought together doctors, nurses, negotiators, policymakers and academics.[44] Other research indicates that there is a significant opportunity for physician medical education to include climate change. In the article, *Teaching about Climate Change in Medical Education: An Opportunity*, Maxwell and Blashki, layout the components of a climate change curriculum for medical students including sample learning objectives and sample assessments for climate change and health.[45]

This ongoing effort to engage and educate medical professionals is critical, and government figureheads have joined this effort as evidenced during the 2015 Public Health Week. On the first day of Public Health Week, Former President Obama, US Surgeon General Vivek Murphy, and EPA head Gina McCarthy met with leaders in a roundtable discussion at Howard University College of Medicine – a Historically Black institution - to highlight the public health concerns associated with climate change. Having high-level government officials meet directly with leaders in the medical profession, especially those representing the vulnerable African American population, was a significant step in raising awareness of climate change as a public health risk.[46]

As the connection between climate change and public health has become a higher-profile component of the climate change discourse and public consciousness, professional organizations such as the APHA are focusing on climate change and health, offering opportunities for professionals to develop knowledge and skills in this emerging area. After issuing its *Climate Change and Health Strategic Plan in 2016,* the APHA 2017 annual conference theme was *Climate Change and Health*.[47] The Strategic Plan outlined a series of goals from 2016-2030 under the categories of: awareness, enabling environment, policy, science, and leadership. The 2017 annual conference included sessions such as: *Climate Changes Health, Climate Change and Its Impact on African Americans,* and *Interfaith Celebration and Reception-Global Faith and Health Perspectives on Climate Change.*[47]

In 2018, the APHA intensified its emphasis on climate change and health. The organization homepage links to a Public Health Resources hub. The Public Health Resources hub starts with a link to the important new report *Adaptation in Action Part II 2018: Grantee Success Stories from CDC's Climate and Health Program*, multiple call-to-actions for grassroots public policy advocacy efforts, the strategic plan, and links to various events, articles, and other resources. Additionally, there have been several open source webinars about climate change and health including *Climate Changes Health Equity*.[48]

Other organizations like the American Lung Association (ALA) also are engaged in the issue of climate change and human health. ALA focuses its attention on air pollution, allergens, flooding and other extreme weather events, and wildfires, all of which have detrimental effects on lung health.[49] Moreover, the George Mason University has an affiliate called the *Medical Society Consortium on Climate and Health*, which engages physicians across the United States to become advocates with foundational tools like continuing education, advocacy opportunities in various states, and social media engagement through the Twitter handle *@docsforclimate*. The *Consortium* also hosts an annual meeting; the theme of the 2018 gathering was Climate and Health Solutions for Our Future.[50]

Notwithstanding all these efforts, public health preparedness cannot occur without the undergirding support of robust and applicable public policy. One example of the potential impact of public policy is the Obama Administration response to the Deepwater Horizon Oil Spill (DWH) of 2010. The DWH Oil Spill into the Gulf of Mexico consisted of "an estimated 5 million barrels of oil for 3 consecutive months, and is the largest marine oil spill in history."[46] The human health impacts of the DWH Oil Spill were swift, and primarily evident as the mental health conditions of anxiety, depression, and post-traumatic stress.[51]

In direct response to the DWH Oil Spill, Former President Obama issued Executive Order 13547 *Stewardship of the Ocean, Our Coasts, and the Great Lakes*.[52] EO 13547 was designed with the objectives of: promoting resilient ecosystems, maintaining and protecting biodiversity, and developing a framework that includes federal, tribal, state, local, and regional stakeholders.[52] One of the contributing factors to the significant health impacts from the DWH Oil Spill was that

the community was impacted by another climate-related event only a few years earlier - Hurricane Katrina. Therefore, this was a vulnerable population experiencing multiple exposures to climate-related health impacts.

This example reflects the impact that public policy can have on the ability to have the consistent support required to improve public health infrastructure regarding climate change. Principally, a subsequent executive order has sought to undo all of these protections, leaving these populations again vulnerable. Section 7 of the *Executive Order Regarding the Ocean Policies to Advance the Economic Security and Environmental Interests of the United States,* called *Revocation*, formally revokes EO 13840, the protections put into place as a response to the DWH Oil Spill. Rather, the focus of the EO content sits squarely on commerce, security, and global competitiveness. Although, clean and healthy water are mentioned as it relates to "fishing, boating, and other recreational opportunities."[53(p13)]

Another example of this public policy pendulum is the 2017 President Trump *Executive Order on Promoting Energy Independence and Economic Growth (EO 13783)*.[54] EO 13783 established a pathway to rollback reduced emissions regulations. Additionally, EO 13783 restarted the ability to expand coal mining of federal lands, eliminated the inclusion of greenhouse gases from certain federal permits, and abolished the *Social Cost of Carbon* regulatory analysis process. Other impacts of EO 13783 include reducing regulatory protections related to power and methane pollution and emission standards, climate change and national security, tribal lands, and natural resource mitigation plans for developers.[55]

In response to EO 13783, US Senator Edward Markey and US Representative Matt Cartwright introduced the bicameral *Climate Change Health Protection and Promotion Act* in their respective chambers. According to the Natural Resource Defense Council expert, Juanita Constible, the legislation would have achieved three primary goals: augmenting state and local health agencies, creating capacity for future scientific inquiry, and focusing on vulnerable populations.[56] Organizations including the Public Health Institute, APHA, American Lung Association, American Academy of Pediatrics, and the National Association of County and City Health Officials supported the legislation, which did not pass.[57]

Even in its cooperation at an international level, the US has been fickle regarding climate change. The Paris Agreement is an international policy dedicated to reducing climate change through a specific action plan, much of which is focused on decreasing greenhouse gas emissions. Under the leadership of Former President Obama, the US entered into the Paris Agreement in Fall 2016.[58] By the middle of 2017, President Trump announced that the US would "cease all implementation of the non-binding Paris Accord and the draconian financial and economic burdens".[59]

Ultimately, various governmental, health, international, organizational and professional associations have recognized the relationship between climate change and health and are taking action to prepare for the potential impacts. While international and national public health participation in climate change and health initiatives are important, policies related to medical practice and action at the state level is remarkably critical due to the mercurial nature of federal policy related to climate change. Specifically, medical protocols, state statutes, and state regulations will need to buffer this erratic federal response with their own policies.

In Nevada, the Climate Change Advisory Panel issued a report in 2008 with recommendations related to climate change within the state under the topical areas of: electricity, residential/commercial/industrial, transportation, waste management, agriculture and other.[60] There has not been an analysis of whether the recommendations from the report have been implemented. While the climate change discourse specific to Nevada tends to focus on economic impacts and water scarcity, there is some recognition of the impact that climate change can have on the health of Nevadans.

One example of the Nevada health care community increasing its awareness of climate change as a public health concern is the Nevada Nurses Association. The professional association has a webpage dedicated to explaining the concept of climate change, showing climate change data specific to Nevada, tying the issue of climate change to human health and the nursing profession and listing resources for additional information.[61] Therefore, the issue of climate change with relation to Nevada is well-established with many resources being dedicated to ongoing research and data gathering. Yet, the connection between climate change and human

health given the unique demographic profile including the transient nature of the population, topography, and geospatial population distribution is less ubiquitous.

In 2012, the thinktank Demos published a white paper calling for Nevada to embrace climate change-reducing public policies to mitigate negative impacts that climate change could have on Nevada's tourism-based economy as well as water resource constraints and potential health risks.[62] Nevada has a need for updated, comprehensive, and comprehensible public policy recommendations. Yet, those public policy recommendations can be made only with sufficient information and analysis. The problem is that there has not been a full geospatial risk analysis of potential health impacts from climate change, or analysis of policies from the various policy-making bodies such as regulators and government agencies impacting clinical care.

## Research Questions

Unfortunately, in Nevada, many conversations about public health preparedness and public policy related to climate change continue to focus on the potential economic opportunities of energy-based businesses and outdoor recreation. This is evidenced by the discussions of renewable and solar energy in the 2017 Nevada Legislative Session in addition to the hot-button issue of development in the Red Rock Conservation area that dogged the powerful elected body of the Clark County Commission the same year.,[63] This emphasis occurs even though there is significant evidence that climate change is affecting weather patterns, natural disasters, and accessibility to water currently. Given the recent knowledge of the relationship between climate change and human health, this study seeks to understand the potential impacts of extreme heat on kidney disease for Nevadans.

Given the complexity of the issue, this study seeks to answer three research questions:

1. What level of risk does Nevada have for an increased incidence of emergency room visits for kidney-related illnesses during extreme heat episodes?
2. Does social vulnerability increase the use of emergency room for kidney-related illnesses during extreme heat episodes?

3. What are the most critical policy needs to address climate change risk for emergency room visits for kidney-related illnesses during extreme heat episodes?

Hypotheses

Null Hypothesis $H_0$: $\mu = \mu_0$ Alternate Hypothesis $H_A$: $\mu < \mu_A$

- $\boldsymbol{\mu}$ – Emergency department visits for kidney-related illnesses in Nevada
- $\boldsymbol{\mu_0}$ – There is no relationship between emergency department visits for kidney-related illnesses during extreme heat in Nevada
- $\boldsymbol{\mu_A}$ . Emergency department visits for kidney-related illnesses in Nevada increase in response to extreme heat in Nevada

The need for the study

Theoretical Need

From a theoretical perspective, the premise of the research questions is based on the disaster management concept of risk, where *Risk = Hazard * (Vulnerability-Resources).*[12] Essentially, the true risk that a population experiences is defined by the combination of the disaster threat or *hazard* and the resilience of the population to that threat. In this case, the threat is the kidney complications tied to extreme heat and climate change. The *vulnerability* variable is addressed with the vulnerable populations, and the *resources* variable encompasses public health infrastructure.

One key part of this research is vulnerability, "the degree to which a population, individual, or organization is unable to anticipate, cope with, resist and recover from the impacts of disasters."[11] In *At Risk in America*, Aday employs a theoretical framework of vulnerability that starts with the three components of health as physical, psychological, and social and connects those components to social determinants such as homelessness, disability, and immigration status.[64] The vulnerable populations theoretical concept is based on the idea that there is an intersection among resources, relative risk, and health status.[65] The purpose of vulnerable populations

theories is to find ways to direct public resources to the individuals who most need those resources.

According to the US Office of Disease Prevention and Health Promotion, public health infrastructure has three components: sufficient health care workforce, current data and information systems, and ability to assess and respond to public health needs.[66] Practically, knowing the kidney-related emergency visit risk, the current state of public health infrastructure, and gaps in public policy are the precursors for Nevada to meet its needs in all three areas of public health preparedness. Although policymakers can make incremental improvement using existing resources, Nevada policymakers may find it challenging to develop a complete strategic approach to mitigating the risk of increased incidence and prevalence of climate-related kidney disease in the absence of a specific, targeted study.

