AN EPIDEMIOLOGICAL STUDY OF MICHIGAN OCCUPATIONAL BURNS: THE POSITIVE CORRELATION BETWEEN MEN AND SEVERE BURN INJURIES

By

James Hosner

A THESIS

Submitted to
Michigan State University
in partial fulfillment of the requirements
for the degree of

Epidemiology- Master of Science

2024

ABSTRACT

Objective: To explore the degree to which occupational burn severity depends upon sex, considering alternative potential explanations such as industry and type of abnormal energy exchange (i.e., chemical, electrical, radiation). This thesis addresses the gaps in epidemiological evidence with respect to the determinants of female-male variations among adult workers and addresses the occurrence of occupational burns in adult female and male workers across a range of industry subtypes. **Study Design:** We examine a study population that includes all workers, 18 years of age and older, in the State of Michigan between 2009 and 2019. The burn ascertainment is based on what is reported to the Michigan Surveillance Data of Burns database maintained by Michigan State University's Division of Occupational and Environmental Medicine. A total of 10,572 occupation-related burns were analyzed. Burn severity, as assessed by the treating physician, was classified by the depth of the burn, or burn degree. Sex was based on the case's medical record. A robust Poisson regression model was used to estimate the sex-specific burn and burn severity occurrence ratios with a 95% confidence interval. Model-based covariate adjustments considered age, race, type of burn injury, and industry of the worker. **Results:** Males had excess of 2nd or 3rd/4th-degree burns, with an occurrence ratio estimate of 1.15 (95% confidence interval, CI=1.12, 1.19). The association's point estimate for 3rd-degree (severe burn) relative to non-severe burns was larger (2.1, CI=1.6, 2.7). The main result of this study indicates that males experience more severe work-related burns as compared to females, even after covariate adjustment. Excess burn occurrence is seen in the Accommodations and Food Service industry type. This study has limitations as reviewed in the Discussion section. Notwithstanding these limitations, this thesis' results confirm the female-male variation in the occurrence of occupational burns and extend our understanding of burn occurrence across industry subtypes. Males in the state of Michigan experience more burns of a higher degree than females and these differences might be a result of occupational variation between the two sexes.

ACKNOWLEDGEMENTS

There are so many people I want to thank who have made this thesis possible. First, I want to thank my committee members, Dr. James Anthony, Dr. Kenneth Rosenman, and Dr. David Barondess. I cannot describe all the help and support I have received throughout the years that I have been working with MSU. I want to thank Dr. Anthony, my thesis advisor, for the years of wisdom and expertise that he has imparted to me while working on this thesis. I want to thank Dr. Rosenman for his unending support during my time at MSU's Division of Occupational and Environmental Medicine. I would also like to thank the entire team at MSU OEM who have not only compiled the data for this thesis but have also given me advice and the skills necessary to complete this thesis. I genuinely feel like they have become my second family. I would finally like to thank Dr. Barondess for helping me navigate my MSU epidemiology degree while always looking out for me.

For my family, thank you for always being there to help me and keep me focused on chasing my dream. I want to thank my wife, Veronica, for always supporting me and being a constant source of happiness when the days got rough. I want to thank my dog, Momo, for always being happy to see me when I arrive home. I want to thank all my friends who have always been there supporting my crazy life as I ponder sometimes the point of this winding road upon which I keep moving.

Finally, I want to thank the Department of Epidemiology and Biostatistics for being a part of my life journey as I continue to grow and develop. Living life is a lot like a river which courses and bends. Rarely is life a straightforward pathway but instead a journey that bends and weaves with every success.

TABLE OF CONTENTS

LIST OF ABBREVIATIONS....................vi
CHAPTER ONE: INTRODUCTION AND SPECIFIC AIMS....................1
CHAPTER TWO: BACKGROUND....................3
CHAPTER THREE: MATERIALS AND METHODS....................15
CHAPTER FOUR: RESULTS....................24
CHAPTER FIVE: DISCUSSION....................31
REFERENCES....................37
APPENDIX A: TABLES....................43
APPENDIX B: FIGURES....................47
APPENDIX C: SUPPLEMENTAL TABLES....................52

LIST OF ABBREVIATIONS

OEM	Occupational Environmental Medicine
MIFACE	Michigan Fatality Assessment and Control Evaluation
PC	Poison Centers
BLS	Bureau of Labor Statistics
CI	Confidence Intervals
CRBO	Clinically Recognized and Referred Burn Occurrence
ED	Emergency Department
TBSA	Total Burn Surface Area
NAICS	North American Industry Classification System
ICD	International Classification of Disease
QWI	Quarterly Workforce Indicator

CHAPTER ONE: INTRODUCTION AND SPECIFIC AIMS

The central topic of this thesis is the severity of occupational burn injuries in relation to the sex of the individual. While evidence of fire extends far into the past of human evolution, the first evidence of fire use for cooking was by *Homo erectus* approximately two million years ago (Gowlett, 2016). The first indications of human species being burned lie within cave paintings, and the earliest records of burn treatment are described in the Edwin Smith Papyrus, an ancient Egyptian medical text from approximately 1600 B.C. named after Edwin Smith who purchased it in Egypt (Lee, et al., 2004). Classifying burns in degrees was introduced in the 18th century by two prominent German surgeons, Heister and Richter, who classified burns into four separate categories (Lee, et al., 2004). William Farr is credited with the first 'vital statistics' contribution that differentiated burns from other injuries within a mid-19th century Report on the Nomenclature and Statistical Classification of Disease (Farr, 1885).

Within the body of subsequently accumulated epidemiological evidence on burns, it is possible to differentiate burns that originate in an occupational setting from burns experienced in a household or other environmental setting. The history of epidemiological studies of occupation-related burns is summarized in Chapter 2 of this thesis after consideration of the more general field of occupational injury epidemiology.

In most epidemiological study reports on occupational injuries, there is a male excess occurrence of burns experienced by workers. There is a gap in epidemiological evidence about female-male variations in the severity of burns. This thesis seeks to fill this gap in evidence and addresses the following specific aims:

The first aim of this thesis on workplace burns that are severe enough to require medical attention involved two parts: (1.1) where the count of each worker with at least one work-related clinically recognizable burn during that interval is in the numerator, and the total sum of Michigan workers ascertained for each year from 2009 to 2019 is in the denominator (i.e. the aggregate estimated number of workers each year summed across all these years otherwise known as an estimated count of worker-years), and (1.2) model-based estimation of slopes that convey the degree to which being a female worker versus being a male worker might help discriminate clinically recognized burns of greater severity from clinically recognized burns of lesser severity, adjusting for known covariates. The estimates of Aim 1.1 will be considered occurrence estimates with the number of first reported burns in the numerator and the number of employee years obtained through the Quarterly Workforce Indicator (QWI) in the denominator. The estimates for Aim 1.2 are based on a robust Poisson regression model with a focus on the numerators of the occurrence estimates described in Aim 1. The robust Poisson regression model for Aim 2 extends the model for Aim 1 by considering these additional covariates: type of industry, age, and race. Cause of the burn as recorded in the burn surveillance record is also considered. These basic covariates were chosen based on previous occupational injury evidence and epidemiological principles when subgroups are being compared. The robust Poisson regression model was chosen over log-binomial regression as the outcome is a count and logistic regression tends to overestimate odd ratios. A standard Poisson regression could overestimate the variance of the measured effect. The robust Poisson uses the classic sandwich estimator under the generalized estimation equation (GEE) framework to correct the inflated variance (also known as over-dispersion) in the standard Poisson regression.

Chapter 2 provides a scholarly review of the history and literature of occupation-related injuries. This chapter also covers the evidence’s potential clinical significance and impact on public health. Chapter 3 describes the Michigan population under study, how the samples were drawn, how cases were chosen, and the analytic approach. Chapter 4 presents the results of the research. Chapter 5 summarizes the main findings, the study limitations, and future research ideas.

CHAPTER TWO: BACKGROUND

Chapter two provides an overview of background issues in the epidemiological study of occupational burns. The first section dictates the history of burns in the human species and the rise of investigating industrial injuries using the Haddon theory of abnormal energy exchange. The second section dictates host and agent factors and the physical and social environment in which occupational burns occur in relation to the Haddon matrix model. The third section summarizes significant epidemiological research findings on such burns, starting with a global perspective and a perspective on the United States (US) as a totality. The fourth section summarizes background information on the variables that will be present in this study tied directly to the biological mechanism of burn injury and how these injuries are measured. The fifth section summarizes important methods issues faced in epidemiological studies of occupational burns. The sixth section provides an overview of the potential public health and scientific significance of thesis of this type.

2.1 Background: Literature Review and Summary

While evidence of fire extends far into the past of human evolution, the first evidence of fire use for cooking was by the ancestors of human *Homo erectus* approximately two million years ago (Gowlett, 2016). The first indications of burn evidence lie within cave paintings, and the earliest records of burn treatment are described in the Edwin Smith Papyrus, written circa 1600 B.C. (Lee, et al., 2004). Hippocrates, in 400 B.C., described the use of bulk dressing. In the first century A.D., Celsus described the first use of burn treatment using bacteriostatic properties, although they did not fully understand the microbial processes that were taking place (Lee, et al., 2004).

With the rise of the automotive industry, in more recent history, William Haddon published his paper "Energy Damage and Ten Countermeasure Strategies" (Haddon, 1973) which shaped current epidemiological studies of injury and injury prevention. An injury to a worker can be characterized from the perspective of an abnormal transfer of energy that is too much for the body to handle, leading to injury. This abnormal energy transfer can be mechanical energy, thermal, electric, chemical, or radiation. Regarding occupational burns, all five types of energy exchange can cause the burn injury in question (Haddon, 1973). Friction burns can cause mechanical injury, and thermal injury can be caused by hot or cold items, applying an energy imbalance that causes the injury in question (Haddon, 1973). Electric injuries can be caused by either the flow of the electric current or the arc flash (Haddon, 1973). Chemical burns can result from reduction, oxidation, corrosion, or desecration of body tissue (Haddon, 1973). Radiation burns are caused by radiation to the individual in question. Haddon describes all injuries as pre-crash, crash, and post-crash phases (Haddon, 1973).

Prevention of injuries, according to Haddon, involves separating vulnerable targets (the host) by space and time from the agent (an animate or inanimate object responsible for the energy transfer) (Haddon, 1973). Haddon also discussed making the vulnerable target more resistant to damage from the energy flow, limiting damage development, or rehabilitating the vulnerable victim (Haddon, 1973). An example is personal protective equipment worn to minimize exposure to hazards that can cause serious injuries. The inverse is also true in that some vulnerable targets, based on specific factors, are more or less likely to suffer an injury at the workplace. For example, workers who drink on the job are more likely to be put in a situation where they are more prone to being exposed to a large enough energy transfer to deal grievous harm to the body (Dawson, 1994). Younger people have less experience on the job and are more prone to occupational injuries than their older counterparts who have worked in other occupational settings and, therefore, have more experience (Mitchell, 1988).

2.2 Covariates in Burn Epidemiology

The purpose of this section is to provide background on occupation-related injuries. This will be presented if data are available on factors that directly influence occupation-related burns. When discussing vulnerable targets in the Haddon Matrix, it is essential to consider host and environmental factors that may expose one more to injuries than others. Males engage in more behavior that exposes them to the risk of injury (Udry, 1998), and men are more likely to work in settings that leave them more prone to having an occupational injury (Biswas, 2021). When it comes to the gender difference, there is great difficulty in performing a study focusing on this aspect. Henceforth, this data could be less precise (Messing, 2003). The World Health Organization (WHO) reported that men are most likely to be burned in the workplace (World

Health Organization, 2023). It is essential to consider that there is a difference in the effect between the socially constructed difference between men and women, known as gender, and the biological difference between men and women, known as sex (ICD10, 2023). Previous research into occupational settings, as listed, shows that it is common in these occupational settings to look at the gender/sex difference to be referred to as "men and women" unless otherwise specified (Biswas, 2021). This study will consist of the sexes male and female only when it comes to data collection and reporting; if transitioning occurred, the individual would be reported as the transitioned gender.

Age is a known factor in occupational injuries, with those who are younger and older known to have more occupational injuries (Mitchell, 1988). This is proposed based on those younger workers needing to gain the necessary skills to avoid or recognize when the host could meet a higher energy agent (Mitchell, 1988). For older workers, being unable to move fast enough or mentally respond fast enough could physically lead to more contact with high-energy agents, leading to injuries (Mitchell, 1988). Those younger than 25 years of age experience the highest rate of occupational injuries in most industry settings, with those aged 18-19 years old having the highest rate of occupational injuries (Guerin et al., 2020).

Current research has yet to determine a definitive answer on the role of race in an occupational setting. The factor of race on occupational injury has been mixed, with some studies indicating that race does play a role in occupational injury (Zierold & Anderson, 2006; Simpson & Severson, 2000; Robinson, 1989; Richardson et al., 2004), while other studies have found no association between race and occupational injury (Zierold & Anderson, 2006; Simpson & Severson, 2000; Robinson, 1989; Richardson et al., 2004). The theory for these inconsistencies is that racial disparity in job risk is strongly influenced by the specific work available (Zierold & Anderson, 2006). Due to occupational risk being heavily tied to the industry and the nature of the work being performed, the disparity may be tied to the occupational setting. Michigan has long had ethnic minorities at greater risk of occupational injuries, with blacks and Hispanics overrepresented in lower-wage occupations (Stanbury & Rosenman, 2014).

Using Haddon's Matrix, thermal burns can be caused by the mechanical transfer of energy through friction burns with high-velocity agents and from energy. Electrical burns involve not only the initial flash causing an external burn but the electrical current which heats bones and can burn the muscle attached to the bone (Friedstat et al., 2017). Chemical burns are unique in Haddon's Matrix as the nature of the energy transfer lies solely in the compound causing the injury. Acids cause damage through coagulative necrosis, while alkali substances cause liquefaction necrosis (Chai, 2022). Chemical burns also require different standards of care and treatment than thermal burns, which, as stated previously, rely heavily on the exact nature of the compound (Chai, 2022). Radiation burns are unlike any other energy transfer mechanism, as the agents are rays. These ionizing rays directly damage the skin and it's deep tissue cells, leading to dryness, loss of elasticity, and microvascular damage to the tissue underneath. The damage can also be acute, with one large dose of radiation leading to burns or a prolonged dose of radiation leading to the burn injury in question (Yang, 2022).

Before discussing the sociological role in the Haddon Matrix, a view of specific host factors must be mentioned. While most host factors, such as age, sex, and race, have been defined as unalterable from a biological viewpoint, it is essential that the sociological or cultural viewpoint be altered (Lu, 2006). It is important to note that ageism, sexism, and racism can be altered, and epidemiologists working with the Haddon Matrix must take note. For the socio-environmental factor in the Haddon Matrix, sex and gender, as previously mentioned, play a significant role in the social aspect of the environment. It is argued that one's environmental, social, or economic experience is risky; not one has an inherited biological or genetic background (Lu, 2006). While a workplace environment can be characterized by the job demands, degree of decisions, and other factors, for the purpose of this thesis, a workplace environment will be considered the industry as defined by the North American Industry Classification System (NAICS) codes. Industry is an essential factor in an occupational injury due to it being the environmental factor that facilitates the injury. In the United States, NAICS is the system used by federal statistical agencies to classify businesses and establishments as well as to collect, analyze, and publish statistical data. It was developed to allow for a high level of comparability in business statistics among the three North American countries. NAICS is based on a production-oriented concept, meaning that it groups establishments into industries according to similarity in the processes used to produce goods or services. NAICS codes are updated every 5 years, with years ending in 2 and 7 being the year the NAICS codes will be updated (US Census, 2024).

2.3 An Overview of Occupation-Related Burns from a Worldwide to a Michigan Scale

The Global Burden of Disease project quantifies Disability-Adjusted Life Years (DALYs) attributable to burns as a combination of two figures: premature mortality, expressed in years of life lost (YLLs), and non-fatal health loss, expressed in years lived with disability (YLDs). The Global Burden of Disease project estimates YLDs for the year 2019 in the United States to be 262,940 years lived with disability attributed to burns. For the same year, males made up 137,613 years lived with disability while females made up the remaining 125,327 years lived with disability attributed to burns (Global Burden of Disease Collaborative Network, 2019). This data consists of all burns in the United States, not just occupational injuries. Compared to other countries, developing low-and middle-income countries are overrepresented due to the preponderance of burns that occur there (Atiyeh et al., 2009).

While reviewing the GBD statistics on burns, I became aware of several prominent challenges that epidemiologists face when making cross-country and other cross-jurisdiction comparisons. For example, surveillance of occupation-related injuries in general, and burns specifically, needs to be uniformly accurate and complete in every jurisdiction. I will return to methods-related issues of this type in the fourth section of this chapter. To my knowledge and with significant research, all reports indicate men had more occupation-related burns than women. Table 1 indicates a review of prominent analysis over multiple countries and timespans with varying percentages of male to female burns and males always have a more significant percentage than females.

Table 1. A Literature Overview of the Prevalence of Burns on an International Scale

Area	Date	Author	Prevalence	
			Sex	Percentage
Australia	2009-2016	McInnes	Male	84.9
			Female	15.1
Switzerland	1984	De Roche	Male	84.0
			Female	16.0
United States	2005	Mian	Male	90.0
			Female	10.0
Michigan	2018	MDHHS	Male	64.5
			Female	35.5
Canada	1984-1990	Ng	Male	94.0
			Female	6.0
Finland	2011-2015	Purola	Male	54.0
			Female	46.0
Singapore	1997-2003	Song	Male	68.6
			Female	31.4
Turkey	1986-1995	Türegün	Male	56.3
			Female	44.7

(McInnes (2018), De Roche (1994), Mian (2011), MDHHS (2021), Ng (1991), Purola (2022), Türegün (1997)).

The Bureau of Labor Statistics (BLS) in the US Department of Labor administers a survey to a sample of employers to generate state and national estimates on occupational injuries and illnesses. When identifying burns that occurred between 2011 and 2019 (burns before 2011 are not available on the BLS website), they identified 662,740 males and 441,500 females in the United States with injuries classified as burns and corrosion (labeled as 15XXXX) (US BLS, 2023). For Michigan, BLS identified 14,840 men and 11,260 females with injuries classified as burns and corrosion (US BLS, 2023). Though BLS contains data on sex and age, it does not contain data on the severity of injuries. It is generally accepted, though, that the BLS surveillance system needs to be improved to provide accurate measurements and that there needs to be more recognition that the system also markedly undercounts the burden of occupational injuries (Hosner and Rosenman, 2023).

A large-scale national study reviewed occupation-related burns in emergency rooms in the United States using the National Electronic Injury Surveillance System—Occupational Supplement to produce national estimates of burns treated in emergency departments (EDs) (Reichard et al., 2015). The findings were that young males had the highest rates of occupation-related burns, with those 15–19 years old having a rate (30.1; 95% CI=±9.4) more than twice as high as any other age group and nearly five times higher than the overall rate (Reichard et al., 2015). In Michigan, findings were similar, though rates of burns vary from year to year; for example, the year 2009 had the highest burn rates among those 20-24 years of age (Kica & Rosenman, 2012). The one consistency across all studies is that males had higher burn rates than females. With the most recent data from 2018-2021, males had the highest burn rate, 49.4 burns per 100,000 Michigan workers, compared to females, at 28.1 burns per 100,000 workers (Hosner & Rosenman, 2023). A common thread is that most of these studies report the rates of male and female and corresponding age but do not delve into the degree of burns and the industry's effect on these rates. While there have been studies in foreign impoverished countries about how burns in young males have different degrees of severity, little research has been done in America (Lam, et al., 2019). A consensus of those studies in impoverished countries is that males have a higher depth of burn and require more surgeries than their female counterparts (Atiyeh et al., 2009). Studies among occupational trainers indicate that training should be tailored to the age group and gender instead of blanket training and safety videos. For example, one study among teens found that "Although the majority believed that safety training was important, many felt that they did not need safety training; that it was 'common sense.' However, 52 % of teens reported workplace injuries" (Zierold & Welsh et al., 2012).

Michigan Public Health regulations require that inpatient and outpatient medical facilities generate reports of patients with occupational burns (Kica & Rosenman, 2012). Most (64.5%) of Michigan’s occupational burns occur among men (Kica & Rosenman, 2012). In a report for 2018 by Michigan State University's Division of Occupational and Environmental Medicine (MSU OEM), 31.8 percent of occupational burns occur in those who are 14–24 years old (MDHHS, 2021). This is not unique to Michigan in that there have been extensive studies into the rates of burns in the United States as a whole, along with individual states, which all indicate that the rates are highest among males and those that are younger (US BLS, 2023; Reichard et al., 2015; Kica &Rosenman, 2012; Hosner & Rosenman, 2023).

This section of the chapter provides a global perspective on occupational burns. It identifies the female-male variation in the occurrence of occupational burns as a noteworthy topic for new research on burns. The current body of evidence suggests that sex (i.e. male versus female) should be included as a covariate in epidemiology's conceptual models when testing other hypotheses about the causes of occupational burns and as a potential marker of subgroup variation when epidemiologists look across strata or levels of explanatory or predictive covariates (Oyebode, 2009).

The section also clarifies a gap in evidence about burn severity, given that more epidemiological evidence needs to be published on how burn severity might vary across the sexes. Another gap in the evidence involves variation in occupational burns across industry subtypes. These are the gaps in evidence that I seek to address in this thesis.

2.4 Measurements of Burns

To convey the impact of a burn, it is important to understand how depth is considered one of the most important determinants of outcome along with the method to measure depth. For the nature of this study, one of the main determinants will be severity of the burn. Burns can be classified based on the depth of the burn, which are divided into first-degree, second-degree, third-degree, and fourth-degree burns.

First-degree burns are usually limited to the outer layer or epidermis of the skin, and the skin may appear red, dry, and painful to the touch (Monstrey et al., 2008). Second-degree burns can be categorized into superficial and deep partial-thickness burns (Monstrey et al., 2008). A superficial partial-thickness burn extends into the superficial papillary dermis and appears red with significant weeping and blisters (Monstrey et al., 2008). It usually takes between two to three weeks to heal. Deep partial-thickness burns extend into the reticular dermis, appear yellow or white and dry, and usually take over three weeks to heal (Monstrey et al., 2008). Based on the number of nerves damaged, these burns can range from extremely painful to having diminished sensation in the deep partial thickness (Monstrey et al., 2008). Full-thickness or third-degree burns extend through the entire thickness of the dermis (Monstrey et al., 2008). These usually appear dry, leathery, black, white, and painless since nerves are usually damaged or destroyed (Monstrey et al., 2008). Third-degree burns do not blanch under pressure (Monstrey et al., 2008). Blanching under pressure is blood being forced out of capillaries, causing the skin to turn white (Monstrey et al., 2008). While first-degree and second-degree burns do not usually have extensive damage, blanching can still be performed on the burn injury, while for third and fourth-degree burns, that is not possible (Monstrey et al., 2008). Fourth-degree burns extend through the skin thickness, including the fat and underlying tendon, muscle, and bone (Monstrey et al., 2008). This causes the burn to be charred or black (Monstrey et al., 2008).

Clinical evaluation by an experienced burn practitioner remains the standard method to determine burn depth (Toussaint & Singer, 2014). While other methods have higher sensitivity and specificity, such as tissue biopsy and ultrasound, these specialized methods are labor and time intensive. Also, a burn over the subsequent two to three days can progress from and to different depth stages. Clinical evaluations involve evaluating the burn based on wound appearance, capillary refill and burn wound sensitivity to touch and pinprick (Monstrey et al., 2008). While clinical evaluations are used for most burns, studies indicate that clinical evaluation estimates for depth assessment is accurate in only about two-thirds of the cases, with overestimations of burn depth being the most frequent error (Heimbach et al., 1984).

Another factor for identifying the severity of burns is Total Body Surface Area (TBSA). TBSA allows an estimate of the size of the burn, with the specific number being a rough estimate of the percentage of the total body surface area affected by the burn. Though like depth, estimation of the TBSA may be inaccurate. Clinical rules and charts are used to improve accuracy in estimating TBSA, with the three most common methods being the Lund-Browder chart, Wallace rule of nines, and the Palmer Method. The Lund-Browder chart is the most accurate (Toussaint & Singer, 2014). When discussing errors in reporting TBSA, it is found that larger burn areas are usually underestimated (Toussaint & Singer, 2014). It was also found that those with obesity had erroneous TBSA with underestimated results when using the three most common methods. In this study, the TBSA used was the percentage recorded in the medical record. It was unknown which individual TBSA method the health care provider used to estimate the TBSA for each patient although the percentages derived from the three TBSA methods can be used interchangeably (Toussaint & Singer, 2014).

When determining burn severity, burns were labeled as severe if the recorded burn degree was 2nd-degree or higher, while those that were 1st-degree were labeled as non-serious. An additional measure of severity are burns where the American Burn Association recommends the patient be referred to a burn center. These burns are partial thickness burns that are greater than 10% of the TBSA, 3rd-degree or higher burns, chemical burns, electrical burns, or lightning strike burns, significant inhalation injuries, burns in patients with comorbidities, and patients that have associated injuries with the burns (Schaefer & Nunez, 2023). These injuries are particularly severe due to the need for fluid resuscitation to maintain urine output due to water loss from the burn (Schaefer & Nunez, 2023).

2.5 Background: Methods Issues

For injury epidemiology generally and for burn epidemiology specifically, there are some methods issues to be discussed before presentation of this thesis' methods and results. One such issue was mentioned in the first section in relation to global burden of disease estimates and death statistics. Namely, there is uneven surveillance of occupational burns from jurisdiction to jurisdiction, whether looking across countries or across states and sub-state jurisdictions within countries.

Based on my personal ranking of the other methods issues, I will mention these other issues, starting with what I judge as most important, namely, the data retrieved did not have access to information on occupation within industry. The issue with this is that a man and a woman may have the same NAICS code but be exposed to different occupational hazards. Even if the exact occupation was listed, studies have indicated that men and women who work in the same occupation may still take on different roles that may expose one sex to more hazards that may lead to a burn (Stergiou-Kita, 2015).

Second, this data was limited to burns treated in a hospital setting or called into the Poison Center (PC). Because of how the data was collected, one sex may be more or less likely to report minor burns, leading to an overrepresentation of one sex over another when it comes to minor burns. Males are less likely to report minor occupation-related injuries than females, more likely to try home remedies or treat the injury at home and are also more likely to hide an injury from their employer than females (Charles, 2018).

Based on the data obtained, issues arise because there is no accurate and precise medical history of individuals involved in an occupational injury. Those who have been previously injured but were not included in the following years or did not seek medical care for the injury may be less likely to receive an injury by being more cautious. Other factors that may be influencing the data but were not accessible for purposes of this thesis were education levels, occupation, prior health issues, activity levels, and smoking/drinking. Individuals who drink more have been reported to have higher risks of having an occupational injury (Dawson, 1994). As previously mentioned, one last issue with the data obtained is that the depth of burn injury is not always a reliable measure of severity due to the nature of burns changing after exposure to the agent of energy. Testing equipment for alternative diagnostic approaches to assess degree of burn are too expensive to place into medical care settings and are usually deemed unnecessary at burn centers (Toussaint & Singer, 2014).