Historically, both climate change and public health policy have aligned with the Irrational Theory and the Incremental Theory. Lindblom describes irrationality as the tendency for people in all areas of life, including public policy, to prioritize their feelings, personal beliefs, and comfort over rigorous and objective analysis.[67] One example of this irrationality is the assertion that climate change is not caused by human activity although over 97% of scientists believe that current climate change is anthropogenic in nature.[1]

Additionally, Lindblom's Incremental Theory applies to the way that changes in policy are often piece-meal and may start at the state-level, e.g. car emissions standards. Most often, incremental policy changes can help the policymaker: focus on well-established strategies and policies and reduce the amount of policy analysis needed before implementation.[67] Though, one could argue that the history of climate-related and public-health related public policy changes have more closely mirrored the Punctuated Equilibrium Model in which policy remains consistent with short bursts of change at various intervals.[68]

Two of the most applicable models for this study are the Model of Choice and the Institutional Friction Model. Model of Choice is a combination of incrementalism and punctuated equilibrium, which adds the variable flow of policy analysis information to policymakers into the equation.[68] The Institutional Friction Model describes the way in which costs are associated with the public

institutions that are engaging in public policy change. Those costs include: decision costs, transaction costs, and cognitive costs.[69]

## Practical Need

In addition to the theoretical need for this study, there is a practical need to improve kidney-related health outcomes for people in Nevada. First, the intersection between climate change and human health, particularly related to extreme heat as shown in Figure 2, has been well-established. Also, there is current interest and engagement in this topic at state, national, and international levels including medical and public health professional associations. Finally, there is a need to understand the implications of the impact of extreme heat on kidney disease for prevention, adaptation planning, and epidemic response as shown in the Adaptive Management Cycle shown in Figure 3 and described in Table 1.[70]

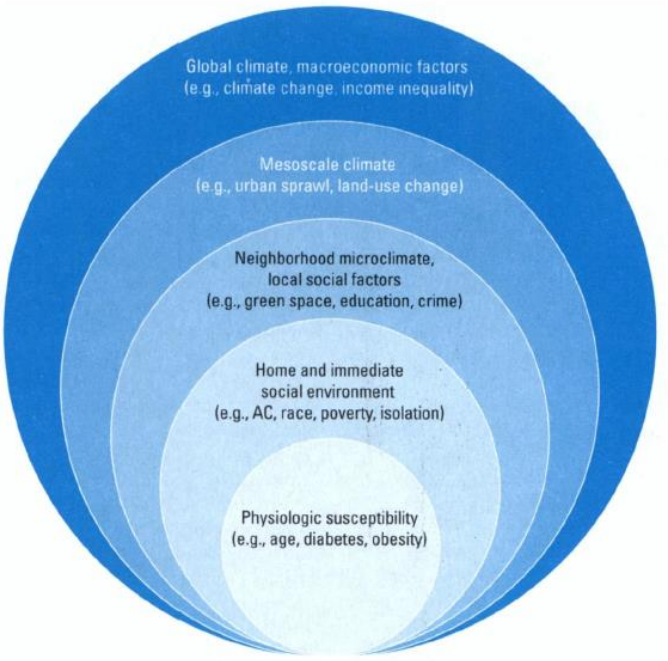


**Figure 2.** Heat-Related Morbidity and Mortality Risk[70]

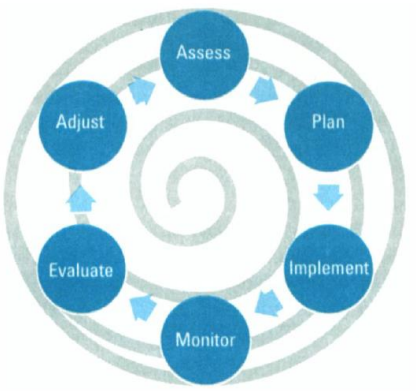


**Figure 3.** Adaptive management cycle[70]

**Table 1.** Steps in the Adaptive Management Cycle[70]

**Table 1.** Steps in the adaptive management cycle, central actions in each step, and tools useful for completing the central actions.

| Adaptive management step | Action | Existing tools | Example | Additional tools needed |
|---|---|---|---|---|
| Assess | Estimate likelihood and severity of exposure currently and in the future | Impact assessment | FEMA Hazus software (FEMA 2011)<br>MIASMA Health Impact Assessment (Tizio BV/Netherlands Environmental Assessment Agency 2011) | Assessment tools to incorporate downscaled climate projections |
| | Gauge susceptibility of population to hazard, including social components of vulnerability | Vulnerability assessment | UNFCCC/WHO Health Vulnerability Guidelines (Kovats et al. 2003) | Better quantitative vulnerability assessment methods that can be projected |
| Plan | Prioritize high-risk populations and areas for response | Vulnerability mapping | California Vulnerability Map (California Department of Public Health 2009) | Easily accessible mapping software with wider geographic coverage |
| | | Hazard mapping | Puerto Rico Disaster Tool (University of Delaware Disaster Research Center 2011) | |
| | Formulate politically and economically feasible response plan | Adaptation options compendia | Center for Climate and Energy Solutions 2011 | Models to predict effectiveness of given adaptation decisions |
| | | Decision support tools | Adaptation Decision Matrix (Stratus Consulting 2007) | |
| | Evaluate cross-sectoral needs under emergency circumstances | Integrated assessment model | Tyndall Center Urban Integrated Assessment Facility (Dawson et al. 2009) | Cross-sectoral models and other tools to avoid cascading impacts |
| Implement | Communicate preparedness and response and plans to stakeholders | Early warning systems | Philadelphia heat early warning system (Ebi et al. 2004) | Improved tools for communicating risk to the public |
| Monitor | Capture data relevant to expected impacts and interventions | Syndromic surveillance | CDC Syndromic Surveillance (Henning 2004) | Better systems to capture and process data in real time |
| | | Remote sensing | NASA data for heat early warning system (Johnson 2011) | |
| Evaluate | Compare pre- and postassessments or two similar events | General M&E guidelines | UNFCCC guidance for monitoring and evaluation of adaptation (UNFCCC 2010) | Quantitative methods to manage uncertainty and changing conditions |
| Adjust | Change management approach based on evaluation, changing future conditions, stakeholder input | Problem-based learning | Adaptive management activities in the natural resources sector (Bryan et al. 2009) | Tools to facilitate ongoing stakeholder engagement and multicriteria decision analysis |

Abbreviations: FEMA, Federal Emergency Management Association; M&E, Monitoring and Evaluation; MIASMA, Modeling Framework for the Health Impact Assessment of Man-Induced Atmospheric Changes; UNFCCC, United Nations Framework Convention on Climate Change.

Definitions

- Acute Kidney Failure (Acute Renal Failure) – when your kidneys suddenly become unable to filter waste products from your blood[28]
- Adaptation - The adjustment in natural or human systems to a new or changing environment that exploits beneficial opportunities or moderates negative effects.[71]

- Adaptive capacity - the ability of a (human) system to adjust to climate change (including climate variability and extremes), to moderate potential damages, to take advantage of opportunities, or to cope with the consequences[65]
- Adaptive management cycle- Integrating climate change adaptation into public health practice: using adaptive management to increase adaptive capacity and build resilience[70]
- Anthropogenic – of, relating to, or resulting from the influence of human beings on nature[72]
- Biodiversity - the name given to the variety of ecosystems (natural capital), species and genes in the world or in a particular habitat. It is essential to human wellbeing, as it delivers services that sustain our economies and societies.[73]
- Carbon footprint - the amount of greenhouse gases and specifically carbon dioxide emitted by something (such as a person's activities or a product's manufacture and transport) during a given period[74]
- Centers for Medicare & Medicaid Services (CMS) – Under the US Department of Health and Human Services, CMS is a federal agency that administers Medicare and Medicaid programs[75]
- Chronic Kidney Disease (CKD) – your kidneys are damaged and can't filter blood the way they should[8]
- Climate change - the broader range of changes that are happening to our planet. These include rising sea levels, shrinking mountain glaciers, accelerating ice melt in Greenland, Antarctica and the Arctic, and shifts in flower/plant blooming times.[31]
- Clinical Practice Guidelines – Systemically developed statements to assist practitioner and patient decisions about appropriate health care for specific clinical circumstances[76]
- Demographics - the statistical characteristics of human populations (such as age or income) used especially to identify markets[77]
- Emissions - substances discharged into the air (as by a smokestack or an automobile engine)[78]

- Geocode - Geocoding is the process of taking an address and returning an actual or calculated latitude/longitude coordinate[79]
- Geomasking - refers to additional techniques that preserve the confidentiality of individual health records. Examples of geomasking include data aggregation, i.e. summing points within enumeration units such as counties or census tracts, and surface generation, i.e. calculating point densities with GIS software[80]
- Geospatial- relating to information that identifies where particular features are on the earth's surface, such as oceans and mountains[80]
- Greenhouse gas - Greenhouse gases released into the atmosphere that trap heat and make the planet warmer. Human activities are responsible for almost all of the increase in greenhouse gases in the atmosphere over the last 150 years.[81]
- Hemodialysis – a dialysis machine and a special filter called an artificial kidney, or a dialyzer…used to clean your blood[82]
- Information systems - an integrated set of components for collecting, storing, and processing data and for providing information, knowledge, and digital products[83]
- Nephrology – an internist who treats disorders of the kidney, both chronic and acute, disorders of high blood pressure, fluid, electrolyte and mineral balance, and manages complications of kidney failure necessitating dialysis (removal of fluid and body wastes) when the kidneys do not function[84]
- Pathogen - a specific causative agent (such as a bacterium or virus) of disease[85]
- Politics - political affairs or business; *especially*, competition between competing interest groups or individuals for power and leadership (as in a government)[86]
- Predictive model – a scientific model based on knowledge and data of phenomena from the past and rely on mathematical analyses of this information to forecast future, hypothetical occurrences of similar phenomena[87]
- Public health infrastructure - the foundation for planning, delivering, evaluating, and improving public health; requires health professionals who are competent in cross-cutting

and technical skills, up-to-date information systems, and public health organizations with the capacity to assess and respond to community health needs[66]

- Public policy - a strategic action led by a public authority in order to limit or increase the presence of certain phenomena within the population[88]
- Sensitivity study - the study of how the uncertainty in the output of a model (numerical or otherwise) can be apportioned to different sources of uncertainty in the model input[89]
- Socio-economic status (SES) - the social standing or class of an individual or group. It is often measured as a combination of education, income and occupation[90]
- Social Vulnerability Index (SVI) - factors, including poverty, lack of access to transportation, and crowded housing may weaken a community's ability to prevent human suffering and financial loss in the event of disaster[91]
- Visual hierarchy - The most important objects on the map should be shown with the greatest contrast to their surroundings[80]
- Vulnerability - the degree to which a population, individual or organization is unable to anticipate, cope with, resist and recover from the impacts of disasters.[11]

# Chapter II

# REVIEW OF RELATED LITERATURE

## Scope and Organization of the Literature Review

The purpose of this literature review is to synthesize the major themes in current literature regarding climate change and human health. The area of human health topic is kidney disease, and the location of research will be in Nevada, USA. Accordingly, the literature review takes a thematic approach to evaluating the current research and knowledge. The themes include risk for extreme heat and kidney disease, adaptation planning, and policy implications. There are also sections regarding: research tools, frameworks and models, and future research.

The researcher conducted key word searches in university journal databases as well as government and NGO documents online. Example keywords included: climate change AND health, climate change AND kidney disease, extreme heat AND dialysis, public health AND climate change, emergency preparedness, extreme weather, extreme heat, heat waves, climate change AND health AND public policy, health policy AND climate change. The literature search also focused on recent research with date search parameters of 2008-2019.

## Research Tools

Within the two prominent research categories on the topic of climate change health, secondary data analysis, and literature reviews. Specifically, administrative data analysis is prevalent throughout the literature when researching the impact of extreme heat on health. For example, Sherbakov et al and Wang et al analyzed hospital data; whereas, Macintyre et al and Eisenman et al analyzed death certificate and mortality data.[92,93,94,95] Other administrative data examples in the literature include claims data used in the article *Association Between Extreme Temperature and Kidney Disease in South Korea, 2003-2013* and the use of national surveillance data in the

article *The Effect of Pre-Existing Medical Conditions on Heat Stroke During Hot Weather in South Korea*.[96,97]

Additionally, there are multiple types of statistical analyses found in the literature. In the article, *Heat Death Associations with the Built Environment, Social Vulnerability, and Their Interactions with Rising Temperature,* Eisenman et al use Poisson multivariate regression modeling to come up with Incident Rate Ratios (IRR) for multiple vulnerability variables on mortality data in Maricopa County, Arizona.[95] Wang et al use conditional logistic regression model "to compare the risks for renal diseases between heatwave and non-heatwave periods" in Brisbane, Australia.[93(p330)] Finally, Kim et al use an independent t-test to analyze continuous variables, but categorical variables were analyzed using a chi-square test or Fisher's exact test if the expected values were low.[96]

Also, the use of climate-specific research tools was common and important to note because it is a point where the interdisciplinary nature of this issue is highlighted. Both Wang et al and Kolivras used geospatial tools; and Wang et al also used weather station data[93,98]. Liang & Gong used data from the NASA Goddard Institute for Space Studies; whereas, Patz et al used the Geophysical Fluid Dynamics Laboratory[99, 100]. This use of climate-specific research tools was in addition to other types of research tools more typically found in biomedical and public health research.