This thesis focuses on adults aged 18 and older. Of course, workers under age 18 might have experienced occupational burns. However, they were not included for this thesis due to those under 18 being minors. This limitation of the study base is mentioned in the Discussion section of the thesis. I will return to these issues when I discuss the limitations of my thesis. I will argue that the findings from my thesis deserve attention despite these issues and the associated limitations of the work.

2.6 Potential Scientific and Public Health Significance

2.6.1 Potential Significance in Science

Given the previously described robustness of Michigan's surveillance of occupational burns, one might hope that future investigations will be completed to build upon the progress made in this thesis. If so, this thesis' investigation should provide evidence as to whether sex-related variations in the occurrence of occupational burns in Michigan are large or small. If small, then future investigations may give little attention to female-male imbalances because there may be no need to make stratifications by sex or model-based statistical adjustments for sex as a covariate when other suspected causal influences are being studied.

I believe this thesis will have scientific significance because there is little published epidemiological evidence on burn severity, as mentioned in earlier sections of this chapter. The issue of burn severity is vital because, while minor burns can be healed with home treatment, severe burns require significant medical interventions.

Finally, a similar gap exists in epidemiological evidence about how the occurrence of occupational burns might be distributed across industry subtypes. The scientific importance of studying these subtypes and job characteristics has been clarified in cancer research, such as the Nordic Occupational Cancer Project (Pukkula, 2009). In a tradition that started with Farr's studies of mortality rates for various occupations in England and Wales in the 19th century, the cancer epidemiologists started by identifying industries with excess occurrences of specific types of cancer and then looked at job characteristics within the specified industry subtypes to find ways to modify the jobs to make them healthier. This research found that mesothelioma was present in occupations where there was exposure to asbestos (Pukkula, 2009). Male servers and tobacco workers also had a higher risk of lung cancers, which was attributed to active and passive smoking (Pukkula, 2009). In this way, the research findings stimulated more probing studies and, as a result, have created changes in the job environment for potential public health benefits, as well as scientific benefits.

2.6.2 Potential Public Health Significance

I am not going to claim that this thesis, by itself, will have immediate public health significance. Nor do I expect, with the limitations that are present, that there will be a way to fully understand the effect that gender has in an occupational setting. Instead, as in the case of the Nordic Occupational Cancer Project, this type of thesis can be a guide to deeper studies of occupational burns and toward operations research or investigations to guide improvements of various job conditions that may currently be promoting the occurrence of occupational burns. Future research studies may take place that may improve safety training and the workplace environment.

CHAPTER THREE: MATERIALS AND METHODS

This chapter describes the research approach of the thesis. The local Michigan State University Human Research Protection Committee reviewed the protocol and judged it not to involve "human subjects" as defined by the Common Rule as codified in the U.S. Department of Health and Human Services (DHHS) regulations for the protection of human research subjects. "This is a secondary analysis of data that has already been previously collected for the Michigan multi-surveillance system. For this secondary analysis, no direct identifiers will be present in the data, and the private investigator will not have access to the previously collected data." The data in the datasets created for this thesis was de-identified to protect patient confidentiality.

3.1.1 Study design

This study aims to outline the demographic scope, methodology, and case criteria of the study. The population under examination comprises all employees in Michigan from 2009 – 2019. Employing a time series approach, the study analyzes occupational burn incidents reported to a state-level surveillance system. Though this may appear cross-sectional, the study exhibits a clear temporal sequence, as burns typically occur subsequent to the identification of potential influencing factors. Regarding burn case definitions, Michigan mandates that any burn sustained by a worker at a worksite be reported. Further elucidation on burn ascertainment is provided in subsequent sections (see Table 3 for numerical breakdown).

In accordance with Aim 1.1 of the thesis project, estimates will focus on occurrence, with the numerator representing the number of initial reported burns and the denominator derived from Quarterly Workforce Indicator (QWI) data, indicating employee-years. The resulting ratio delineates the frequency of first-registered burns relative to worker-years from 2009-2019.

Transitioning to Aim 1.2, emphasis shifts to the numerator of the aforementioned ratio, where the unit of analysis becomes the total number of burns incurred by individuals in the study populace, limited to each worker's initial burn. Utilizing data from the burn registry, burns are categorized as severe or non-severe, and the ratio of severe to non-severe burns is modeled using a robust Poisson regression technique outlined later in this section.

3.1.2 Details on Case Definition and Ascertainment

A case included in this study was defined as an individual who had a work-related burn injury that was a clinically recognized and referred to burn occurrence (CRBO). For a case to be a CRBO, three steps had to occur. First, the worker must have experienced the burn in an occupational setting (e.g., at a worksite). Second, the worker must have sought medical care at a hospital emergency department (ED), hospital outpatient clinic, or via a call placed to the state's Poison Center (PC) (e.g., chemical burns), or the burn was ascertained via Michigan's Fatality Assessment and Control Evaluation (MIFACE) program if death occurred from a work-related burn. Third, the occupation-related burn must be coded as a burn during the treatment process.

Thereafter, the burn records were collected and formed into databases known as 'Michigan Surveillance Data of Burns' as designed by and for Michigan State University's Division of Occupational and Environmental Medicine. For the years 2009 through 2019, there was a yearly collection of occupational burn reports and the merging of 11 individual data sets for each year. In aggregate, the major reporting units for this thesis research project consists of Michigan's 134 acute care facilities, including Veterans' Administration hospitals, which are required by state regulations to identify and report work-related burns (Hosner & Rosenman, 2023).

The compilation of all the database information totaled 18,149 work-related burns in workers aged 18 years and older. Of those 18,149 work-related burns, those with missing values from severity evaluations (n=3,978), with respect to male-female sex (n=336), the NAICS code (n=3,140), or were a second-time injury (n=123) were removed. The final study design population consisted of 10,572 individuals, each with a first-experienced burn in the surveillance registry. See Figure 1 in Appendix B for a full breakdown of the removal of cases.

Coding: Burns that occurred from 2009 through September 30, 2015 were identified through ICD-9 coding. Any burns after September 30, 2015 were classified using ICD-10 coding (see specific ICD-9 and 10 codes in Appendix C). Individuals who had CRBO and received care at one of Michigan's 134 hospitals or emergency departments, were an outpatient at a hospital-based clinic, or had a call placed to the Poison Center (PC) were included as cases. For the PC, the part of the body injured was specified by the caller and coded using the ICD-9 codes or ICD-

10 codes based on the year of the incident. Those who died from a work-related burn injury that occurred in Michigan were also included. Information from the hospital/ED/outpatient hospital clinic's medical reports, PC reports, and MIFACE reports on each case was abstracted onto a form after a review of the record confirmed that the burn was indeed due to an occupation-related injury. For this study, the only information retrieved for analysis was injury date, race, age, sex, Total Burn Surface Area (TBSA), North American Industry Classification System (NAICS) code, mechanism of burn, and degree of burn.

For the analysis, data was restricted to only those 18 years and older for whom sex information was available, industry could be determined, and had burn degree recorded in the medical record. Information on sex collected from medical records was limited to male or female.

3.2 Response Variables and Explanatory Variables

The primary response variable in this study is the depth of the burn injury recorded in the reports by the Michigan Multi-Surveillance Report. The focus of this report will be those who received 2nd-degree burns, which will be considered a serious burn, and those who received 3rd-degree burns, which will be considered a severe burn. In this thesis, most of the burn evaluations were made by the treating physician in emergency departments, the PC, or, if the individual died, from the medical care facility where the individual was evaluated/treated before death. Due to the small number of 4th-degree burns, one severity category was formed to include both 3rd and 4th-degree burns. This study used two separate response variables for two separate analyses, one for serious burns and one for severe burns. A dummy variable was created for serious burns, with 0 for burns of 1st-degree or lower, while 1 indicated burns of 2nd-degree or higher. For the analysis of severe burns, a dummy variable was created with 0 for burns of 2nd-degree or lower, while 1 indicated burns of 3rd-degree.

Sex was listed as male and female in the report. As stated in section 2, most of these classifications would be the gender of the individuals but if a person had transitioned, then that would likely be the sex abstracted.

3.3 Variables

Multiple covariates, specifically age, race, and industry type were included in this thesis' models. In addition, the type of burn (e.g., electrical, thermal) was considered. Chapter 2 describes the rationale for selecting this limited set of covariates, given the thesis' focus on sex-related variations and on strata defined by industry type.

Age was specified as an ordered multinomial variable in relation to the following age strata from 1 to 7. The categories for age were 18-21, 22-24, 25-34, 35-44, 45-54, 55-64, and 65 and older. In a sensitivity analysis, a term for age in years was used in place of the k-1 dummy-coded indicator variables for these categories, with the youngest age category specified as a reference (intercept) category in the analysis models.

Race-ethnicity, as defined for the US Census before an allowance for multiple self-identified categories, was specified as a discrete multinomial variable after extraction from the surveillance datasets. Non-Hispanic white was used as a reference category. Separate dummy-coded indicator variables were used to indicate members of these other race-ethnicity categories: non-Hispanic black, Hispanic, other, and unknown.

Industry type was also a multinomial variable, with Accommodation and Food Services as a reference category. Dummy-coded indicator terms were created for these subtypes, and a complete list of North American Industry Classification System (NAICS) code groupings can be found in the Supplemental Appendix. The grouping of NAICS codes is commonplace in occupational research. One key difference necessary for this study is that most reports group Accommodation and Food Services within Other, but due to the large number of burns that occur in these workplaces, it was necessary to include Accommodation and Food Services as its own separate dummy-coded indicator.

3.4 Statistical Analysis

The purpose of this section is to cover the preparation of the data, how the descriptive statistics were obtained, and how the final model was chosen for Aim 2. The dataset included multiple burn events for some of the workers, distributed across years from 2009 through 2019. In preparation for the analysis and to avoid complexities involved in the study of recurrent events of each individual worker, the first-occurring burn event was retained. All subsequent burn events for these individuals were removed from the final analysis dataset and will be considered in a future investigation of workers who experienced recurrent burn events, and with statistical modeling of the recurrent events (i.e., each worker's count of burn events during the time interval under study). In addition, errant values outside the logical range of the covariates were coded as unknown values.

Overview on Aim 1.1: The analysis plan for Aim 1.1 involved a calculation of estimated occurrence rates across population subgroups, with numerators and person-time denominators as described in the first sections of this Chapter. Essentially, the count of the worker-specific first-experienced burn event, as aggregated across the interval from 2009 through 2019, was divided by the count of worker-years, calculated by adding up all workers in the State of Michigan employment records year by year across all years of that interval. The resulting numerator is a count of unduplicated burn events, after exclusions described in prior chapter sections. The resulting denominator is effectively the sum of all year-specific worker counts from the Michigan records.

Overview on Aim 1.2: The analysis plan for Aim 1.2 originally was specified as a simple general linear model with a Y response variable coded as 1 for severe burns (defined above) and 0 for not severe burns (also defined above). That is, the Aim 1.2 estimates are based strictly on the numerators described for Aim 1.1 (e.g., without recurrences of burns in the same individual, a topic to which I return in the Discussion chapter). The pre-specified model was that of logistic regression (i.e., generalized linear model with a logistic link function) and the estimated slopes after exponentiation could be interpreted as odds ratios. As an example, consider the proportion of all workers with at least one severe burn during the 2009-2019 interval among all workers with at least one surveillance registry burn as a starting point. Then, dividing that proportion (p-hat) by its complement (q-hat), the odds of a severe burn among workers with a first-experienced burn is calculated as p-hat divided by q-hat. Then, the generalized linear model with a logit link function estimates the odds of a severe burn event versus a non-severe burn event for each subgroup under study with resulting odds ratio estimates (e.g., the odds of a severe burn event versus a non-severe burn event for males, relative to the odds of a severe burn event versus a non-severe burn event for females).

As the Aim 1.2 analysis plan proceeded, it was brought to my attention that there might be an advantage to start with the count of severe burns versus the count of non-severe burns, and to avoid the conversion to odds (and odds ratios) by shifting the generalized linear model to the Poisson count response variable and a natural log link function, with resulting direct estimation of count ratios without the involvement of the odds. For this reason, the analysis model was specified for a generalized linear model of counts (severe burn counts versus non-severe burn counts), with the Poisson count distribution specified as the 'family' of distribution and the link function specified as the natural log.

Prior to fitting the models to the data, I completed a series of pre-estimation steps, I then completed my estimation steps, and then completed post-estimation steps that were intended to check on some of the assumptions of my modeling approach. This sequence of steps is described below.

Pre-Estimation Steps for Aims 1.1 and 1.2: Inspection of the burn surveillance dataset disclosed individual-specific multiple burn events for some of the workers, distributed across years from 2009 through 2019. As sketched in a prior section of this chapter, in preparation for the analysis and to avoid complexities involved in the study of recurrent events of each individual worker, the first-occurring burn event was retained. Thus, for Aim 1.2, all subsequent burn events for these individuals (temporally after the first registered burn event) were removed from the final count of burns. These recurrences might be considered in a future investigation of workers who experienced recurrent burn events, and with statistical modeling of the recurrent event count distributions (i.e., each worker's count of burn events during the time interval under study). In addition, errant values outside the logical range of the covariates were coded as unknown values.

Descriptive Statistics: Thereafter, I calculated descriptive statistics for all first-experienced burn events for all workers and for males and females separately. Under Aim 1.1, I estimated burn counts and proportions for all persons and for males and females separately. In these calculations, the numerator data included the number of sex-specific first-experienced burn events. The denominator was the summed number of sex-specific person-years from the Bureau of Labor Statistics (BLS) database of number of workers by sex and industry, with the Quarterly Workforce Indicator (QWI) for employees for each year from 2009 through 2019 added together to obtain a total estimate of employees for the time interval from 2009-2019.

I note that the worker count for each employment year was calculated by taking the mean of the beginning of quarter employment counts of Michigan workers. One issue I faced involved the inclusion of minors (<18 years) in state worker statistics, although the burn surveillance registry datasets were restricted to workers aged 18 years and older. To address this issue, I asked for consultation and, based on this consultation, I specified an assumption that 25% of those in the category 14-18 years old were 18 years old. My calculations of the final estimates are based on this assumption. These rates are reported in Table 4 of the Results section.

The total number of burns were summed for year, month, and weekday to evaluate any drastic changes between the years, months, or days of the week that would have to be considered during analysis. Finally, testing was performed to ensure that the removal of individuals who had a CRBO but were removed due to incomplete data did not introduce bias. The final data set did not have any detectable bias introduced by removing those individuals.

Generic Pre-Estimation Steps for Both Aims: After the initial summarization of the data, I completed Tukey-style exploratory data analyses to understand the marginal distribution of each study variable one by one (e.g., frequency tables, box and whisker plots for age in years). In the process, I was able to produce an analysis-ready ‘clean’ dataset for both of my thesis aims.

Estimation Steps: After the just-described pre-estimation steps, a series of estimation steps were completed. For Aim 1.1, these estimation steps basically involved taking ratios of the numerators and denominators described in prior sections of this chapter.

For Aim 1.2, as sketched above, with a Poisson ‘family’ specification and with a ‘natural log’ link function specification, I used a generalized linear modeling approach. In my pre-specified model, I coded a binary burn response variable with 0 for a non-severe burn and with 1 for a second-degree burn or higher in level of severity. As described below, after this initial primary specification, I completed an alternative analysis, which was to code 1 for third-degree burn or higher severity level versus code 0 for a below third-degree burn.

The model specification for this binomial response variable (Y) was a special case of the generalized linear model known as a Poisson regression with robust variance. As with logistic regression, the Poisson regression can be used to answer questions such as what factors can predict the frequency of an event. Count data follow a Poisson distribution which is positively skewed and usually contains a large proportion of zeros. Logarithmic transformation can linearize the distribution; thus, the link function is log.

$$\ln p = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \ldots\ldots\ldots \beta_k X_k$$

Exponentiation of the slope coefficients from a Poisson regression model yields an estimated ratio of the event occurrences as of a single point in time or as time passes for a population under study (not the ratio of odds as in the case of logistic regression) (Chen, 2018). In this study, for Aim 2 analyses, I specified the response variable Y as 'burns', the explanatory variable as 'sex' and used the logarithmic function listed below:

$$\text{Log}(p) = \beta_0 + \beta_1\text{Sex} + \beta_2\text{Industry} + \beta_3\text{Race} + \beta_5\text{InjuryType} + \beta_6\text{Age}$$

Post-Estimation Steps for Aim 1.2: After the primary estimation steps in this thesis research project, my first sensitivity analysis was performed on the unadjusted data set to determine the difference between serious burns (2nd-degree burns or higher) and minor burns. The same analysis was performed on severe burns (3rd-degree burns) compared to those 2nd-degree burns and lower. This was done using a robust Poisson regression model to estimate the Occurrence Ratios (OCRs) described in the introduction and the 95% confidence intervals (CI). The resulting slope estimates then were covariate adjusted based on previous studies researching occupation-related injuries (Oyebode et al., 2009; Tessier-Sherman et al., 2014; Islam et al., 2001). Table 3 describes what I learned in this step.

Potential influential confounding variables were added to each model in a stepwise fashion with likelihood ratio tests used to compare models to indicate which model had the best fit. The likelihood ratio test was performed with Poisson regression without robustness. The model fit statistics indicated that a new slope should be estimated for each industry group represented in the burn surveillance registry dataset, to the extent allowed by the number of workers in each industry. When looking at the rate of burns that occurred among each level of burn severity, it is noted that there were large fluctuations in estimates across different industries.

Due to the extensive hospitalization and possible long-term damage due to third-degree burns, I also completed a post-estimation analysis with focus on the distinction of 3rd-4th degree burns from less severe burns, using a roughly similar analysis approach as just described. Industry type proved to be important for improving model fit, with the Accommodation and Food Services industry type as a reference industry type (see Supplemental Table 3 of NAICS codes).

Finally, Total Body Surface Area (TBSA) was used as a secondary measure of severe burns by calculating the extensive surface area where a burn occurs. Among all burns in the dataset (n=10,572), only 2,302 events had coded information on the TBSA. Due to the small number of cases, it was not possible to include tests for each industry slope. Instead, the generalized model of previous occupational setting testing was used (TBSA above 10%), which consists of known socio-economic factors that can influence the occurrence of receiving an occupation-related injury.

All analyses were conducted using SAS statistical software (Version 9.4; SAS Institute Inc., Cary, NC) and Stata statistical software (version 18.0; StataCorp, College Station, TX). The Human Research Protection Program at Michigan State University determined that the thesis did not involve human subjects.

CHAPTER FOUR: RESULTS

This chapter is organized around the aims of the thesis. The first part of this section shows the results of pre-estimation descriptive analysis. The second part of this section shows results from the two aims of this thesis. The first aim estimates the occurrence of burn events in the State of Michigan between 2009 and 2019, as recorded in the burn surveillance registry, with initial estimates of the size of the association between male and female worker severe burns. The second aim, focused strictly on workers with at least one burn in the 2009-2019 interval, involves estimation of the extent to which severe occupational burns are associated with potentially influential covariates.

4.1 Descriptive Analysis

Descriptive analysis of occupation-related burns follows general trends previously documented (MDHHS, 2021). The most common time period for occupational burns were June, July, and August. Except for 2009, the number of Clinically Recognized Burn Even Occurrences (CRBOs) remained stable throughout the subsequent years, with an average of 961 CRBOs per year and ranging between 824 and 1101 (Figure 2).

Descriptive analysis commonly describes the study sample, including the proportions of females and males in the analysis, the distribution of age groups, and so on. The total number of first-time CRBOs among individuals during the time frame, and after eliminating those with incomplete information, was 10,572 (Figure 1). Among these individuals, 6,585 burns were experienced by male workers, with 3,987 burns experienced by female workers. Work-related burns cross-classified by sex can be seen in Figure 2. Of the total CRBO in the study, 62.3% were male. For minor CRBO coded as 0, females comprised 50.40%. For serious CRBO, males comprised 67.1%, and for severe CRBO, 86.4%. In Table 5, among both sexes, most burns were thermal burns, and most occurred among whites. Among all burns, the age group with the most burns was those aged 25 to 34. Looking across all industry subtypes, the majority of burns occurred in those working in the Accommodation and Food Services. As for serious burns (2nd and 3rd degree), the incidence of serious burns in this study was 7,659 (72.4%). Among the CRBO, 699 were deep enough to be classified as a severe (3rd degree and higher) burn (6.6%).

Those who suffered serious or severe injuries, compared to those who suffered minor injuries, were more likely to have thermal burns, be male, non-Hispanic white, and in early adulthood (age 25-34) (Table 5 in Appendix A). For serious burns, most burns were inflicted while working in Accommodation and Food Services, while for severe burns, most of them took place in Manufacturing (Table 5 in Appendix A).

4.2 Occurrence Estimates (Aim 1.1)

The occurrence estimates for this thesis are as described in Chapter 3, Section 4. As described in that section, in the numerator of the occurrence estimate is the surveillance-based count of workers with at least one work-related clinically recognized burn event during the interval from 2009 through 2019. The denominator of the occurrence estimate is the sum of the average of the beginning of Quarter employment from the Quarterly Workforce Indicator (QWI) explorer, overall and stratified by industry type and by sex. The numerator and denominator can be seen in Table 3 when looking at the employment count when stratified by age and Table 4 when stratified by Industry. The occurrence estimates for all workers in Michigan, irrespective of sex and of industry type, has 10,572 burns in the numerator and 4,444,0256 worker years in the denominator. The estimate is 23.8 per 100,000 worker years, with the count of clinically recognized burns being the aggregate for the interval from 2009 through 2019, and with a restriction to an individual worker's first-recognized burn event during that interval. The corresponding estimate for female workers is 17.9 per 100,000 female worker years. For male workers, the estimate is 29.8 per 100,000 male worker years. With respect to the first-degree first-recognized work-related burn event under surveillance, the industry type with the largest occurrence estimate is Accommodation and Food services with 25.8 per 100,000 worker years. The industry type with the smallest occurrence estimates is Educational Services including State Education and its occurrence estimate is 2.5 burn events per 100,000 worker years. Estimates for other industry types are shown in Figures 3 and 4. With respect to the higher degree burns (i.e., 2nd-degree and higher), the estimate for female workers is 17.9 per 100,000 female worker years. The corresponding estimate for male workers is 23.2 per 100,000 worker years.

The industry type with the largest occurrence estimate for these more severe burn events was Accommodation and Food Service industry and its occurrence estimate for severe burns is 68.8

per 100,000 worker years. The industry type with the smallest occurrence estimate for these more severe burn events was Educational Services including State Education and its occurrence estimate for severe burns is 4.2 per 100,000 worker years. The secondary analysis of occurrences and removing minors from the total employment of Michigan workers using approximation did not affect the occurrence rates or the order from highest occurrence to lowest occurrence in any meaningful way (Table 3).

Table 2. Occurrence Rate of Clinically Recognized and Referred Burn Occurrence (CRBO) Stratified by Age[1]

Age Group	Male Serious CRBO Count	Male Severe CRBO Count	Female Serious CRBO Count	Female Severe CRBO Count	Total Male Employees	Total Female Employees	Male Serious Rate*	Male Severe Rate*	Female Serious Rate*	Female Severe Rate*
19-21	639	41	471	9	4110788	4515060	15.5	1.0	10.4	0.2
22-24	579	50	314	13	5000116	5218268	11.6	1.0	6.0	0.2
25-34	1446	159	665	28	17364556	15982252	8.3	0.9	4.2	0.2
35-44	1015	146	400	15	16713708	14988204	6.1	0.9	2.7	0.1
45-54	819	111	340	18	18211600	16703544	4.5	0.6	2.0	0.1
55-64	408	74	178	8	12950476	11915288	3.2	0.6	1.5	0.1
>65	74	17	22	*	3449600	3065392	2.1	0.5	0.7	*

1 Numbers lower than 5 were obscured to protect the identity of the individual

*Rate is per 100,000 worker years

Table 3. Occurrence Rate of Clinically Recognized and Referred Burn Occurrence (CRBO) Stratified by Industry[1]

Industry Group	Male Serious CRBO Count	Male Severe CRBO Count	Female Serious CRBO Count	Female Severe CRBO Count	Total Male Emp.	Total Female Emp.	Male Serious Rate	Male Severe Rate	Female Serious Rate	Female Severe Rate
Agriculture, Forestry, Fishery	66	20	12	*	194445	100980	33.9	10.3	11.9	*
Construction	409	74	9	*	1426545	234402	28.7	5.2	3.8	*
Manufacturing	1362	253	189	21	4544167	1658171	30.0	5.6	11.4	1.3
Wholesale Trade	231	38	31	4	1275560	531775	18.1	3.0	5.8	0.8
Retail Trade	166	18	216	10	2384834	2581810	7.0	0.8	8.4	0.4
Transportation and Warehousing	100	18	8	*	877706	348105	11.4	2.1	2.3	*
Educational Services including State Education	55	*	104	*	1185781	2644373	4.6	*	3.9	*
Health Care and Social Assistance	172	6	450	12	1431928	5537405	12.0	0.4	8.1	0.2
Accommodation and Food Services	1534	55	1218	29	1679633	2265617	91.3	3.3	53.8	1.3
Public Administrations	331	22	31	*	881922	771859	37.5	2.5	4.0	*
Other	714	97	251	15	6228161	5655077	11.5	1.6	4.4	0.3

1 Numbers lower than 5 were obscured to protect the identity of the individual

*Rate is per 100,000 worker years

Table 4. Occurrence Rate of Clinically Recognized and Referred Burn Occurrence (CRBO) Stratified by Industry Adjusting for Minors

Industry Group	Male Serious CRBO Count	Male Severe CRBO Count	Female Serious CRBO Count	Female Severe CRBO Count	Total Male Emp.	Total Female Employees	Male Serious Rate	Male Severe Rate	Female Serious Rate	Female Severe Rate
Agriculture, Forestry, Fishery	66	20	12	*	173908.8	95183	38.0	11.5	12.6	*
Construction	409	74	9	*	1414448	222304.8	28.9	5.2	4.0	*
Manufacturing	1362	253	189	21	4524199	1647943	30.1	5.6	11.5	1.3
Wholesale Trade	231	38	31	4	1266889	527296.5	18.2	3.0	5.9	0.8
Retail Trade	166	18	216	10	2294185	2476847	7.2	0.8	8.7	0.4
Transportation and Warehousing	100	18	8	*	872388.5	345956.5	11.5	2.1	2.3	*
Educational Services including State Education	55	*	104	*	1181475	2636145	4.7	0.3	3.9	*
Health Care and Social Assistance	172	6	450	12	1421604	5508722	12.1	0.4	8.2	0.2
Accommodation and Food Services	1534	55	1218	29	1486004	1996725	103.2	3.7	61.0	1.5
Public Administrations	331	22	31	*	874324.8	763538.3	37.9	2.5	4.1	0.1
Other	714	97	251	15	5905156	5574326	12.1	1.6	4.5	0.3

1 Numbers lower than 5 were obscured to protect the identity of the individual

*Rate is per 100,000 worker years.