Again, literature review and essay-style articles are common. Generally, they include peer-reviewed journal articles as well as government documentation related to climate change and were detailed about process and methodology. Popular databases for keyword searches included: PubMED, MEDLINE, Scopus, and Elsevier ScienceDirect. Another source of information was project reports such as those reviewed in *European Union Research in Support of Environment and Health: Building Scientific Evidence Base for Policy*, which was an essay-style article substantiating the investment that the European Union has made in projects related to climate change and health.[101]

Theoretical Frameworks and Models

Researchers incorporate various frameworks and models to investigate the risk for diseases because of climate change. One pattern in the literature was the attempt to modify an existing model to fit the topic of climate change and disease, which leads to the conclusion that existing tools are insufficient when applied to this topic. Schijven et al modified the Quantitative Microbial Risk Assessment (QMRA) to create an admittedly difficult to use CC-QMRA, where the *cc* indicates *climate change.*[102] Similarly, Wang et al modified a commonly-used epidemiological equation, *relative risk* (RR), and modified it to measure *relative sensitivity (RS).*[103]

Additionally, researchers are using public health models as frameworks to study our public health response to climate change and health. In *An Evidence-Based Approach to Climate Change Adaptation*, researchers applied the evidence-based standard used across Public Health to the issue of climate change and health and, ultimately, determined that the model can be used, but would need to be modified.[104] Keim based his research in *Building Human Resilience: The Role of Public Health Preparedness and Response As an Adaptation to Climate Change* on the Disaster Risk Management Cycle.[105,12] Meanwhile, Barrett et al incorporate Omran's *epidemiological transition.*[106,107] Again, overall, researchers advocate for these models to be updated so that they can be applied to the specific issue of climate change and disease risk. Although in this scenario, the recommendations apply to adaptation.

Due to the gap in models designed for climate change and human health, there are many other frameworks and models being leveraged in the literature. However, there were not many attempts to create entirely new frameworks and models specifically to address the issue of climate change-related health impacts. Table 2 is a brief listing of some of the models encountered in the literature that have not been mentioned in this section previously.

**Table 2.** Frameworks and Models Noted in the Literature

| | |
|---|---|
| 1. | Climate-disease-method scale[99] |
| 2. | Essential Public Health Services[70, 108] |
| 3. | Causal pathway[109] |
| 4. | Relative Operating Characteristic (ROC) skill[110] |

| | |
|---|---|
| 5. | Global Climate Models (GCMs)[111] |
| 6. | Parallel Climate Model (PCM)[111] |
| 7. | State Environmental Health Indicators (SEHIC)[112] |

While not discussed explicitly, undergirding the literature related to the public policy implications for climate change and health were two public policy theories: the new institutional theory and the rational theory. The new institutional theory emphasizes government agencies as drivers of the policies that are created and implemented by those agencies. Regarding climate change and human health, researchers suggested interventions and mitigation strategies that would be generated from within the agencies.[113,114]

Already, the European Centers for Disease Prevention and Control created a handbook for use in the international community to address climate change-related infectious disease, which includes extreme temperatures as a communicable disease risk. This is an indication that the international community is subscribing to the new institutional theory and is setting global best practices on the premise that "multiple levels of governance can provide mutually reinforcing opportunities for climate leadership".[115(p441)] This presumption can be critical when discussing anything related to climate change. An agency may have a difficult time convincing policymakers and the general public about the need to address climate change-related disease and overall health implications.

In addition, the US Global Change Research Program identifies the possible influence of climate change on people with Alzheimer's Disease, Asthma, Chronic Obstructive Pulmonary Disease, Cardiovascular Disease, Mental Illness, Obesity, and Disability. For example, Diabetes increases sensitivity to heat stress and medication and dietary needs may increase vulnerability during and after extreme weather events.[116] The US Environmental Protection Agency (EPA) also a fact sheet called *Climate Change and the Health of People with Existing Medical Conditions* that offers information on climate change health risks for specific chronic diseases.[117]

Yet, as there continues to be disagreement between agencies and policymakers about climate change. The research of Friel et al concludes that thoughtful cross-sectional climate policy is

needed to reduce inequities in climate change health impacts.[113] Agencies may need to influence policymakers and the general public for there to be any serious movement towards meaningful public policy. Capon and Rissel suggest that emphasizing the co-benefits of climate change policies on public health may be persuasive to policymakers. One example is that reducing greenhouse gas emissions by creating active transportation (e.g. walking and biking) also may also help people manage their Diabetes. The inverse approach would be a health coach advising a Diabetes patient to engage in active transportation which would have the co-benefit of reducing greenhouse gas emissions.[118]

Next, the literature assumes that public policy follows the process theory, which indicates that there must be a rational process by which agencies come to their public policymaking decisions.[67] This is evidenced by the absence of narrative regarding resources for public health adaptation. Generally, researchers simply state what should occur and why, as though the public policy decisions that will enable those recommendations to occur will be made using a linear, logical process. Often, this process, also described as politics, is less than linear and involves many interests, allegiances, timelines, and priorities. These underlying theoretical frameworks of rational theory and process theory are apparent throughout the literature and may not be reflective of the real-world public policy environment.

Risk for Climate Change-Related Disease

There have been substantial publications about climate change increasing human population risk for disease. The majority of that research falls into two categories: (1) literature reviews, reports, and essays, and (2) case studies discussing specific impacts of climate change to specific diseases. The literature is definitive in its conclusion that there is a causative correlation between climate change and disease or other health impacts. Gislason terms climate change impact on infectious disease a *glocal* issue; that is, a global issue with local impacts.[109]

However, an almost ignored sentiment present in the literature is that the impact of climate change, including extreme heat, may not be negative. The literature review from Liang & Gong found that a disproportionate amount of research was being conducted in areas that are less susceptible to climate variability.[99] Additionally, while Wu et al summarized that “climate change

can affect the transmission of infectious diseases through altering the contact patterns of human-pathogen, human vector, or human host," he also acknowledges that the effects of climate change is tied to unpredictable variables making it difficult to determine what those impacts will be ultimately.[119(p18)] That assertion is substantiated by the focus on weather, temperature, and precipitation in the research of Wang, Soverow, and Keim.[103,105,120]

From this, one could gather that the terminology of *climate change* is somewhat of a misnomer when referencing human health impacts. Generally, it is not the overall climate that will have the most immediate impacts. Rather, it is that the changing climate will create changing weather patterns that will lead to changes in disease patterns, particularly when it comes to diseases of the kidneys.

Another aspect of the intersection between climate change and human health is that each type of weather event such as extreme heat, does not occur in isolation. Extreme heat contributes to the increased frequency of other extreme weather events such as hurricanes, floods, and wildfires that can lead to the spread of infectious diseases like cholera. This is particularly applicable in areas with compromised or underdeveloped infrastructure. People with chronic diseases, including kidney disease, are more likely to contract these communicable diseases and have the most severe reactions. The relationships between extreme weather events as a result of climate change and infectious diseases are shown in Figure 4. Climate change, human infectious diseases, and human society[119].

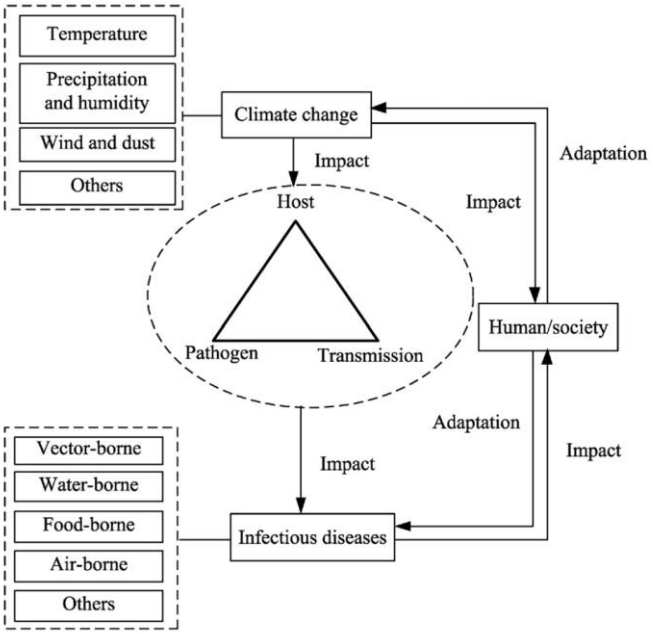


**Figure 4.** Climate change, human infectious diseases, and human society[119]

Much of the research focuses directly on understanding these downstream *glocal* impacts of climate change on infectious disease. Within the US, Kolivras studied risks for the infectious disease dengue in Hawaii and references the work of Schreiber's study of dengue risk in Puerto Rico.[98] Further, Patz et al studied the risk of waterborne infectious disease in the Great Lakes region of the US.[111] One area of recurring interest in the literature was El Nino Southern Oscillation and West Nile Virus (WNV).[121] The WNV research of Soverow et al included Illinois, Pennsylvania, Michigan, Indiana, Ohio, South Dakota, North Dakota, Nebraska, Montana, Wyoming, Idaho, Colorado, Texas, Louisiana, Arizona, California, and New Mexico.[120]

International research spans throughout Europe, China, Canada, and overall global assessments. This disbursement of research location supports the assertion from Liang & Gong regarding the need for research in regions that will see the most impact from climate change.[99] Specifically, Eastern Europe, South America, Africa, Southeast Asia and Australia are not prominent in the literature. Ebi & Barrio attempted to address this issue in the article *Lessons Learned on Health Adaptation to Climate Variability and Change: Experiences Across Low- and Middle- Income Countries* by including focus groups and reports covering: Albania, Arbados,

Bhutan, China, Fiji, Jordan, Kazakhstan, Kenya, Krgyzstan, Philippines, Russian Federation, Tajikistan, and Uzbekistan.[39]

One significant concept throughout the literature is the unpredictability of climate change impacts on weather. In the article, *Climate Change and Infectious Diseases: Can We Meet the Needs for Better Prediction?,* Rodò et al conducted an assessment of existing infectious disease forecasting systems and noted that the weather variability caused by climate change will cause significant challenges in developing accurate predictive models.[110] This aligns with the findings in the article *Changes in Dengue Risk Potential in Hawaii, USA, Due to Climate Variability and Change*, in which, Kolivras asserts that regional vulnerability to dengue has shifted from historically only occurring tropical areas to expanding to Hawaii and Puerto Rico.[98]

The other component of variability that makes disease predictability challenging is that the development of a chronic disease or communicable disease transmission is dependent on many variables. Hoberg & Brooks discuss the relationship between the climate change-related transformations to biodiversity, while Elmer & Meyer discuss the changes to ecology in response to climate change.[122,123] Both sets of research highlight the potential evolution of infectious disease vectors in response to climate change, which would change the transmission of those infectious diseases. Wu et al illustrates the volatility of infectious disease transmission by noting that a weather variations as like the wind [and extreme heat] can be a determining factor in the distribution of an infectious disease.[119]

Rodò et al suggests that previously-eradicated infectious diseases may return, and human populations that historically would have had immunities against those infectious diseases would no longer be immune.[110] Additionally, both Hodges et al and Patz et al reference infrastructure as a risk factor for vulnerability to infectious diseases due to climate change.[124,100] These types of variabilities undermine the ability to create predictive models. This challenge is also intensified when for populations with kidney disease.