4.3 The Association between Sex and Severity of Occupational Burns

The central research question for Aim 1.2 is based on a stratification of the burn events by level of severity which is indicated in this thesis based on burn depth and to estimate the degree to which experiencing a severe burn event (as the first burn event recorded in the surveillance dataset during the interval from 2009 through 2019) might be associated with being a female or a male worker. For Aim 1.2, there is a covariate adjustment for age of the worker who experienced the burn event. That is, these Aim 1.2 estimates are from the robust Poisson regression model with covariates restricted to a term for being male (coded male=1 versus female=0), and for worker age in years at the time of the burn event.

Before age is introduced as a covariate, the slope estimates from the robust Poisson model indicate a tangible association that links burn severity with having a sex that is male in the workplace. This is quantified with exponentiation of the slope estimate, resulting in an occurrence ratio of 1.24 (95% CI=1.18, 1.30).

Aim 1.2 also addresses whether there might be some attenuation of this observed degree of subgroup variation when a term for age is added to the first regression model. Quantified as a slope estimate (and before exponentiation), with age held constant as a covariate in the model, the degree of excess occurrence of a burn being severe as experienced by male workers after exponentiation of the slope, the resulting covariate-adjusted occurrence ratio is 1.23 (95% CI= 1.18 1.29).

4.4 Discriminating More Severe from Less Severe Burns (Aim 2)

Aim 2 extends the just-described Aim 1.2 model by adding covariate terms for industry type and for race as recorded in the surveillance dataset. After adding terms for sex, age, and industry type to the regression model (and before adding race as a covariate), I found that the excess odds of a more severe burn (versus a less severe burn) for males was estimated as 2.01 with a 95% CI of 1.60 to 2.52 with covariate adjustment for the other covariates. I studied variation across industry types by taking differences of the linear combinations of the covariate slopes and then exponentiating the difference. With the reference type specified to be the Accommodation and Food industry, the industry with the numerically largest sex-and age-covariate-adjusted excess odds of more severe burns was Agriculture, Forestry, and Fishing (Occurrence Ratio, OCR=5.8; 95% CI=3.7, 9.1). I then changed linear combinations for each industry type to make a comparison of each pair of industry types. In this comparison of industry types, I found that those that did not have large counts, such as Educational Services including State Education, had very large 95% confidence intervals. Those that also had a large female to male ratio of work force, such as Health Care, had more women suffering severe burns when compared to the Accommodation and Food industry. I then removed industry type from the model and added the term(s) for race to the model. Based on this model, I found that the excess odds of a more severe burn (versus a less severe burn) for males was estimated as 3.84, with age and race considered via covariate adjustment. When looking at the race subgroup, those that were black had a slightly increased occurrence ratio of 1.14. The final likelihood ratio test deemed a final model that considered all covariates without product terms.

4.5 Post-Estimation Exploratory Data Analysis

To further explore modeling the covariates when exploring less severe to severe burns, product terms were attempted between each covariate. First, product terms of age and race were studied. I found no appreciable variation of slopes for these cross-classified subgroups. I then used the product term of type of burn with Industry to glean information about industry and severity of the burn. I found that those that received electrical burns and worked in heavy machinery were more likely to suffer a more severe burn. Industry examples were Construction and Agriculture, Forestry, and Fishing. The product term of age and industry was also considered to see if any industry could possibly have specific age groups that are more likely to receive a severe burn versus a lesser one. No age group difference was noticeable when using ages 18-21 as the reference category. All modeling of post estimation exploratory data did not have a likelihood ratio test that was superior to the original model discussed in 4.3.

CHAPTER FIVE: DISCUSSION

My thesis is summarized in this chapter. It provides an overview of my results and their convergence (or non-convergence) with what others have theorized. This study has observed an association between males and having a severe burn injury. While this study has many limitations, its findings disclose important new epidemiological evidence that can help guide future research on these topics. I will discuss future directions for research of a type that might be completed as part of a doctoral dissertation project. My final paragraph concerns the main conclusions from this thesis research project. When comparing males and females, males had a higher occurrence of serious burns when compared to females. The association was more robust when determining severe burn injury.

5.1 Main Findings

Within this Michigan study population, from 2009 to 2019, the estimates for clinically recognized burn occurrences (CRBO), when classified as 'severe,' were larger for male workers. This finding is similar to what others have found. A central limitation to consider is whether female workers are more likely to seek care for burns as compared with male co-workers, except when the burns are quite severe in nature. It is this author's opinion that men are more likely to receive minor burns more often in the workplace and that minor burns of men are under-represented given the burn surveillance approach based on seeking treatment. This opinion is based on previous research that males are more likely to take risks and may be taking on additional risks to maintain expectations of masculinity (Stergiou-Kita et al., 2015).

In Michigan burn surveillance reports since 2009, the statistics indicate that males have more burns in general compared to females. Males are also more likely to work in more hazardous occupations than their female counterparts.

Cohort studies reviewing manufacturing plants and other high-risk areas have also previously reported that men are at a higher risk of obtaining an occupational injury, and these occupational injuries are usually more severe than their female counterpart's injuries. As per this author's knowledge, this is the first report to research how burns are specifically related to male-female distinction.

In terms of the main findings, the male-female occurrence ratio of severe burns after covariate adjustment was not as pronounced as expected. While the occurrence ratio suggests that males might experience more surveillance-detected burns than females, the estimates of this project are not as large as what was expected based on prior evidence and the descriptive analyses of the data. There was a male excess in severe burn occurrence even with covariate adjustments described in the Results chapter.

5.2 Strengths and Limitations

A major strength of this study is its large Michigan-focused surveillance of burns in the total population of employee-adults and its ascertainment of clinically recognized burn occurrences across multiple years and worksites. Another strength involves the comprehensive coverage of surveillance sites that range from hospital emergency rooms to Poison Centers in Michigan. Due to the time frame, this allowed for a large study sample of Michigan residents.

The extended time scale and the wide range of years allowed for a more generalized approach to how burn severity differs between sexes. Another strength of this study was focusing only on burns, as most studies focus on occupational injuries overall when performing their analysis and do not have a separate area for burns. This study was able to recreate similar results found with occupation-related injuries while focusing intensely on burns only. Another strength of this study is that all burns were not self-reported but verified by a healthcare provider, reducing the self-reporting bias that can occur during cross-sectional studies.

There are limitations to this study, listed here based on my subjective judgment about the most limiting to the least limiting in this author’s opinion. This study's most salient limiting factor is that the worker's occupation was not present in the data set. While the North American Industry Classification System (NAICS) codes help establish the environment in which the men and women of Michigan work, it is well known that men and women in the same NAICS codes may have different occupations. As stated in previous studies, even if occupations for each worker were known, the job title does not always indicate the roles or experiences workers might encounter in the workplace; they may be exposed to agents based on social obligations (Biswas, 2021). Another limitation with regards to the Haddon Matrix is that the host factor presents males as more likely not to report occupational injuries than females (Biswas, 2021). The actual number of burns in males, even among the higher severity, is probably underrepresented. Host factors based on social and biological factors were unavailable in the data set. Examples would be drinking habits, smoking habits, or diseases that may make the host more prone to a clinically recognized burn occurrence (CRBO).

When discussing the sampling methods and the nature of the study, there are limitations as well. While providing many cases, the large number of hospitals means that the same health care provider did not perform and record the response variable of burn degree. This author counterpoints that the large number of health care providers used for this study might reduce the bias that any one provider would skew degree of burns reported on individual patients. Many of the injuries did not have a Total Body Surface Area (TBSA) assigned to them. Even with the extensive sampling size required to obtain a large sample of results, there were not enough individuals to adjust accurately for all covariates in performing a Poisson regression. Without TBSA, it was only possible to judge burn severity based on the depth of the burn when following the Haddon Matrix, indicating enough energy was introduced to cause damage to the deepest parts of the human body. TBSA allows the distinction between focused deep burns and either shallow widespread burns or widespread deep burns. Finally, the individual's NAICS codes were only recorded at the time of the clinically recognized burn occurrence.

Considering limitations regarding the outcomes derived from robust Poisson regression models, the credibility and understanding of slope approximations in any model aimed at gauging rely on two primary assumptions: (1) the model is accurately specified with no significant omissions, and (2) it is feasible to encapsulate the relationships with covariate terms using a single slope for each covariate, without necessitating consideration of subgroup variations in slope estimates, which would demand more than one slope per covariate term.

In this thesis, the aim has not been to make causal inferences. Instead, the focus has been on an Aim 1.1 description of burn surveillance estimates and an Aim 1.2 task of identifying worker subgroups where there might be a higher likelihood of more severe burns compared to less severe burns. In such a scenario, the issue of model misspecification and overlooking crucial covariates is less pronounced, in contrast to situations where cause-and-effect inferences are intended.

While these limitations hold back this thesis research project when the goal is to understand sex as a biological and sociological variable about the degree of burns, these limitations don't hold back the main aims of the thesis. To the best of this author's knowledge, this thesis is the first to estimate occurrence rates for burns that vary across subgroups based on data from a pre-specified state-level surveillance system. It also is the first to estimate male-female variations with adjustments for alternative sources of variation and covariates. This thesis cannot be specific about how sex plays a role as a biological or sociological determinant of burn injury occurrences; future study should be considered. In future research, it will be important to address non-binary gender identity, as well as to consider issues neglected in this project such as job title and job roles.

5.3 Future Directions and Conclusion

I have already mentioned some directions for future research, such as obtaining occupational and Total Body Surface Area data. Another direction for future research stems from the nature of sex (male versus female) as an explanatory variable. This thesis focused on female-male sex as a binary gender variable. In recent years, non-binary gender identity assessment questions and protocols have been added to research. It will be imperative to add these non-binary gender options in understanding the role of gender in future research on burns and other injuries as they might vary across occupational settings.

In this thesis, I did not utilize recurrent event models, which could have been employed to examine the patterns of burn event occurrences when workers encounter more than one clinically recognized burn event within a study interval. This represents another avenue for future research, necessitating access to the study data but not requiring additional data collection efforts.

In future research, there is an opportunity to assess the extent of the clustering of more severe burns (or less severe burns) within industry types that exhibit consistent occurrence patterns of these burns. These estimations can be obtained through generalized linear models employing generalized estimating equations. These models can derive estimates of pairwise odds ratios, supplementing the slope estimates derived in this thesis.

For a future study design, a cohort study should be considered to account for the variability of people moving in and out of the workforce and the variability that occurs within the industry. This future study should investigate specific industries, and due to the significant rates in the Accommodation and Food Service Industry, this would be a perfect place to start such an investigation. This new study should also focus on identifying the occupation of those in the workplace and how the exact exposure differs between the two sexes. This would allow the removal of a frustrating aspect of the comparison between the two sexes; most studies are limited in identifying how frequently workers are exposed to hazardous working conditions that can cause burns, based only on the industry and occupational status of the individuals involved. It would also allow more factors to be adjusted and controlled for during modeling to portray the role of sex/gender more accurately in the workplace versus all the factors playing significant roles. In this sense, the cross-sectional survey designs do not provide the best opportunity to study the link between severe burns and sex. Until prospective or other longitudinal data projects are completed to investigate these associations, these results may serve as helpful evidence to guide future studies.

Overall, the results of this thesis can be summarized within the boundaries of the following statements. First, male workers seem to experience a greater occurrence rate of burns than female workers within the State of Michigan. Second, in analyses focused upon workers with a first-experienced burn, the observed associations depart from the null and suggest that more severe burns might be experienced by male workers, even with covariate adjustments. Issues of differential male-female treatment seeking behaviors will have to be resolved via future studies. There are limitations within the overall formation of this study design, such as requiring a different study design to obtain the necessary data for a further deep dive into the material.

As indicated in Chapter 5, much remains to be learned about the role of male-female variations in the study of burns and other occupational injuries. Haddon's Matrix serves as a guide to future research. It reminds us that injury epidemiological research progresses to the extent that investigators inspect each new situation of injury occurrence and further evolve it with each new project. This thesis represents a small step, but provides new insight that can be used to guide future burn epidemiology research and occupational injury research more generally.

REFERENCES

Ahonen, E.Q., Benavides, F.G., Benach, J. (2007). Immigrant populations, Work and health-A systematic literature review. Scandinavian Journal of Work, Environment and Health. 2007;33(2):96–104.

Atiyeh, B., Masellis, A., Conte, C. (2009). Optimizing burn treatment in developing low- and middle-income countries with limited health care resources (part 1). Ann Burns Fire Disasters. 2009 Sep 30;22(3):121-5. PMID: 21991167; PMCID: PMC3188147.

Biswas, A., Harbin, S., Irvin, E., Johnston, H., Begum, M., Tiong, M., Apedaile, D., Koehoorn, M., Smith, P. (2021). Sex and gender differences in occupational hazard exposures: A scoping review of the recent literature. Curr Environ Health Rep. 2021 Dec;8(4):267-280. doi: 10.1007/s40572-021-00330-8. Epub 2021 Nov 27. PMID: 34839446; PMCID: PMC8627292.

Chai, H., Chaudhari, N., Kornhaber, R., Cuttle, L., Fear, M., Wood, F., Martin, L. (2022). Chemical burn to the skin: A systematic review of first aid impacts on clinical outcomes. Burns. 2022 Nov;48(7):1527-1543. doi: 10.1016/j.burns.2022.05.006. Epub 2022 May 14. PMID: 35662479.

Chen, W., Qian, L., Shi, J. *et al.* (2018). Comparing performance between log-binomial and robust Poisson regression models for estimating risk ratios under model misspecification *BMC Med Res Methodol* 18, 63. https://doi.org/10.1186/s12874-018-0519-5.

Charles, N., Walters, V. (2008). Men are leavers alone and women are worriers: gender differences in discourses of health. Health Risk Soc. 2008;10(2):117–132.

Dawson, D.A. (1994). Heavy drinking and the risk of occupational injury. Accid Anal Prev. 1994 Oct;26(5):655-65. doi: 10.1016/0001-4575(94)90027-2. PMID: 7999210.

De Roche, R., Lüscher. N.J., Debrunner, H.U., Fischer, R. (1994). Epidemiological data and costs of burn injuries in workers in Switzerland: an argument for immediate treatment in burn centres. Burns. 1994 Feb;20(1):58-60. doi: 10.1016/0305-4179(94)90108-2. PMID: 8148079.

Farr, W., Humphreys, A. (1885). Vital statistics. Royal Sanitary Institute Great Britain. London. Online. Pg. 254. https://www.google.com/books/edition/Vital_statistics/UWuHDS9l3aIC?hl=en&gbpv=1&dq=%22All+the+preceding+diseases+are+modified,+and+some+are+induced,+by+external+agents,+but+the+present+class+comprises+the+evident+results+of+physical+and+chemical+forces+acting+on+the+organisation.+Burns,+asphyxias,+wounds,+poisonings,+stings,+are+types+of+the+several+sub+orders+of+the+class.+%22&pg=PA254&printsec=frontcover.

Friedstat, J., Brown, D.A., Levi, B. (2017). Chemical, electrical, and radiation injuries. Clin Plast Surg. 2017 Jul;44(3):657-669. doi: 10.1016/j.cps.2017.02.021. Epub 2017 Apr 21. PMID: 28576255; PMCID: PMC5488710.

Global Burden of Disease Collaborative Network. Global Burden of Disease Study 2019 (GBD 2019). Seattle, United States: Institute for Health Metrics and Evaluation (IHME), 2020.Washington https://www.healthdata.org/research-analysis/gbd. Accessed 2/4/2024.

Gowlett, J.A. (2016). The discovery of fire by humans: a long and convoluted process. Philos Trans R Soc Lond B Biol Sci. 2016 Jun 5;371(1696):20150164. doi: 10.1098/rstb.2015.0164. PMID: 27216521; PMCID: PMC4874402.

Guerin, R.J., Reichard, A.A., Derk, S., Hendricks, K.J., Menger-Ogle, L.M., Okun, A.H. (2020). Nonfatal occupational injuries to younger workers - United States, 2012-2018. MMWR Morb Mortal Wkly Rep. 2020 Sep 4;69(35):1204-1209. doi: 10.15585/mmwr.mm6935a3. PMID: 32881848; PMCID: PMC7470462.

Haddon, W. Jr. (1973). Energy damage and the ten countermeasure strategies. J Trauma. 1973 Apr;13(4):321-31. doi: 10.1097/00005373-197304000-00011. PMID: 4700110.

Heimbach, D., Afromowitz, M., Engrav, L., Marvin, J., Perry, B. (1984). Burn depth estimation—man or machine. The Journal of Trauma: Injury, Infection, and Critical Care 24(5):p 373-378, 1984, May. PMID: 6371255.

Hosner, J., Rosenman, K. (2023). Work relation burns in Michigan: Twelfth Report https://oem.msu.edu/images/annual_reports/2021/2019-2021_BurnAnnualReport.pdf. Accessed 2/25/2024.

ICD10Data.com. (2023). https://www.icd10data.com/ICD10CM/Codes/S00-T88/T30-T32/T30-/T30.0. Accessed 8/27/2023.

ICD9Data.com. (2015). http://www.icd9data.com/2012/Volume1/800-999/940-949/default.htm. Accessed 08/27/2023.

Islam, S.S., Velilla, A.M., Doyle, E.J., Ducatman, A.M. (2001). Gender differences in work-related injury/illness: analysis of workers compensation claims. Am J Ind Med. 2001 Jan;39(1):84-91. doi: 10.1002/1097-0274(200101)39:1<84::aid-ajim8>3.0.co;2-t. PMID: 11148018.

Katz, J., Carey, V.J., Zeger, S.L., Sommer, A. (1993). Estimation of design effects and diarrhea clustering within households and villages. Am J Epidemiol. 1993 Dec 1;138(11):994-1006. doi: 10.1093/oxfordjournals.aje.a116820. PMID: 8256785.

Khoo, A.K., Wee, J.T., Ngim, R.C., Wong, M.K. (1994). Occupational burns in the Burns Centre at the Singapore General Hospital. Ann Acad Med Singap. 1994 Sep;23(5):680-3. PMID: 7847747.

Kica, J., Rosenman, K. (2012). Multisource surveillance system for work-related burns. Journal of Occupational and Environmental Medicine 54(5): p 642-647, May 2012 | DOI: 10.1097/JOM.0b013e31824ed31a.

Lam, N.N., Hung, N.T., Duc, N.M. (2019). Influence of gender difference on outcomes of adult burn patients in a developing country. Ann Burns Fire Disasters. 2019 Sep 30;32(3):175-178. PMID: 32313529; PMCID: PMC7155400.

Lee, K.C., Joory, K., Moiemen, N.S. (2014). History of burns: The past, present and the future. Burns Trauma. 2014 Oct 25;2(4):169-80. doi: 10.4103/2321-3868.143620. PMID: 27574647; PMCID: PMC4978094.

Lu, T.H. (2006). Unalterable host factors? A social epidemiologist's view of the Haddon matrix. Inj Prev. 2006 Oct;12(5):285-6. doi: 10.1136/ip.2006.013912. PMID: 17018667; PMCID: PMC2563446.

Majno, G. (1975). The healing hand: Man and wound in the ancient world. Cambridge: Harvard University Press.

McCullough, J.E., Henderson, A.K., Kaufman, J.D. (1998). Occupational burns in Washington State, 1989-1993. J Occup Environ Med. 1998 Dec;40(12):1083-9. doi: 10.1097/00043764-199812000-00008. PMID: 9871885.

McDermott, K.W., Weiss, A.J., Elixhauser, A. (2006). Burn-related hospital inpatient stays and emergency department visits, 2013. 2016 Dec. In: Healthcare Cost and Utilization Project (HCUP) Statistical Briefs [Internet]. Rockville (MD): Agency for Healthcare Research and Quality (US); 2006 Feb-. Table 6, ICD-9-CM diagnosis codes defining CCS diagnosis category 240, Burns. Available from: https://www.ncbi.nlm.nih.gov/books/NBK409513/table/sb217.t6/.

McInnes, J.A., Cleland, H., Tracy, L.M., Darton, A., Wood, F.M., Perrett, T., Gabbe, B.J. (2019). Epidemiology of work-related burn injuries presenting to burn centres in Australia and New Zealand. Burns. 2019 Mar;45(2):484-493. doi: 10.1016/j.burns.2018.09.011. Epub 2018 Sep 28. PMID: 30274814.

Messing, K., Punnett, L., Bond, M, et al. (2023). Be the fairest of them all: challenges and recommendations for the treatment of gender in occupational health research. Am J Ind Med. 2003;43(6):618-629.

Mian, M.A., Mullins, R.F., Alam, B., Brandigi, C., Friedman, B.C., Shaver, J.R., Hassan, Z. (2011). Workplace-related burns. Ann Burns Fire Disasters. 2011 Jun 30;24(2):89-93. PMID: 22262966; PMCID: PMC3230153.

Michigan Department of Health and Human Services. (2021). Work-related burns Michigan 2018. https://www.michigan.gov/-/media/Project/Websites/mdhhs/Folder4/Folder35/Folder3/Folder135/Folder2/Folder235/Folder1/Folder335/2018_Burns_Report.pdf?rev=8a67f4ee9a4d4973a61b4e7d4f2f4615.

Mitchell, O. (1998). The relation of age to workplace injuries. Monthly Labor Review. 1988, July. https://www.bls.gov/opub/mlr/1988/07/art2full.pdf.

Monstrey, S., Hoeksema, H., Verbelen, J., Pirayesh, A., Blondeel, P. (2008). Assessment of burn depth and burn wound healing potential. Burns. 2008 Sep;34(6):761-9. doi: 10.1016/j.burns.2008.01.009. Epub 2008 Jun 3. PMID: 18511202.

Ng, D., Anastakis, D., Douglas, L.G., Peters, W.J. (1991). Work-related burns: a 6-year retrospective study. Burns. 1991 Apr;17(2):151-4. doi: 10.1016/0305-4179(91)90140-c. PMID: 2054074.

Oyebode, A., Taiwo, L. F., Cantley, M.D., Slade, K.M., Pollack, S.V., Fiellin, M.G., Cullen, M.R. (2009). Sex differences in injury patterns among workers in heavy manufacturing, *American Journal of Epidemiology*, Volume 169, Issue 2, 15 January 2009, Pages 161–166, https://doi.org/10.1093/aje/kwn304.

Pukkala, E, Martinsen, J.I., Lynge, E, Gunnarsdottir, H.K., Sparén, P., Tryggvadottir, L., Weiderpass, E., Kjaerheim, K. (2009). Occupation and cancer - follow-up of 15 million people in five Nordic countries. Acta Oncol. 2009;48(5):646-790. doi: 10.1080/02841860902913546. PMID: 19925375.

Purola, L., Kavola, H., Vuola, J. (2022). Occupational burn injuries in Finland 2011-2015. Inj Epidemiol. 2022 Aug 26;9(1):28. doi: 10.1186/s40621-022-00387-5. PMID: 36028913; PMCID: PMC9419400.

Reichard, A.A., Konda, S., Jackson, L.L. (2015). Occupational burns treated in emergency departments. Am J Ind Med. 2015 Mar;58(3):290-8. doi: 10.1002/ajim.22407. PMID: 25678457; PMCID: PMC4528302.

Richardson, D.B., Loomis, D., Bena, J., Bailer, A.J. (2004). Fatal occupational injury rates in southern and non-southern States, by race and Hispanic ethnicity. American journal of public health. 2004;94(10).

Rizzo, J.A., Coates, E.C., Serio-Melvin, M.L., Aden, J.K., Stallings, J.D., Foster, K.N., Abdel Fattah, K.R., Pham, T.N., Salinas, J. (2023). Higher initial formula for resuscitation after severe burn injury means higher 24-hour volumes. J Burn Care Res. 2023 Sep 7;44(5):1017-1022. doi: 10.1093/jbcr/irad065. PMID: 37339255.

Robinson, J.C. (1989). Exposure to occupational hazards among Hispanics, blacks and non-Hispanic whites in California. American journal of public health. 1989;79(5):629–30.

Runyan, C.W., Baker, S.P. (2009). Preventing injuries by understanding energy damage. Bull World Health Organ. 2009 May;87(5):402-3. doi: 10.2471/blt.09.063586. PMID: 19551259; PMCID: PMC2678760.

Schaefer, T.J., Nunez Lopez, O. (2023). Burn resuscitation and management. 2023 Jan 23. In: StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing; 2024 Jan–. PMID: 28613546.

Schaefer, T., Szymanski, K. (2023). Burn evaluation and management. https://www.ncbi.nlm.nih.gov/books/NBK430741/. PMID: 28613492.

Simpson, C.L., Severson, R.K. (2000). Risk of injury in African American hospital workers. Journal of Occupational and Environmental Medicine. 2000;42(10):1035.

Song, C., Chua, A. (2005). Epidemiology of burn injuries in Singapore from 1997 to 2003. Burns. 2005 Jan;31 Suppl 1:S18-26. doi: 10.1016/j.burns.2004.10.005. PMID: 15649612.

Stanbury, M., Rosenman, K.D. (2014). Occupational health disparities: a state public health-based approach. Am J Ind Med. 2014 May;57(5):596-604. doi: 10.1002/ajim.22292. Epub 2013 Dec 30. PMID: 24375809.

Stergiou-Kita, M., Mansfield, E., Bezo, R., Colantonio, A., Garritano, E., Lafrance, M., Lewko, J., Mantis, S., Moody, J., Power, N., Theberge, N., Westwood, E., Travers, K. (2015). Danger zone: Men, masculinity and occupational health and safety in high risk occupations. Saf Sci. 2015 Dec 1;80:213-220. doi: 10.1016/j.ssci.2015.07.029. PMID: 27239098; PMCID: PMC4880472.

Strong, L.L., Zimmerman, F.J. (2005). Occupational injury and absence from work among African American, Hispanic, and Non-Hispanic White workers in the national longitudinal survey of youth. American journal of public health. 2005;95(7):1226.

Tessier-Sherman, B., Cantley, L.F., Galusha, D., et al. (2014). Occupational injury risk by sex in a manufacturing cohort Occupational and Environmental Medicine 2014;71:605-610.

Toussaint, J., Singer, A.J. (2014). The evaluation and management of thermal injuries: 2014 update. Clin Exp Emerg Med. 2014 Sep 30;1(1):8-18. doi: 10.15441/ceem.14.029. PMID: 27752547; PMCID: PMC5052819.

Türegün, M., Sengezer, M., Selmanpakoglu, N., Celiköz, B., Nişanci, M. (1997). The last 10 years in a burn centre in Ankara, Turkey: an analysis of 5264 cases. Burns. 1997 Nov-Dec;23(7-8):584-90. doi: 10.1016/s0305-4179(97)00081-8. PMID: 9568329.

Udry, J.R. (1998). Why are males injured more than females? Inj Prev. 1998 Jun;4(2):94-5. doi: 10.1136/ip.4.2.94. PMID: 9666360; PMCID: PMC1730355.

US Bureau of Labor Statistics. (2023). https://data.bls.gov/gqt/InitialPage;jsessionid=B59F8355036C0C256D8B8E8A88FB0AEC._t3_07v. Accessed 8/27/2023.