Public Policy Implications

Peer-reviewed research regarding the public policy implications of climate change-related impact on human health is less robust. There does not seem to be a recognition of the role of public policy both in identifying disease risk, protecting people with chronic diseases, or in implementing adaptation plans. The National Library of Medicine of the US National Institutes of Health defines *health policy* as, “The development by government and other policy makers of present and future objectives pertaining to health care and the health care system, and the articulation of arguments and decisions regarding these objectives in legislation, judicial opinions, regulations, guidelines, standards, etc. that affect health care and public health.”[125]

In summary, public policy includes laws and regulations that govern how medical professionals and the public engage in health-related activities. One example of the impact of public policy is the ability for policymakers to make funding available. Karjalainen found that, though the European Union has been engaged in public policy on the topic of climate change and infectious disease, that engagement has been limited to the three areas of: nanomaterials safety and risk, lifestyle and socioeconomic determinants of health, and chemical exposure risks.[101] While these areas of focus are important, they do not fully encapsulate the multidimensional nature of the problem of extreme heat and health. Similarly, Ebi & Barrio noted after reviewing the public policy of 13 low-income and middle-income countries that the only way to address the issue adequately was to incorporate the issue ubiquitously throughout all of government and policymaking.[39]

In perhaps the most comprehensive assessment of public policy in this space, the Lancet Commission issued a report called, *Health and Climate Change: Policy Responses to Protect Public Health* in 2015. This report was a global assessment of the current policy approaches and provided recommendations for the subsequent five years. The figure below, taken from the Lancet Commission report, demonstrates the number of issues that contribute to the climate change and infectious disease dynamic, and, in doing so, also highlights the number of public policy areas touched by this single issue.[126]

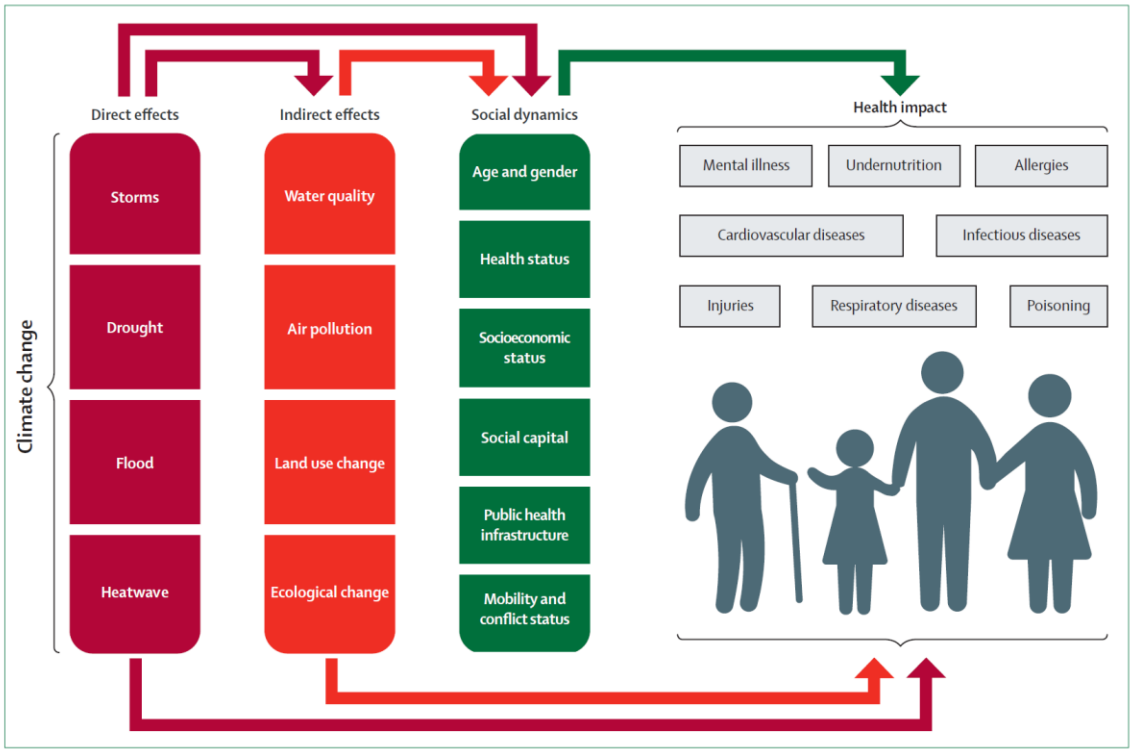


**Figure 5.** The direct and indirect effects of climate change on health and wellbeing[126]

The Lancet Commission report states that "Population growth, urbanisation trends, and migration patterns mean that the numbers exposed to hot temperature extremes, in particular, will increase, with major implications for public health planning."[126(p5)] The Lancet Commission recommends public health investments, one health approaches, surveillance, and monitoring. Ultimately, the Lancet Commission proposes a single, global initiative called *A Countdown to 2030: Global Health and Climate Action*[126]. Such a global initiative would need to incorporate "community-based risk reduction activities" and aging infrastructure.[105(p515)]

Finally, one of the most overlooked areas of research regarding climate change and human health is the underlying ethical considerations. The issue of improved living conditions for the developing world plagues international negotiations regarding climate change overall and may have life-altering consequences for any associated health risk. In the article, *Climate Change Matters*, Cox MacPherson discusses socioeconomic mobility as inextricably linked to climate-harming lifestyles. Essentially, decreasing poverty in much of the world also increases the carbon footprint of that region.[127]

Further, in the book *Climate Justice: Hope, Resilience, and the Fight for a Sustainable Future*, Special Envoy of the UN Secretary-General on El Niño and Climate, Mary Robinson, discusses the plight of indigenous communities around the world including: the Peule-M' Bororo of Chad, the Yupik people of Alaska, and the Saami of Sweden.[128] Within the US, the National Association for the Advancement of Colored People (NAACP) has a series of reports, toolkits, campaigns, newsletters, blog posts, publications, webinars, and videos on the topic of climate justice, which it has identified as a civil rights issue.[129] In its report, *Equity in Building Resilience in Adaptation Planning,* the NAACP lists "persons with pre-existing health conditions" as a *pre-existing vulnerability* to climate change impacts.[130] This concept of climate justice suggests that climate change is a variation of social justice overall.[131]

Although not directly contemplated in the article, this often is an accurate evaluation even in a developed country, where one could climb the socioeconomic rungs by purchasing a car in lieu of using public transportation, purchase a larger home, and otherwise consume more. Yet, the issue that Cox MacPherson discusses is critical, whether the industrialized world that is responsible for climate change should deny those in the developing world the opportunity to build out of extreme poverty. This becomes an increasingly challenging proposition when acknowledging that living in extreme poverty imposes its own set of health risks.[127] While this juxtaposition is not covered sufficiently in the literature, it is critical to any global policymaking and US-based policymaking as both countries and states with higher rates of poverty may be resistant to public policy changes.

Although the actual patterns of climate change-related diseases may be difficult to predict, the literature indicates a movement towards public health preparedness. The literature surrounding public health preparedness focuses on the concept of adaptation, which Panic & Ford define as, "policies, measures and strategies designed to reduce climate change impacts and foster resilience, a concept analogous to the population health notions of primary, secondary and, at times, tertiary prevention."[132(p7084)] In their literature review, Panic & Ford found that the primary classifications of adaptation included: occupational health, vector-, water-, and food-borne diseases, disease monitoring, disease surveillance, and capacity-building[132]. Although their research focused on national-level public health preparedness, the work of English et al and Hess

et al, both of which specifically reviewed state-level public health preparedness and reflected substantial elements of adaptation as Panic & Ford described.[112,104,132]

Within the sphere of public policy, there also are regulations and medical protocols that impact the way that kidney care is delivered. A literature review on these topics included the following search terms: cms policy kidney; cms policies kidney; cms protocol esrd; clinical practice guidelines kidney; clinical practice guidelines renal, clinical practice guidelines, and ckd. The vast majority of the search results were studies of specific guidelines or protocols rather than a global review of the concept of these types of clinical decision-making tools.

On the regulatory side, CMS has numerous policies specific to diseases and treatments. Typically, payment policies are considered significant because providers adhere to those policies to receive payment for the services that they have rendered to patients. In the context of kidney care, CMS accredited providers who are eligible to receive payments include: acute care hospitals, nephrologists, and dialysis facilities. Private insurers may mimic CMS payment policies for their contracted providers, especially if the private insurance company operates a CMS-affiliated managed care product such as a Medicare Advantage plan or a Medicaid MCO (managed care organization) plan.

Regarding clinical guidelines, Kidney Disease: Improving Global Outcomes (KDIGO), a nonprofit organization originally started by the National Kidney Foundation, establishes and publishes evidence-based guidelines. The guidelines are defined through a peer-review process that includes guideline workgroups and controversies conference steering committees. KDIGO then focuses on translating those guidelines into practice across nephrology.[133]

Although clinical practice guidelines and medical protocols are common, there is disagreement as to whether providers should follow them. Upshur argued generally that the rise of clinical practice guidelines directly contradicts the need to provide individualized care. Upshur highlighted the lack of diversity present in the patient populations referenced in most of these guidelines. These issues likely would have a disproportionate impact on kidney patients because of the vulnerable populations impacted, who may not be reflected in those medical protocols.[134]

However, the consensus for kidney-specific protocols is that they are positive. Both Eknoyan and Vassalotti talk about improved health outcomes for kidney patients since clinical practice guidelines were introduced in the early 1990's.[135,136] Yet, both of them also address the process by which the protocols are created, and Vassalotti even refers to a Continuous Quality Improvement (CQI) component built into the *Cycle of Development, Publication, and Implementation of Clinical Practice Guidelines*.[136] Interestingly, Eknoyan discusses the impracticality of nephrologists having to search and read the literature on an ongoing basis to keep up with current research, then decipher and synthesize that information to determine the best practices and how to apply them to their unique patients. Eknoyan also describes the strenuous development process as an attribute of clinical practice guidelines as shown in the following Figure.[135]

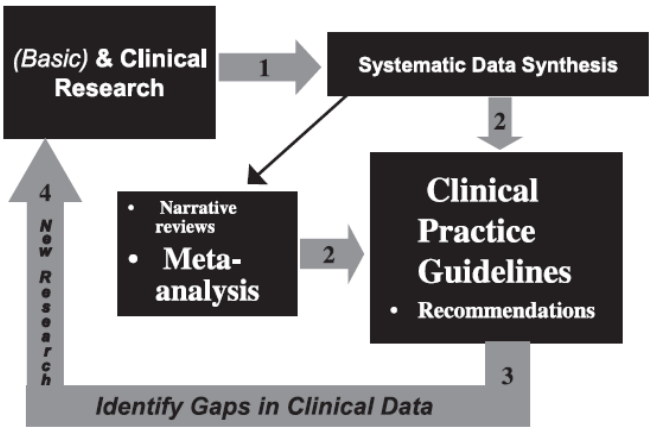


**Figure 6.** Evidence-Based Guidelines[135]

Climate Adaptation and Planning

Climate and Health Adaptation is a specific sub-category of adaptation defined as "The intentional adjustment in natural or human systems to a new or changing environment that exploits beneficial opportunities or moderates negative health effects."[137] Climate and Health Adaptation has three levels, primary, secondary, and tertiary. Primary adaptation is preventing exposure to climate-related events that could have a health impact. Secondary adaptation is reducing the vulnerability of people who have been exposed to climate-related events to potential health impacts. Finally, tertiary adaptation is treating the health impact after exposure.[137]

There are numerous examples of Climate and Health Adaptation planning and implementation at local, state, national, and international levels. For example, the City of Chicago conducted a study that resulted in the following (not exhaustive) recommendations: implement a heat warning system, reduce summer energy use through a home weatherization program, and mitigate erosion along Lake Michigan.[138] In the aftermath of Hurricane Maria, Puerto Rico is exploring the use of solar power, homes with storm-safe roofs, and various land-use modifications as a part of its adaptation planning process.[139]