US Census Bureau. Economic Census: NAICS Codes & Understanding Industry Classification Systems. (2024). NAICS Codes & Understanding Industry Classification Systems (census.gov). Accessed 3/13/2024.

World Health Organization. (2023). Burns. 13 Oct., 2023. https://www.who.int/news-room/fact-sheets/detail/burns. Accessed 3/14/2024.

Yang, X., Ren, H., Guo, X., Hu, C., Fu, J. (2020). Radiation-induced skin injury: pathogenesis, treatment, and management. Aging (Albany NY). 2020 Nov 16;12(22):23379-23393. doi: 10.18632/aging.103932. Epub 2020 Nov 16. PMID: 33202382; PMCID: PMC7746368.

Zierold, K.M., Anderson, H.A. (2006). Racial and ethnic disparities in work-related injuries among teenagers. Journal of adolescent health. 2006;39(3):422–6.

Zierold, K.M., Welsh, E.C., McGeeney, T.J. (2012). Attitudes of teenagers towards workplace safety training. J Community Health. 2012 Dec;37(6):1289-95. doi: 10.1007/s10900-012-9570-z. PMID: 22614536.

APPENDIX A

TABLES

Table 5. Sociodemographic, industry, and characteristics of occupation-related burns that were reported during the time period between 2009-2019 in the State of Michigan separated based on reported sex at time of admittance N=10,572

	Sex at time of burn			
	Male (n=6,585)		Female (n=3,987)	
Characteristic of patient and occupation-related burn at time of admittance	N	(%)	N	(%)
Race/Ethnicity				
Non-Hispanic White	3252	(49)	1947	(49)
Non-Hispanic Black	495	(8)	310	(8)
Hispanic	114	(2)	36	(1)
Other	143	(2)	89	(2)
Unknown	2581	(39)	1605	(40)
Age, years				
18-21	1067	(16)	938	(24)
22-24	752	(11)	503	(13)
25-34	1856	(28)	1061	(27)
35-44	1301	(20)	587	(15)
45-54	1025	(16)	557	(14)
55-64	500	(8)	307	(8)
>65	84	(1)	34	(1)
Industry				
Agriculture, Forestry, and Fishery	90	(1)	19	(1)
Construction	517	(8)	15	(0)
Manufacturing	1637	(25)	268	(7)
Wholesale Trade	298	(5)	43	(1)
Retail Trade	246	(4)	346	(9)
Transportation and Warehousing	130	(2)	12	(0)
Educational Services including State Education	80	(1)	176	(4)
Health Care and Social Assistance	270	(4)	872	(22)
Accommodation and Food Services	1962	(30)	1806	(45)
Public Administrations	426	(6)	52	(1)
Other	929	(14)	378	(10)
Burn Injury Type				
Thermal	5107	(78)	3469	(87)
Chemical	989	(15)	337	(8)
Electrical	275	(4)	28	(1)

Table 5. (Cont'd)

Radiation	26	(0)	3	(0)
Other	26	(0)	13	(0)
Unknown	162	(3)	137	(4)
TBSA				
Unknown	4961	(75)	3314	(83)
<10%	1344	(23)	618	(16)
≥10%	280	(1)	55	(0)

Table 6. Sociodemographic, industry, and characteristics of occupation-related burns that were reported during the time period between 2009-2019 in the State of Michigan separated based on reported severity of burn at time of admittance N=10,572

		1st-degree (N=2,913)		2nd-degree (N=6,960)		3rd-degree (N=699)
	N	%	N	%	N	%
Race/Ethnicity						
Non-Hispanic White	1391	(48)	3440	(49)	368	(53)
Non-Hispanic Black	196	(7)	545	(8)	64	(9)
Hispanic/Latino	37	(1)	101	(1)	12	(2)
Other/multiple	49	(2)	166	(2)	17	(2)
Unknown	1240	(43)	2708	(39)	238	(34)
Age						
18-21	606	(21)	1340	(19)	59	(8)
22-24	362	(12)	830	(12)	63	(9)
25-34	806	(28)	1924	(28)	187	(27)
35-44	473	(16)	1254	(18)	161	(23)
45-54	423	(15)	1030	(15)	129	(18)
55-64	221	(8)	504	(7)	82	(12)
≥65	22	(1)	78	(1)	18	(3)
Industry						
Agriculture, Forestry, and Fishery	31	(1)	57	(1)	21	(3)
Construction	114	(4)	343	(5)	75	(11)
Manufacturing	354	(12)	1277	(18)	274	(39)
Wholesale Trade	79	(3)	220	(3)	42	(6)
Retail Trade	210	(7)	354	(5)	28	(4)
Transportation and Warehousing	34	(1)	90	(1)	18	(3)

Table 6. (Cont'd)

Educational Services including State Education	97	(3)	155	(2)	4	(1)
Health Care and Social Assistance	520	(18)	604	(9)	18	(3)
Accommodation and Food Services	1016	(35)	2688	(38)	84	(12)
Public Administrations	116	(4)	339	(5)	23	(3)
Other	342	(12)	853	(12)	112	(16)
Type						
Thermal	2157	(74)	5935	(85)	484	(69)
Chemical	592	(20)	619	(9)	115	(16)
Electrical	76	(3)	155	(2)	72	(10)
Radiation	14	(0)	11	(0)	4	(1)
Other	9	(0)	23	(0)	7	(1)
Unknown	65	(2)	217	(3)	17	(2)
TBSA						
Unknown	2578	(89)	5263	(76)	430	(62)
<10%	310	(11)	1485	(23)	167	(31)
>=10%	25	(0)	209	(1)	101	(8)

Table 7. Rate and Occurrence Ratio and 95% confidence intervals for the association between sex and severity of burn degree.

Rate of Serious Burns[a] that Occurred in Michigan					
	Rate per 100,000 Michigan workers	**Unadjusted OCR**	**Unadjusted CI**	**Adjusted OCR[b]**	**Adjusted CI[b]**
Male	23.2	1.24	1.18-1.30	1.16	1.14-1.21
Female	17.9	1.0	1.0	1.0	1.0

Abbreviations: CI, Confidence Interval; OCR, Occurrence Rate Ratio.
[a] Serious burn defined as an individual presenting and diagnosed with a 2nd-degree burn or higher.
[b] Adjusted for Age (group)*, Industry (NAICS code), Type (Thermal, Chemical, Electrical, Radiation, Other/Multiple), Race (Non-Hispanic White, Non-Hispanic Black, Hispanic/Latino, other/multiple, unknown)
*Age for occupational injuries does not have a continuous effect so age categories were used for adjustment

Table 8. Rate and Occurrence Ratio and 95% confidence intervals for the association between sex and severity of burn degree.

Rate of Severe Burns[a] that Occurred in Michigan					
	Rate per 100,000 Michigan workers	**Unadjusted OCR**	**Unadjusted CI**	**Adjusted OCR[b]**	**Adjusted CI[b]**
Male	2.7	3.85	3.10-4.78	2.01	1.60-2.52
Female	0.4	1.0	1.0	1.0	1.0

Abbreviations: CI, Confidence Interval; OCR, Occurrence Rate Ratio.
[a] Severe burn defined as an individual presenting and diagnosed with a 3rd-degree burn or higher
[b] Adjusted for Age (group), Industry (NAICS code), Type (Thermal, Chemical, Electrical, Radiation, Other/Multiple), Race (Non-Hispanic White, Non-Hispanic Black, Hispanic/Latino, other/multiple, unknown)
*Age for occupational injuries does not have a continuous effect so age categories were used for adjustment

APPENDIX B

FIGURES

Figure 1. The study focused on occupational burns in individuals aged 18 and older, specifically the first burn injury within a defined timeframe with complete data on sex, burn depth, and industry code

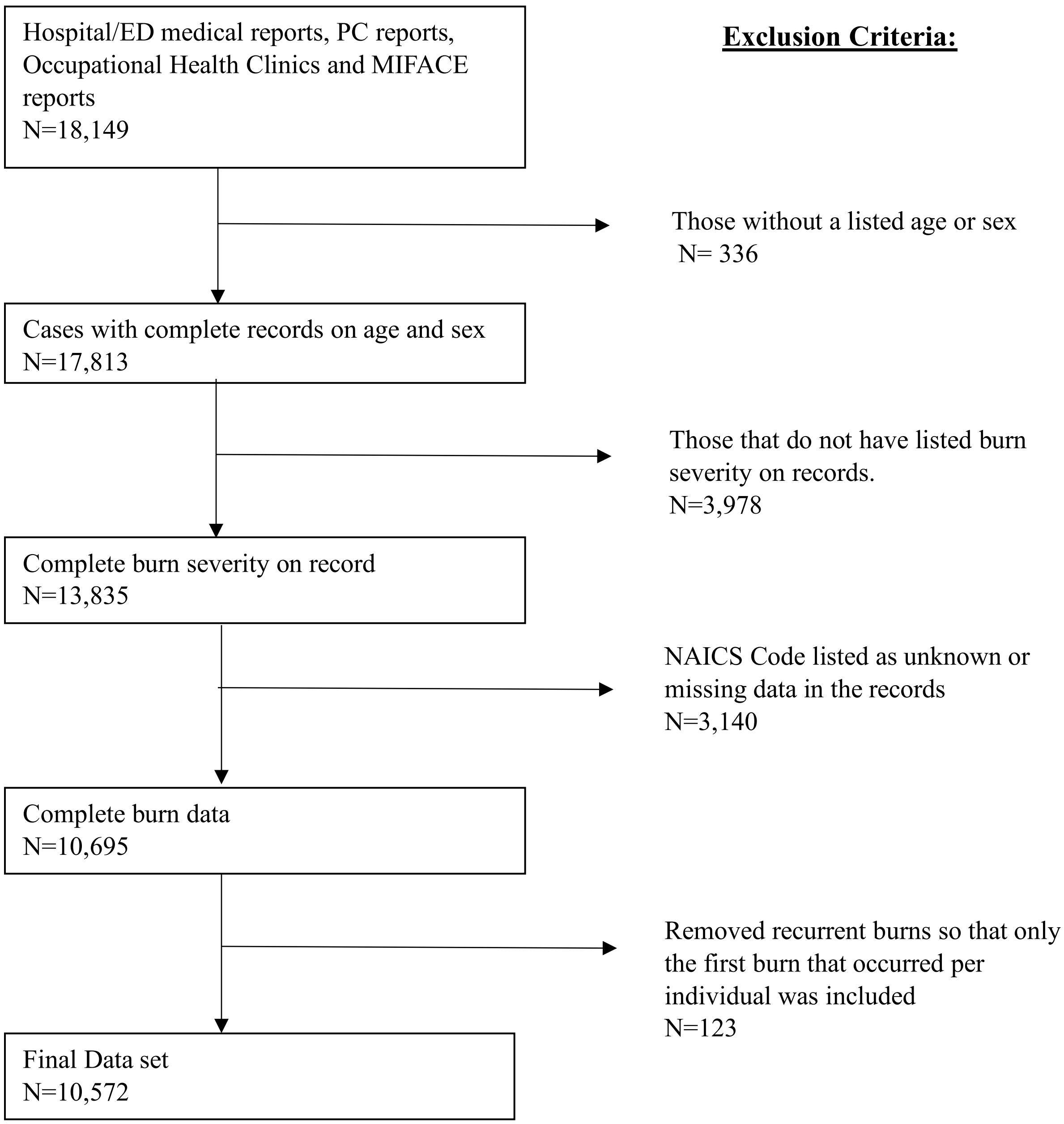
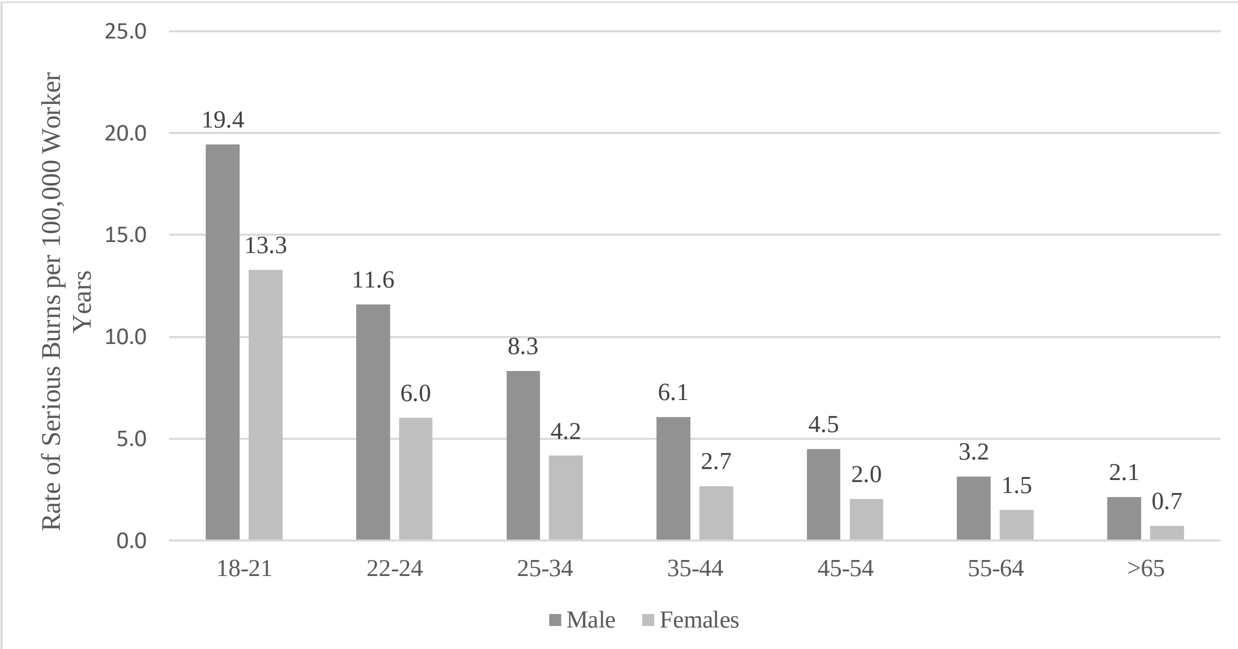