These anecdotal examples of Climate and Health Adaptation abound. Yet, in 2016, Barrett et al asserted that there simply was inadequate research into climate change-specific public health preparedness[106]. Figure 7 illustrates how a Climate-Health Adaptation model can be applied to extreme heat. The application of this model takes the potential impacts of extreme heat - death, injuries, and illness – and replaces those outcomes with policy implementation and a community-based resource to address vulnerability.[137]


**Figure 7.** General Climate-Health Adaptation Model and Adaptation Model Example for Extreme Heat[137]

Further, Chadwick found that there was a chasm between public health efforts related to climate change and the health communications experts capable of translating that into digestible messaging for the general public to be able to respond.[140] The recent research of Rodò, Barrett and Chadwick indicates that the assessment of Frumkin et al in the 2008 article, *Climate Change: The Public Health Response* that the existing standard public health framework should be used for climate change preparedness has not been fully-implemented in the decade since its publication.[110,106,140,108]

While Barrett, Chadwick, and Rodò may be valid regarding peer-reviewed published research, there are anecdotal examples that Climate and Health Adaptation planning models and programs are being replicated. In fact, the Georgetown Climate Center, in collaboration with the American Society of Adaptation Professionals and other partners, has a digital *Adaptation Clearinghouse.* As with other clearinghouses, the *Adaptation Clearinghouse* offers tested models with resources available for others to implement in their respective communities or for research purposes. One of the six identified sectors is public health, which offers tools, plans, planning guides, education & communication, law & policy, funding information, organizations, and a geographic search.[141]

In total, there are eleven resources available in the Public Health category. This is substantial when compared to other clearinghouses, such as the Substance Abuse and Mental Health Services Administration (SAMHSA) Evidence Based Practices Center, which has 174 resources across four categories in a much more established discipline.[142] Each resource in the Adaptation Clearinghouse has a star rating, an abstract of the resource, and a mechanism to track and save.[141] While all of the resources available in the Adaptation Clearinghouse may not be pulled directly from peer-reviewed journals, they are considered to be evidence-based practices and do reference research in the literature. One example of this is *Conveying the Human Implications of Climate Change*, produced by the George Mason University Center for Climate Change Communication, which lists 98 references.[143]

Climate-Health Adaptation activities such as those included in the Clearinghouse are designed to mitigate the health impact from occurring after exposure to the climate-related event or to help people respond to the exposure. The mitigation process of adaptation actions is shown in Figure 8. The figure shows that adaptation actions interrupts the impacts that climate-sensitive exposure would have – illness, injury, and death. One important way to determine the appropriateness of the adaptation activity is through a calculation of motivation, general capacity, adaptation, and specific capacity.[144]


**Figure 8.** Adaptation Actions Mitigate Impact of Climate-Sensitive Exposure[137]

Overall, there is a combination of evidence-based practices, emerging models, and peer-reviewed research in the burgeoning field of Climate and Health Adaptation. While some researchers suggest that there should be more rigorous and traditional scientific testing, adaption practitioners are moving forward with planning and programming based on what is available today in communities and policymaking spaces globally, and particularly within the US. The process in which adaptation professionals engage is called *adaptive management*. Adaptive management models in Climate and Health Adaptation are not very distinct from each other, let alone climate adaptation or public health adaptations.[70]

The five-step CDC BRACE Framework of adaptive management and the six-step adaptive management model of Hess et al in Figure 9 both include assessments, implementing an adaption action plan, and evaluation.[70,145] The CDC BRACE Framework was used for the Climate-Ready States & Cities Initiative Grants that went to 18 states, not including Nevada. The primary distinction between the two models is that the Adaptation Management Model can be applied to climate change adaptation and to climate-health adaptation.


**Figure 9.** CDC BRACE Framework and Adaptation Management Model[145,70]

Adaptation planning includes a community readiness assessment.[145,70] The Community Readiness model in Figure 10 shows one model of assessment that can be used in tandem with the BRACE Framework or the Adaptation Management Model. The model measures: attitudes, knowledge, efforts & activities, and resources across five dimensions: community knowledge of efforts, community knowledge of issue, community climate, leadership, and resources. Implementer readiness is also critical and focuses on the motivation and the capacity to implement the adaptation plan.[70] The Community Readiness model is one way of determining the type of intervention that should be implemented in a particular community.

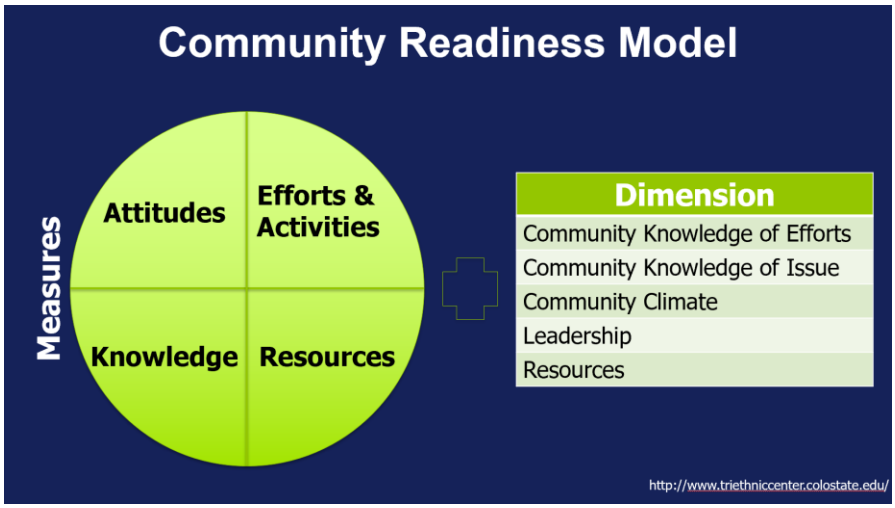


**Figure 10.** Community Readiness Model[137]

# Chapter III

# METHODOLOGY

## Data

This study will analyze two datasets: emergency department use for kidney-related illness and weather data. The emergency department data parameters include a service date range of January 1, 2016-December 31, 2019, patient age group categories of under 65 or 65 and over, patient race, Medicaid payment indicator, treatment county, treatment city, ICD-10 code and kidney disease category for each code. The health data is from the University of Nevada, Las Vegas (UNLV) Center for Health Information Analysis.

The weather data is from the National Centers for Environmental Information, a part of the National Oceanic and Atmospheric Administration and the UNLV Measurement and Instrumentation Data Center. The weather data parameters include daily weather for a date range of January 1, 2016 – December 31, 2019 for all weather stations in Nevada. It is important to note that there was no weather data from Storey County, a rural county with a population of approximately 4,100 people.[146]

Additionally, this study incorporates geocoded files for ArcGIS from multiple sources. Data from the 2018 SVI report was included because it measures social data, housing data, demographic data, and economic data.[91] Other data came from the Homeland Infrastructure Foundation-Level Data, a collaborative data sharing solution aimed at "support[ing] community preparedness, response and recovery, resiliency, [and] research" across the US. Those datasets are public health departments, dialysis facilities, hospitals, Federally Qualified Health Centers, and Indian Health Services.[147] Finally, chronic disease vulnerability was included using data from three categories in the Robert Wood Johnson Foundation's 2020 *County Health Rankings & Roadmaps: Building a Culture of Health, County by County - Length of Life, Quality of Life, and Health Behaviors*.[148]

Instruments

For the purposes of this research, extreme heat will be determined using the Wet Bulb Globe Temperature (WBGT), which measures heat stress on the body and "takes into account: temperature, humidity, wind speed, sun angle and cloud cover (solar radiation)."[149] One study comparing the use of WBGT, heat index, and air temperature to predict health risk found that WGBT had the highest correlation with "significant risks for all-cause mortality, hospitalization due to respiratory diseases, and hospitalization due to heat disorders."[150(p168)] Although Bernard and Iheanacho found that the WGBT does not account for clothing and airspeed and Bud identified activity levels as another limitation, Bernard and Iheanacho "do not recommend using heat index or adjusted temperature instead of WGBT" when screening for occupational heat stress, which aligns with the findings of Morris et al.[151–153(p323)]

The National Weather Service has identified WBGT ranges and their associated heat stress risk as shown in Table 3. This analysis will include any WBGT of 80 or above as extreme heat. Including the lowest level of 80-85 is important because WBGT originally was used in the 1950's in a "successful campaign to control serious outbreaks of heat illness in training camps of the United States Army and Marine Corps."[152(p20)] The US military continues to be use this WBGT to prevent and conduct clinical intervention for heat-related illness, as does the US Occupational Safety and Health Administration in its Heat Hazard Assessment to protect workers.[151,153] as a guide for healthy, active people, not vulnerable populations, and vulnerable populations are the focus of this research.

**Table 3.** Suggested Actions and Impact Prevention[149]

| Suggested Actions and Impact Prevention | | |
|---|---|---|
| **WBGT(F)** | **Effects** | **Precautionary Actions** |
| < 80 | | |
| 80-85 | Working or exercising in direct sunlight will stress your body after 45 minutes. | Take at least 15 minutes of breaks each hour if working or exercising in direct sunlight |
| 85-88 | Working or exercising in direct sunlight will stress your body after 30 minutes. | Take at least 30 minutes of breaks each hour if working or exercising in direct sunlight |
| 88-90 | Working or exercising in direct sunlight will stress your body after 20 minutes. | Take at least 40 minutes of breaks each hour if working or exercising in direct sunlight |
| >90 | Working or exercising in direct sunlight will stress your body after 15 minutes. | Take at least 45 minutes of breaks each hour if working or exercising in direct sunlight |

The challenge with using the WBGT is that it is not typically included in standard weather data reports. Dimiceli et al and Haijzadeh et al both identify the following formula to calculate the WBGT: $WBGT = .7NWB + .2GT + .1DB$, where *NWB* is *nature wet bulb temperature*; *GT* is *globe temperature;* and *DB* is *dry bulb temperature*.[154,155] Weather stations include the wet bulb temperature and the dry bulb temperature as standard metrics. However, globe temperature is not included routinely. The globe temperature was calculated using a formula from Haijzadeh et al using the variables of dry bulb temperature, solar radiation, and relative humidity.[155]

In the article, *Offering a Model for Estimating Black Globe Temperature According to Meteorological Measurements*, Haijzadeh et al state that the "model is suitable for estimating black globe temperature in hot and dry areas" and that it "may be applicable for assessing the heat stress in the outdoor thermal environment for public health purposes."[155(p307)] Since solar radiation was not included in the data collected from the weather stations shown in Table 3, it was collected from the University of Nevada, Las Vegas (UNLV) Measurement and Instrumentation Data Center.[156]

**Table 4.** Weather stations utilized in this study

| Weather Station Code | Weather Station Name |
|---|---|
| WBAN: 24128 | Winnemucca, NV |
| WBAN: 94190 | Silver Zone, NV |
| WBAN: 53145 | Tonopah Test Range #74, NV |

| | |
|---|---|
| WBAN: 23153 | Tonopah Airport, NV |
| WBAN: 00279 | Reno Stead Airport, NV |
| WBAN: 23185 | Reno/Cannon International Airport, NV |
| WBAN: 03160 | Desert Rock, NV |
| WBAN: 53136 | Mercury, NV |
| WBAN: 23169 | Las Vegas/McCarran International Airport, NV |
| WBAN: 24172 | Lovelock/Derby Field, NV |
| WBAN: 23112 | Nellis Air Force Base, NV |
| WBAN: 53127 | Henderson Executive Airport |
| WBAN: 53138 | Baker, NV |
| WBAN: 24119 | Battle Mountain/Lander County, NV |
| WBAN: 00269 | Boulder City Municipal Airport, NV |
| WBAN: 00171 | Carson City, NV |
| WBAN: 04139 | Denio, NV |
| WBAN: 24121 | Elko Municipal Airport, NV |
| WBAN: 23154 | Ely/Yelland Field, NV |
| WBAN: 03170 | Eureka/Amos, NV |
| WBAN: 00170 | Eureka Airport, NV |
| WBAN: 93102 | Fallon/NAAS, NV |
| WBAN: 23141 | Indian Springs, NV |
| WBAN: 53123 | North Las Vegas Airport, NV |