Figure 2. Temporal Trends in the Total Number of Occupation-Related Burns

Figure 3. Comparison of Rates of Serious and Severe Burn between Males and Females Stratified by Age Groups



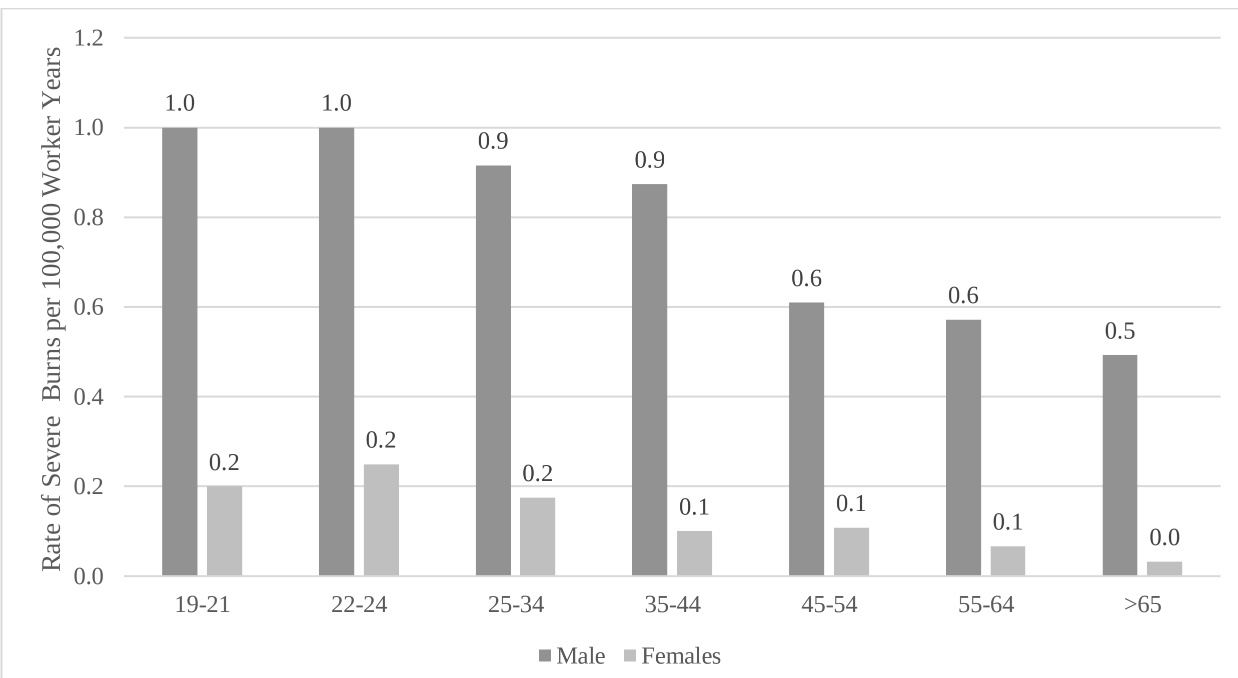


Figure 4. Comparison of Severity of Burn between Males and Females Stratified by Industry.

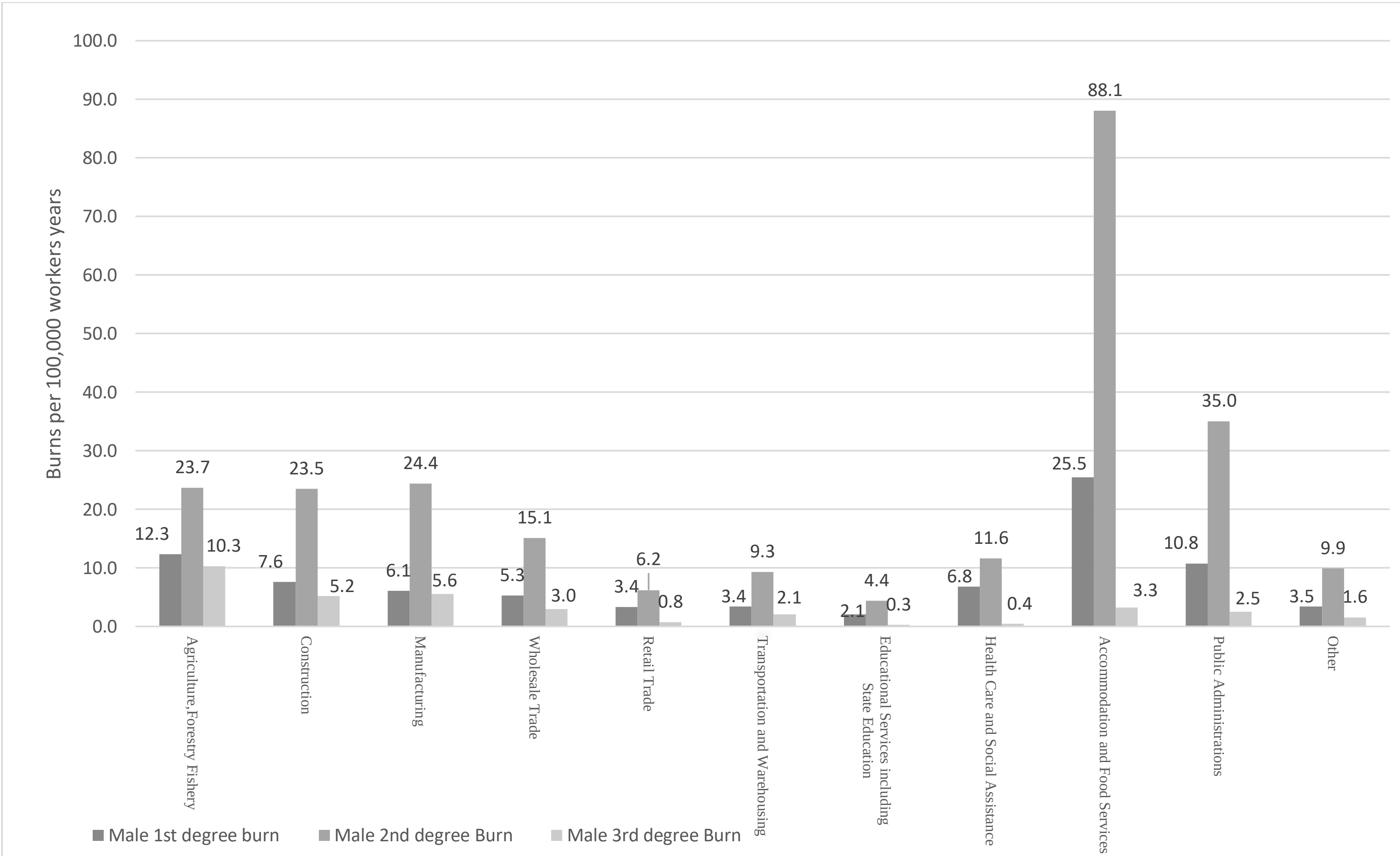
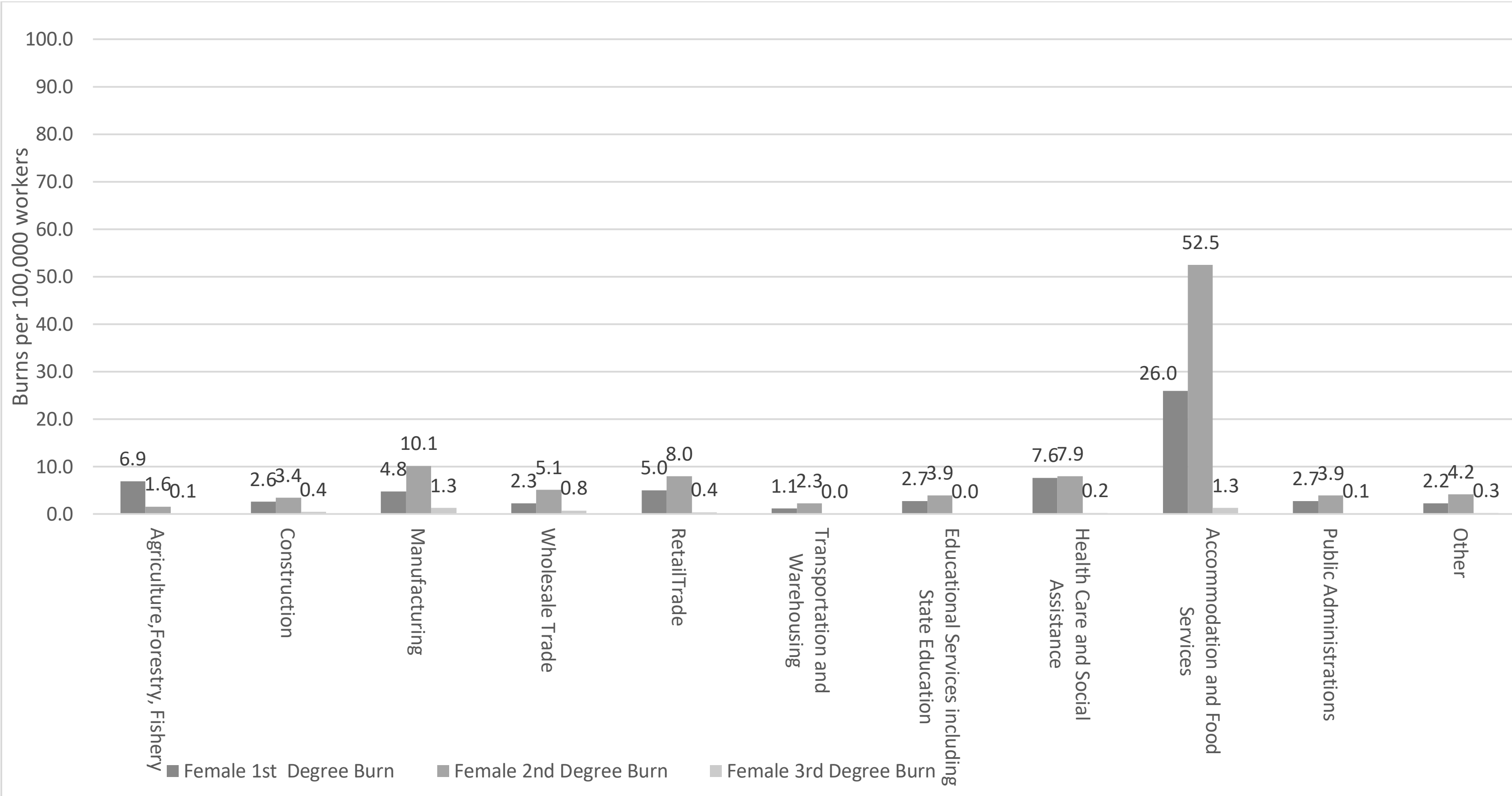


Figure 4. (Cont'd)



APPENDIX C

SUPPLEMENTAL TABLES

Supplemental Table 1.

ICD-9-CM Diagnosis Codes

ICD-9-CM Codes	Area Affected
940.0-.9	(burn confined to eye)
941.0-.5	(burn of head, face, neck)
942.0-.5	(burn of trunk)
943.0-.5	(Burn of upper limb, except wrist and hand)
944.0-.5	(burn of wrist[s] and hand[s]),
945.0-.5	(burn of lower limb),
945.0-.5	(burns of multiple, specified sites),
946.0-.5	(burns of internal organs),
947.0-.5	(burns classified according to extent)
949.0-.9	(burn, unspecified)

Supplemental Table 2.

ICD-10-CM Codes Used to Identify Burn Injuries

ICD-10-CM Codes	Injury Classification
T20.00-T20.79, T21.00-T21.79, T22.00-T22.79, T23.00-T23.70, T24.00-T24.79, T25.00-T25.79, T26.00-T26.92, T27.0-T27.7, T28.0-T28.9	Burn injury (by part of body burned)
T30.0, T30.4, T31.0-T31.9, T32.0-T32.9	Burn injury (by extent of body surface involved

Supplemental Table 3.

North American Industry Classification System

NAICS Code	Industry Classification
11	Agriculture, forestry, fishing and hunting
21	Mining, quarrying, and oil and gas extraction
22	Utilities
23	Construction
31-33	Manufacturing
31	Food manufacturing
32	Wood products manufacturing
33	Primary metal manufacturing
42	Wholesale trade
44-45	Retail trade
48-49	Transportation and warehousing
51	Information
52	Finance and insurance
53	Real estate and rental and leasing
54	Professional, scientific, and technical services
55	Management of companies and enterprises
56	Administrative and support and waste management and remediation services
61	Educational services
62	Health care and social assistance
71	Arts, entertainment, and recreation
72	Accommodation and food services
81	Other services (except public administration)
92	Public administration
99	Unknown

Supplemental Table 4.

Study Industry Grouping

Industry Grouping	NAICS Code
Agriculture, Forestry, and Fishery	11
Construction	23
Manufacturing	31-33
Wholesale Trade	42
Retail Trade	44-45
Transportation and Warehousing	48-49
Educational Services including State Education	61
Health Care and Social Assistance	62

Supplemental Table 4. (Cont'd)

Accommodation and Food Services	72
Public Administrations	92
Other	21,22,51-56,71,81