The number of emergency room or emergency department (“ED”) visits include ICD-10 codes related to kidney disease, shown in Table 4. The data includes the date of admission, age, gender, race, and metropolitan area of the patients. This data is from the UNLV Center for Health Information Analysis.[157]

**Table 5.** ICD-10 Codes utilized in this study[158]

| Category | Code and Description |
|---|---|
| Cysts of Kidney | • N13.30 – Hydronephrosis<br>• N28.1 – Kidney cyst, acquire<br>• Q61.02 – Multicystic kidney<br>• Q61.3 – Polycystic Kidney, unspecified<br>• Q61.5 – Nephronopthisis<br>• Q61.9 – Cystic Kidney Disease |
| Chronic Renal Disease | • N18.1 – Chronic Kidney Disease Stage I<br>• N18.2 – Chronic Kidney Disease Stage II<br>• N18.3 – Chronic Kidney Disease Stage III<br>• N18.4 – Chronic Kidney Disease Stage IV<br>• N18.5 – Chronic Kidney Disease Stage V<br>• N18.6 – End Stage Renal Disease<br>• N18.9 – Chronic Kidney Disease, unspecified |
| Infections and Inflammation | • N00.9 – Acute glomerulonephritis, Acute nephritis<br>• N02.2 - Membranous nephropathy<br>• N02.8 - IgA nephropathy<br>• N03.9 - Chronic glomerulonephritis<br>• N05.5 - Membranoproliferative nephritis<br>• N05.8 - Proliferative nephritis<br>• N05.9 - Glomerulonephritis, unspecified; Nephritis, unspecified<br>• N10 - Acute pyelonephritis w/o renal medullary necrosis<br>• N17.2 - Acute pyelonephritis with renal medullary necrosis<br>• N11.9 - Chronic pyelonephritis w/o renal medullary necrosis<br>• N17.2 - Chronic pyelonephritis with renal medullary necrosis<br>• N12 - Pyelonephritis, unspecified<br>• N15.9 - Kidney infection, Renal infection<br>• N28.9 – Nephropathy, unspecified |
| Kidney Stones | • N20.2 – Kidney stone<br>• N20.0 Renal calculus<br>• Q63.8 – Congenital kidney stone |
| Other Kidney Diseases | • N18.9 - Chronic renal insufficiency<br>• N28.1 – Solitary Kidney<br>• N28.81 – Hypertrophy of kidney<br>• N28.89 – Floating kidney<br>• N28.9 – Acute Renal Insufficiency, Kidney disease, Renal disease |
| Renal Dialysis | • Z49.01 – Removal of renal dialysis catheter<br>• Z91.15 – Noncompliance with renal dialysis<br>• Z99.2 – Peritoneal dialysis, Renal dialysis, Renal dialysis status |
| Renal Failure | • N17.0 – Acute tubular necrosis<br>• N17.2 – Necrotizing renal papillitis<br>• N17.9 – Acute renal failure<br>• N19 – Kidney failure; Renal failure, unspecified<br>• N26.1 – Renal atrophy<br>• N26.9 – Renal cirrhosis, Renal sclerosis |
| Hypertensive Chronic Kidney Disease | • I12.0 - Malignant hypertensive chronic kidney disease with chronic kidney disease, Stage V or ESRD<br>• I12.0 - Benign hypertensive chronic kidney disease with chronic kidney disease, Stage V or ESRD<br>• I12.0 - Unspecified hypertensive chronic kidney disease with chronic kidney disease, Stage V or ESRD |

| | |
|---|---|
| | • I12.9 - Malignant hypertensive chronic kidney disease with chronic kidney disease, Stage I-IV or NOS<br>• I12.9 - Benign hypertensive chronic kidney disease with chronic kidney disease, Stage I-IV or NOS<br>• I12.9 - Unspecified hypertensive chronic kidney disease with chronic kidney disease, Stage I-IV or NOS<br>• I13.0 - Malignant hypertensive heart and chronic kidney disease with heart failure and chronic kidney disease, Stage I-IV or NOS<br>• I13.0 Benign hypertensive heart and chronic kidney disease with heart failure and chronic kidney disease, Stage I-IV or NOS |

Additionally, the study used geospatial software and technology, ArcGIS, to create a map showing the potential impact of increased emergency room incidence rates for patients according to a scored level of risk. ArcGIS is the standard GIS software used in Public Health and is at the center of the CDC GIS Training Curriculum.[159]

Climate Change and Health Adaptation data was obtained using information from the CDC's Climate and Health Program, which identifies cities and states that have received funding and support to implement recognized adaptation programs and strategies. The programs include: CDC's Climate-Ready States and Cities Initiative, Building the Capacity of the Public Health System to Improve Population Health through National, Nonprofit Organizations, Climate-Ready Tribes Program, Interactive Climate Adaptation Map, and the Climate-Ready Tribes Mini-Grant Program.[33] For Nevada to prepare adequately for the impacts of extreme heat on human health, it would be critical for the state to participate in these national programs.

Finally, there were several data sources for a qualitative public policy analysis. The sources included the Nevada Revised Statutes (NRS) – laws passed by the Nevada Legislature. Also, this study reviewed information from the Nevada Administrative Code, which are the regulations used to implement the NRS. CMS policies and clinical practice guidelines also were sources of data for review and analysis. Guideline Central and publications from the National Kidney Foundation were important to finding and interpreting clinical practice guidelines.

Procedures

CDC SVI data was used to identify geographic areas of social vulnerability, scored at high risk for SVI total flags greater than or equal to 20, moderate risk for SVI total flags from 10-20), low risk for SVI total flags 1-9, or no risk for SVI total flags of -999-0.[160] Additionally, public health

infrastructure was measured by identifying the presence of acute care hospitals, public health departments, Federally Qualified Health Centers, and Indian Health clinics.[161–164] The public health infrastructure also was given a score of no risk, low risk, moderate risk, and high risk.

All data was scored at the zip code level, with the exception of the chronic disease risk, which was identified by combining the *Length of Life, Quality of Life, and Health Behaviors* categories of the Robert Wood Johnson Foundation County Health Rankings and Roadmap.[148] A County health ranking score of 1-4 was low risk; 5-11 was moderate risk, and 12 or more was high risk. The physical accessibility of dialysis treatment facilities was considered as a vulnerability factor because any missed treatments can exacerbate the impact of dehydration and otherwise stress kidney function. Each of the types of risk was included in a weighted average: SVI – 40% weight, County Rankings – 40% weight, Public Health Infrastructure – 15% weight, and Dialysis Facilities – 5%.This required geocoding all sets of data by attaching a specific location to each datum point.

In keeping with Public Health industry standards, maps generated in this study conformed with the CDC Cartographic Guidelines for Public Health (CGPH). The CGPH is a set of best practices, primarily dealing with formatting maps for consistency and ease-of-use throughout the Public Health professional community. Both elements, consistency and ease-of-use, are important to the quality of maps so that they can be used as the bases for decision-making. The CGPH were created by a specially-assigned committee of the Geography and Geospatial Science Working Group, which is a part of the CDC and the Agency for Toxic Substances and Disease Registry. Formatting elements covered in the CGPH include: display of quantitative data, display of quantitative data, appropriate color contrast for visual hierarchy, and map accessibility for individuals with disabilities.[80]

A final recommendation in the CGPH is to aggregate identifiable data as much as possible to avoid confidentiality violations of the Health Insurance Portability and Accountability Act of 1996 (HIPAA) Privacy Rule. For example, using public health data to map the residences of individuals with ESRD could prove problematic if someone were able to identify the homes, causing a HIPAA Privacy Rule violation. Sometimes, cartographers may not have a map set to a view showing the

individual data, but the risk still remains. To avoid HIPAA concerns altogether, this study did not use identifiable data and adhered to the minimum cell size standard.[80]

Additionally, the CGPH recommends using geomasking techniques to avoid personal identifiable pinpoints on maps. In this context, *geomasking* techniques to protect confidentiality. Suggested geomasking techniques are, aggregating data across geographic areas like census tracts, calculating point densities, or shifting point locations. This study did not use the emergency department use data in the geospatial analysis at all and used zip codes and counties as the geographic areas.

The geospatial analysis visually demonstrates the areas of Nevada that are at high-risk for increased incidence rates of kidney-related emergency room visits when excessive heat occurs along with existing adaptation. This is a tool that public health professionals and policymakers can use to target Climate Change and Health adaptation resources. The geospatial analysis technique used to identify those high-risk locations was the weighted average scoring system described above.

For example, researchers used geospatial analysis to investigate the high incidence of End Stage Renal Disease in agricultural regions of California using ArcGIS. The findings were presented in a heat map that revealed a correlation between environmental risks related to agriculture and unexplained ESRD. The use of geospatial analysis was particularly effective in visualizing the results of the analysis.[165] This study used a similar approach, using a heat map analysis to show the areas of risk on a spectrum from highest risk in yellow and lowest risk in blue. The scores by zip code and county were geocoded prior to mapping the levels of risk across the state.

Finally, improving policy would help create the infrastructure needed to advance Climate-Health Adaptation. Therefore, the study included a public policy analysis at state and local levels as they related to areas deemed at-risk. The CDC Policy Analytical Framework, also called the *POLARIS Policy Process,* is a comprehensive way of approaching public policy needs and the efficacy of those policies. The various steps: problem identification, policy analysis, strategy and policy development, policy enactment, policy implementation, are paired with the continuous

activities of stakeholder engagement/education and evaluation. This study incorporates the problem identification and policy analysis steps to the extent applicable.[166]

The first phase of the policy analysis is to identify the problem that should be addressed through public policy. In this scenario, the problem of kidney-related emergency department use secondary to climate change was established through the data analysis. The implementation of adaptation best practices also will be established through analysis. The next domain in the Policy Analysis Process is the actual policy analysis.[166]

The policy analysis begins with identifying the policy options that would address the identified problem(s) and describing those options. Policy options can be derived from “reviewing literature on the topic; surveying best practices; and conducting an environmental scan to understand what other jurisdictions are doing". Any policy options must be assessed for appropriateness and feasibility in the applicable Nevada jurisdiction(s).[166]

Analyses

Statistical analyses testing the hypothesis was conducted using SAS Studio statistical software. Essentially, the study was seeking to identify a correlation between extreme heat and emergency department visits for kidney-related illnesses during the January 1, 2016 – December 31, 2019 period. The beginning date of January 1, 2016 was chosen to avoid challenges and inaccuracies stemming from combining ICD-9 and ICD-10 data. The transition from ICD-9 to ICD-10 happened during the final quarter of 2015.

The levels of heat came directly from the strata in Figure 13. Prior to analyzing the data in SAS Studio, a random sample of the WBGT and corresponding ED visit count data were identified in Excel by categorizing the data according to the color-coded heat exposure level (Figure 13) then using the $= rand(\ )$ formula to select from each level. Next, a distribution analysis in SAS Studio found that the data followed a normal curve, and that was followed by the correlation analysis. The correlation analysis was used to test the Null Hypothesis and the Alternate Hypothesis, and the parameters were as follows:

- Data

        - Date of admission: January 1, 2016 – December 31, 2019
        - Variables
            - INDEPENDENT Climate change – Temperature as represented by WBGT
            - DEPENDENT – Emergency department visits in Nevada during extreme heat episodes as identified and categorized in Table 4[158]
- Statistical parameters
    - Observations, N=161
    - Significance testing, p-value $\alpha = .05$

The geospatial risk analysis was completed using ranked scores across SVI, public health infrastructure, dialysis center proximity, and county health rankings. The final data was geocoded and analyzed as a heat map in ArcGIS Pro. The heat map shows four levels: no risk, low risk, moderate risk, and high-risk areas.

The policy analysis steps were completed by reviewing the programs, initiatives, and recommendations from the CDC's Climate and Health Program and identifying which, if any, have been implemented in Nevada. This included the *CDC's Climate-Ready States and Cities Initiative, Building the Capacity of the Public Health System to Improve Population Health through National, Nonprofit Organizations, Preparing for the Regional Health Impacts of Climate Change in the United States, Climate-Ready Tribes Program, Interactive Climate Adaptation Map, and the Climate-Ready Tribes Mini-Grant Program*.[167–171] Additionally, recommendations from the Governor Jim Gibbons' Nevada Climate Change Advisory Committee Final Report document were reviewed to determine if they had been implemented since its release in 2008.[60]

# Chapter IV

# RESULTS

Hypothesis testing was completed for a random sample of the date parameters of January 1, 2016-December 31, 2019 using a correlation analysis followed by a linear regression in SAS Studio to determine if there was any correlation between the kidney-related emergency room visits, using the ICD-10 codes from Table 4 and the WBGT scale in Table 3. Data used to calculate the WBGT came from the National Centers for Environmental Information and the UNLV Measurement and Instrumentation Data Center.[172] The emergency department data came from the UNLV Center for Health Information Analysis.[157]

The correlation analysis indicated that there was a positive relationship between the WBGT and the Total Emergency Room visits for kidney disease, r= .76, p<.0001. The scatter plot with the linear regression line are shown in Figure 11. While the linear regression and equation are shown in Figure 12. The linear regression equation for this model is Y=1.5612x-15.571. Where Y=the predicted ED Visits, the slope is 1.512 of ED Visits per WBGT degree, and the intercept is -15.571. The model predicts that each additional degree of WBGT is associated with an additional 1.5612 ED Visits. The WBGT would be at -15.571 for there to be 0 ED Visits.

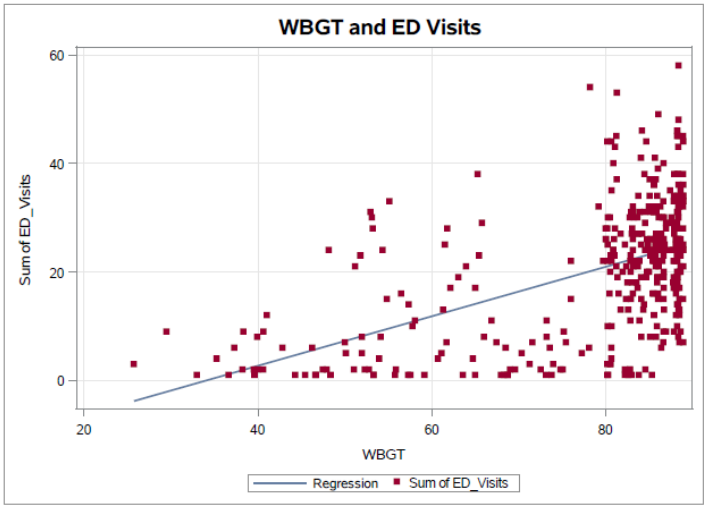


**Figure 11.** Positive Correlation between WBGT and ED Visits for Kidney Illnesses

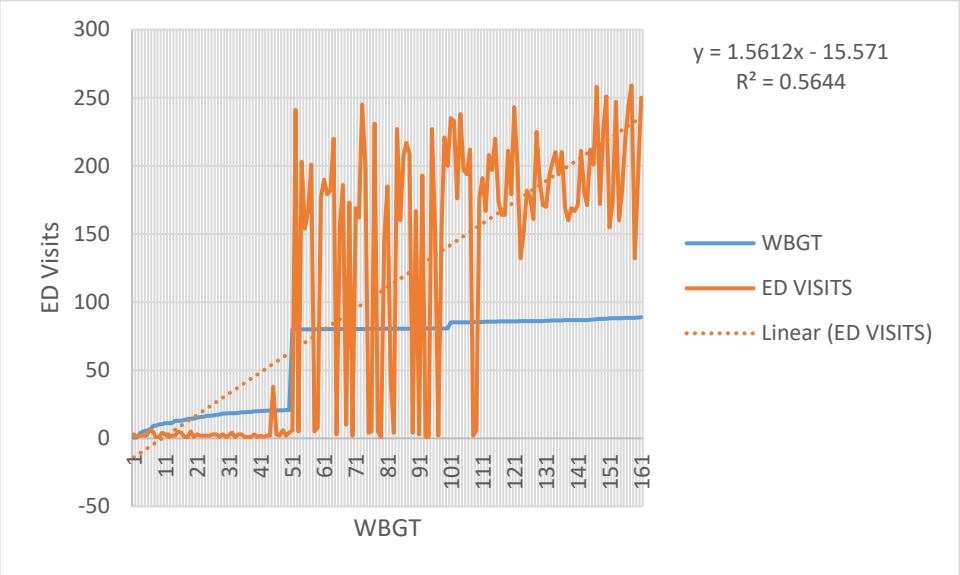


**Figure 12.** Linear Regression Equation Showing Relationship between WBGT and ED Visits

Based on the results of the correlation analysis, linear regression, and p-value level of significance, the Null Hypothesis there is no relationship between extreme heat and emergency department visits for kidney-related illness was rejected. Additionally, the Alternate Hypothesis, that there is a positive relationship between extreme heat and emergency department visits for kidney-related illness was accepted.

The hotspot geospatial analysis, shown in Figure 16, indicates that the geographic region where people with the highest level of susceptibility to kidney-related illness as the temperature increases is the Las Vegas metropolitan area of Clark County, extended out into Nye County in bright yellow. The second area of vulnerability concentration is in the Reno and Carson City area of the state. The Elko region has a concentration of low-level vulnerability, as indicated in blue.

It is also important to note that there are large, rural areas of the state that do not have any identified vulnerability. However, even in those areas, Indian reservations, which are outlined in bold black, indicate some level of vulnerability. The exceptions are the Goshute Reservation and the Summit Lake Reservation, which do not have any vulnerability indicated through this analysis.

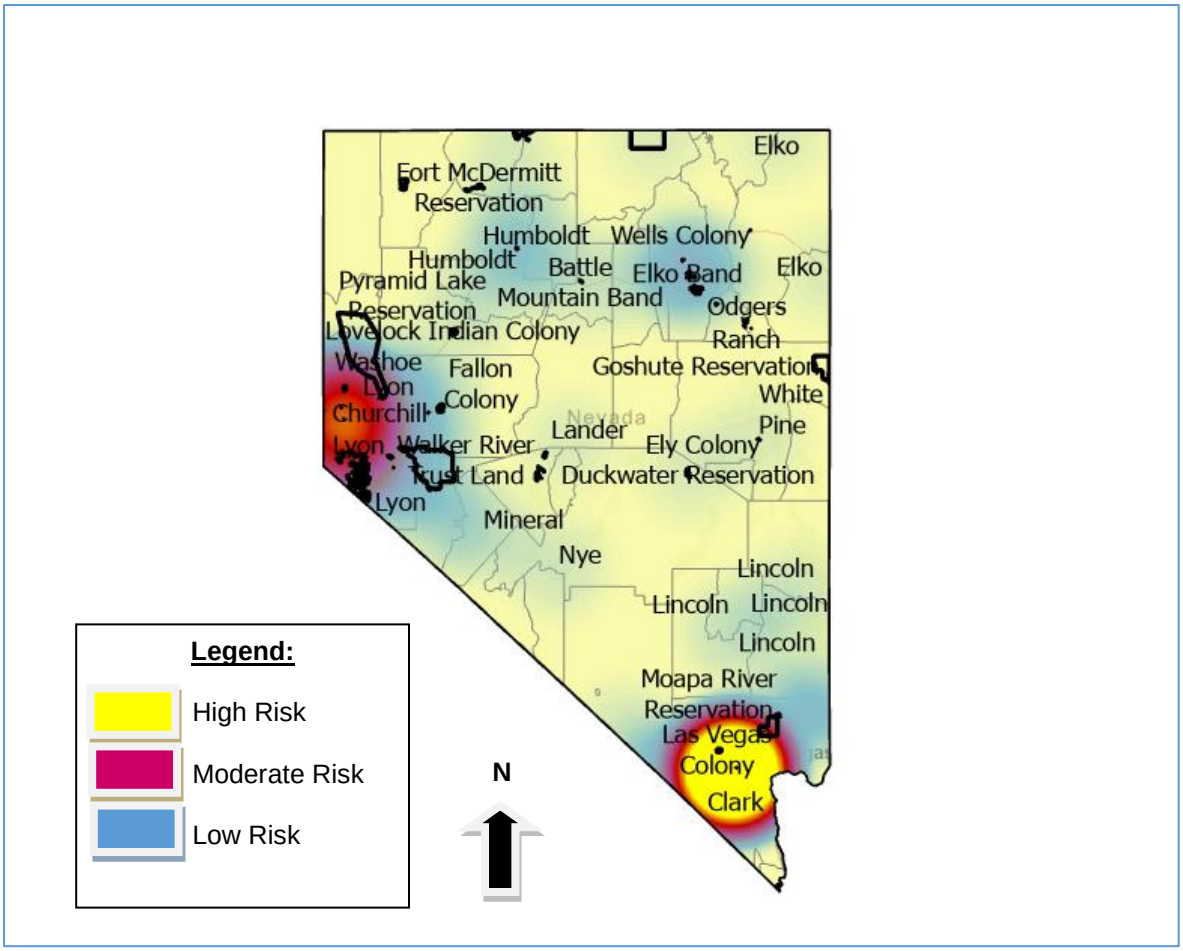


**Figure 13.** Heatmap of Risk in Nevada

Upon reviewing the climate and health adaptation initiatives and programs through the CDC's Climate and Health Program, Nevada as a state, including its counties and cities, have not implemented any of the recommended programs. This means that the entities and individuals in regions of vulnerability identified in the geospatial analysis are not prepared to respond to this risk adequately. Although, one of the strategies in the technical report series, *The Use of Cooling Centers to Prevent Heat-Related Illness: Summary of Evidence and Strategies for Implementation* describes the benefits of using cooling centers, which Nevada has implemented. However, the cooling centers in Nevada do not reflect the recommendations of this technical report nor the findings of the peer-reviewed literature on cooling center effectiveness.[173] In the end, cooling centers represent a singular way that Nevada has taken steps towards the implementation of a CDC Climate and Health Program recommended practice.

Further, *Governor Jim Gibbons' Nevada Climate Change Advisory Committee Final Report* had 27 recommendations in the categories: electricity, residential/commercial/industrial, transportation, waste management, agriculture, and other.[60] Of those recommendations, approximately two-thirds were implemented in some way or have been expanded upon in recent years. For example, the *Gibbons' Report* stated that "increasing the RPS standard beyond the 20% required by 2015 to 25% by 2020 is also an option for reducing electricity consumption in the state."[60(p28)] As recently as 2019, the Nevada Legislature passed a law setting a 50% Renewable Portfolio Standard (RPS) for renewable energy adoption for utility companies.[174]

Yet, perhaps the most significant recommendation that there be a "State Climate Action Plan for Nevada that will set objectives and performance standards for activities related to the reduction of greenhouse gases" was never completed. There may be some momentum "to move forward over the next year [2019-2020] towards a climate action plan."[60,175] There also may be renewed interest in moving forward on climate policies with the appointment of the state's first Climate Policy Coordinator, Dr. Kristen Averyt.[176]

Finally, a review of the following clinical practice guidelines indicated that there was no mention of disease management for kidney disease that relates to taking precautions during extreme heat or the possible health impacts of heat exposure.

- Clinical Practice Guidelines and Clinical Practice Recommendations for Diabetes and Chronic Kidney Disease[177]
- KDIGO Clinical Practice Guidelines for Acute Kidney Injury[178]
- KDIGO Clinical Practice Guideline for Glomerulonephritis Clinical Practice Guidelines[179]

Additionally, the commentaries *KDOQI US Commentary on the 2012 KDIGO Clinical Practice Guideline for Acute Kidney Injury* and *KDOQI US Commentary on the 2012 KDIGO Clinical Practice Guideline for the Evaluation and Management of CKD* did not mention heat-related illness risk.[178,180]

# Chapter V

# DISCUSSION

Nevada is at significant risk of kidney-related illness related to extreme heat. There are three primary factors contributing to this risk: the substantiated positive correlation between WBGT and emergency department visits for kidney-related illness, the increasing heat across the state linked to anthropogenic climate change (and to a lesser extent natural global warming cycles), and the vulnerability of the state's most populous geographic areas as shown through the geospatial analysis.

The literature has established that there is a strong relationship between social vulnerability specifically, with indicators such as income, housing, and race. That social vulnerability combined with the lack of health resources or public health infrastructure and negative chronic disease indicators may leave many Nevadans without the ability to respond to extreme heat and health care or medical needs. Therefore, this study added the factors of public health infrastructure, access to dialysis facilities, and chronic disease indicators.

The results of this research align with the current literature, which was the basis of the hypotheses. Several studies have demonstrated some relationship between heat and kidney-related illness. However, those studies generally have been in global, non-US settings, and the few that have been in the US often are not representative of Nevada's demographic and ecological profile. This study augments the current science by addressing that profile and including social vulnerability data, several indicators of access to care, and indicators of overall health status as a proxy for chronic disease vulnerability.

Understanding the specific risks and outcomes using these risk factors for vulnerable populations in Nevada is increasingly important as the general population across the US begins to mirror the majority-minority population already in Nevada. This is occurring more rapidly than expected, with the white population below 50% in 293 counties spanning states from Washington

to North Carolina in 2018.[181] State and local governments will need to assess this risk to determine the best climate-health adaptation activities to implement and how to evaluate their efficacy in a culturally and linguistically competent way.

Further, this study used the WBGT to stratify the heat risk, a type of data that more closely aligns with the stress that heat places on the human body than the frequently-used heat index metric. However, WBGT is not included in routine weather data, and calculating it is challenging and slightly imprecise because it is not being collected directly in the environment. The WBGT was calculated using an equation established in the literature as an adequate proxy for direct WBGT data that includes solar radiation as a variable, which also is not included in routine weather data.[154,155] The National Solar Radiation Database had data available through 2017, which did not meet the date parameter criteria for this study.[182] Ultimately, the data was available from the NREL Solar Research Laboratory at the University of Nevada, Las Vegas, and the study incorporated the WBGT data instead of heat index.[156]

While Nevada has not been engaged in the implementation of climate and health adaptation initiatives and programs through CDC's Climate and Health Program or those identified in the Adaptation Clearinghouse, the state has moved forward with many of the recommendations from the *Governor Jim Gibbons' Nevada Climate Change Advisory Committee Final Report*, as evidenced in the NRS and NAC. This may indicate that Nevada policymakers are more responsive to Nevada-specific recommendations and resources. It also means that Nevada has not been awarded the federal funding needed to implement the evidence-based initiatives and programs. In a state with limited sources of revenue to compared to other states, such as: no corporate income tax, no taxes on corporate shares, no personal income tax, and no inheritance or gift tax, securing federal funding would be critical to achieve robust climate and health adaptation planning and implementation in areas of high risk.[183]

Additionally, the analysis of various clinical practice guidelines demonstrated that nephrologists and other nephrology providers, overall, are not incorporating awareness of extreme heat as a risk factor for emergency department visits. This is glaring when it comes to *Clinical Practice Guidelines and Clinical Practice Recommendations for Diabetes and Chronic*

*Kidney Disease* because of the relationship between Diabetes and dehydration.[117,177] The issue of emergency department use for kidney care is important for the bottom line of some nephrology practices and hospitals as value-based reimbursement policies become continue to expand.[184] KDIGO does not contemplate the need for nephrologists to be aware of heat as a risk factor for kidney disease.[185]

# Chapter VI

# SUMMARY AND CONCLUSIONS

## Summary

This research contributes to the burgeoning interdisciplinary field of Climate Change and Human Health. Currently, there is a need for research in this area of study to help us understand and respond to the impact that climate change is having today. Research in Climate Change and Human Health also will help decision-makers at international, federal, state, local, community, and family levels to prepare for the coming decades. An example of this is the policy recommendations that stem from the statistical analysis, geospatial analysis, and the public policy analysis that comprised this study.

## Conclusions

This study revealed a significant linear relationship between extreme heat and emergency department visits for kidney-related illness. The knowledge of this relationship can inform public policy, medical professional awareness, and messaging to the general public about preventive measures and disease self-management. Public policy can be impacted at all levels, focusing on adaptation and implementing nationally-recognized models in the high-risk areas identified in the geospatial analysis.

Medical professionals can use this information to educate patients, to prepare emergency rooms for kidney-care capacity during high-heat weather forecasts, and to engage in the issue of climate change. The results of this study will be particularly useful when communicating to people with Diabetes, Hypertension, or existing kidney disease so that they can take precautions by limiting exposure during heat warnings.

## Recommendations

This study included a qualitative review of public policy related to climate change and human health and heat and kidney-related illness. Since the previous advisory committee by Governor Gibbons was impactful for policy change, Nevada's current governor, Steve Sisolak, should define the role of his appointee, the Climate Policy Coordinator. There also should be an advisory board charged with developing specific policy recommendations. Unlike the previous report, these recommendations should be tied to detailed timelines, aligned with the biennial legislative and budget cycle. After making the formal policy recommendations, the advisory committee should transition into an action planning and implementation workgroup.

Incorporating public health expertise will be important to this process. That public health expertise must encompass health disparities and social vulnerability in addition to other elements such as: health communications, program evaluation, behavior change theory, and implementation science. The two aspects –environmental and climate change science and public health acumen must work in tandem to be effective.

Medical professionals also need to be educated about the intersection between climate change and health to use this information in clinical decision-making. State licensing boards should require training as a prerequisite to initial or renewal licensure. The Nevada System of Higher Education Board of Regents should mandate a course on climate change and health for all health sciences programs at four-year institutions. All trainings and courses should focus on incorporating climate and weather-related information into medical practice.

In summary, Nevada should move forward with the following policy recommendations:

- Defining the role of the new Climate Policy Coordinator that would report directly to the Governor as an advisor
- Appointing an advisory board to
    - Advise the Climate Policy Coordinator
    - Conduct surveillance activities and identify geographic areas and populations at risk for climate-related health impacts

    - Use the CDC BRACE Framework (Figure 9), Adaptation Management Model (Figure 10), and Community Readiness Model (Figure 11) to determine interventions and activities to recommend
    - Recommend specific interventions from national resources, evidence-based and best practices, including recommendations for the Governor's proposed budgets
    - Consist of public health professionals, climate experts, public policy experts, and members of the general public who do not also fit into any other category
    - Transition to an implementation workgroup that will report to the Climate Policy Coordinator to assure that all accepted recommendations are implemented to fidelity
- Require training as a condition of licensure for medical professionals
- Require training for all health science curricular programs at all public four-year institutions
- Require health plans operating in the state to cover the costs of kidney-related visits, diagnostics, patient education, and treatment during heat episodes when other clinical criteria are not met

Future Work

The geospatial analysis indicated that the most urban areas of Nevada were also the most at risk. Future work may focus on the impact of urban heat islands and vulnerability factors. Preliminary research could use Macropolitan and Metropolitan geocoded data available from the US Census Bureau to determine if more granular research is warranted. A more detailed analysis would compare paved, more densely populated areas to those that are more rural and less developed, even within urban communities. An overlay analysis of vulnerability factors would help identify the risk of kidney-related emergency department visits by geographic region. This type of analysis also should occur outside of Nevada to identify high-risk areas in other states.

One limitation of this research is that it is based on data before the COVID-19 pandemic occurred. At the time of this study, the pandemic is ongoing with minimal reliable predictions. This is significant particularly for Nevada, where the Brookings Institute and Moody's Analytics found

that Nevada's largest metropolitan area, Las Vegas, is in the top 5 for cities with high-risk jobs at 33.8% shown in Table 5.[186]

**Table 6.** Metropolitan areas by share of jobs in industries at high risk from COVID-19

TABLE 2

**Top 15 and bottom 5 metropolitan areas by share of jobs in industries at high risk from COVID-19**
2019

| Rank | Metro area | Jobs, 2019 | Share of jobs, 2019 |
|---|---|---|---|
| 1 | Midland, TX | 46,618 | 42.5% |
| 2 | Kahului-Wailuku-Lahaina, HI | 32,092 | 40.4% |
| 3 | Atlantic City-Hammonton, NJ | 44,227 | 34.2% |
| 4 | Las Vegas-Henderson-Paradise, NV | 342,050 | 33.8% |
| 5 | Odessa, TX | 26,853 | 33.3% |
| 6 | Laredo, TX | 30,500 | 29.7% |
| 7 | Ocean City, NJ | 12,392 | 29.7% |
| 8 | Houma-Thibodaux, LA | 24,560 | 29.3% |
| 9 | Myrtle Beach-Conway-North Myrtle Beach, SC-NC | 48,179 | 29.2% |
| 10 | Flagstaff, AZ | 17,288 | 27.5% |
| 11 | Orlando-Kissimmee-Sanford, FL | 342,495 | 27.3% |
| 12 | Brunswick, GA | 11,146 | 26.0% |
| 13 | Savannah, GA | 43,660 | 24.7% |
| 14 | East Stroudsburg, PA | 14,026 | 24.6% |
| 15 | Gulfport-Biloxi-Pascagoula, MS | 36,613 | 24.0% |
| ... | ... | ... | ... |
| 378 | El Centro, CA | 6,360 | 10.1% |
| 379 | Jefferson City, MO | 7,596 | 10.0% |
| 380 | Elkhart-Goshen, IN | 13,091 | 9.6% |
| 381 | Yakima, WA | 10,556 | 9.2% |
| 382 | Madera, CA | 4,632 | 9.1% |
| | **Total** | **24,241,000** | **16.5%** |

Source: Zandi, "COVID-19: A Fiscal Stimulus Plan," (Moody's Analytics, 2020) and Brookings analysis of Emsi data

B | Metropolitan Policy Program at BROOKINGS

Unemployment claims filed in Nevada totaled 528,350 from March 14, 2020 to June 27, 2020.[187] Meanwhile, the State of Nevada "is estimating a $1.3 billion shortfall" due to the resort industry shutdowns in the wake of COVID-19.[188] A slow economy for individuals while state and downstream local governments cut social services to mitigate the budget shortfall may increase vulnerability substantially, impacting the results of the geospatial analysis in this study significantly. It also could change the way that people use emergency departments or otherwise seek medical attention due to a decrease in financial resources or transportation to access preventive or secondary care. An increased number of people could lose their employer-sponsored medical insurance coverage as well. Future research should look at the economic and social impact of COVID-19 on the topic of emergency use for kidney-related illness during extreme heat episodes.

Future research should compare the population demographics and ecological profile of Nevada to other parts of the world for applicability. While other parts of the world may not have the same policy levers, they can take action to mitigate emergency department visits for kidney-related illness during extreme heat episodes. This could be especially relevant in areas where there is an arid desert environment or in areas where people have more arduous, outdoor occupations.

Also, future research can look at the types of kidney-related illness that are most highly correlated with the WBGT. This would be useful for clinicians, health educators, and people with CKD or ESRD to engage in appropriate disease management strategies during extreme heat episodes. From a policy perspective, this data also would help enhance the recommendation to modify existing clinical protocols and guidelines, which may include nutrition guidance.

Finally, Nevada Medicaid was one aspect of public policy that this study did not encompass fully due to limitations in the data. This research has the potential to reduce emergency department volume for kidney-related illness, which could be of interest to Nevada Medicaid from a cost-savings perspective. Future research would need to investigate the leadership hierarchy, decision-making hierarchy, and influencers such as the Nevada Legislature to evaluate how the predictive model from this study could be used to reduce the need for emergency department visits.

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