2022

Etiology of Firefighter Injuries: A Health Care Practitioner Perspective

Alyssa Quinn Eastman
University of Kentucky, alieastman8@gmail.com
Digital Object Identifier: https://doi.org/10.13023/etd.2022.292

STUDENT AGREEMENT:

I represent that my thesis or dissertation and abstract are my original work. Proper attribution has been given to all outside sources. I understand that I am solely responsible for obtaining any needed copyright permissions. I have obtained needed written permission statement(s) from the owner(s) of each third-party copyrighted matter to be included in my work, allowing electronic distribution (if such use is not permitted by the fair use doctrine) which will be submitted to UKnowledge as Additional File.

I hereby grant to The University of Kentucky and its agents the irrevocable, non-exclusive, and royalty-free license to archive and make accessible my work in whole or in part in all forms of media, now or hereafter known. I agree that the document mentioned above may be made available immediately for worldwide access unless an embargo applies.

I retain all other ownership rights to the copyright of my work. I also retain the right to use in future works (such as articles or books) all or part of my work. I understand that I am free to register the copyright to my work.

REVIEW, APPROVAL AND ACCEPTANCE

The document mentioned above has been reviewed and accepted by the student's advisor, on behalf of the advisory committee, and by the Director of Graduate Studies (DGS), on behalf of the program; we verify that this is the final, approved version of the student's thesis including all changes required by the advisory committee. The undersigned agree to abide by the statements above.

Alyssa Quinn Eastman, Student

Dr. Mark G. Abel, Major Professor

Dr. Melinda J. Ickes, Director of Graduate Studies

ETIOLOGY OF FIREFIGHTER INJURIES:
A HEALTH CARE PRACTITIONER PERSPECTIVE

THESIS

A thesis submitted in partial fulfillment of the
requirements for the degree of Master of Science in the
College of Education
at the University of Kentucky

By
Alyssa Quinn Eastman
Lexington, Kentucky
Director: Dr. Mark G. Abel, Professor of Kinesiology and Health Promotion
Lexington, Kentucky
2022

ABSTRACT OF THESIS

ETIOLOGY OF FIREFIGHTER INJURIES: A HEALTH CARE PRACTITIONER PERSPECTIVE

BACKGROUND: Structural firefighting involves the performance of rigorous occupational tasks in unpredictable, dynamic, and hot environments which increases firefighters' risk of injury. Specifically, the National Fire Protection Association reported that musculoskeletal injuries account for 56% of non-fireground and 41% of fireground injuries. Furthermore, physical training is the most common cause of injury, accounting for one-third of all injuries and resulting in 41% of post-injury absences from work. There is limited research identifying occupational and exercise injury risk factors among firefighters. However, experienced health care practitioners working with fire departments may provide critical insight into potential mechanisms of these common injuries. Therefore, the purpose of this study was to query health care practitioners who regularly treat structural firefighters to identify potential mechanisms and risk factors associated with musculoskeletal injuries during occupational tasks and during exercise. METHODS: A phenomenological design was utilized to describe the experiences of health care practitioners when treating musculoskeletal injuries in firefighters. Semi-structured interviews were conducted virtually with 14 health care practitioners. Inclusion criteria included licensed health care practitioners (e.g., Athletic Trainer, Physical Therapist), who had at least one year of experience in treating and rehabilitating firefighter injuries. Two interviews were pilot tested with health care practitioners to ensure reliability and validity. Subsequently, 12 practitioners' (Relevant clinical experience = 11.8 ± 10.4 yr) interviews were used in the data analyses. Interviews were transcribed and uploaded to a qualitative analysis software program. To ensure reliability and validity of codes and categories, two researchers coded to a level of agreement of at least 90%. Member checking was used to ensure the accuracy of findings with health care practitioners' responses. RESULTS: Health care practitioners indicated that the back and shoulder were the most prevalent anatomical locations for exercise and occupational injuries. Identified risk factors for exercise injuries included age, immobility, movement proficiency, and general fatigue, recovery, and sleep. Identified risk factors for occupational injuries included age, immobility, and general fatigue, sleep, and recovery. Lifting was considered the most prevalent injury mechanism for exercise and occupational injuries. Specifically, for exercise injuries, poor lifting technique was commonly associated with resistance training. For occupational injuries, patient transfers and poor lifting technique were cited as common injury mechanisms. These findings provide key areas of focus for research and programmatic interventions to reduce injury risk among firefighters.

KEYWORDS: firefighters; musculoskeletal injuries; health care providers; risk factors

Alyssa Quinn Eastman

(Name of Student)

07/25/2022

Date

ETIOLOGY OF FIREFIGHTER INJURIES:

A HEALTH CARE PRACTITIONER PERSPECTIVE

By

Alyssa Quinn Eastman

Dr. Mark G. Abel

Director of Thesis

Dr. Melinda J. Ickes

Director of Graduate Studies

07/25/2022

Date

DEDICATION

Robert John Eastman

Deputy Chief, South County Fire, Washington State

Retired Master Sergeant Nevada Air National Guard

Retired United States Coast Guard

Meritorious Service Medal

Air Force Commendation Medal X2

Army Achievement Medal

Coast Guard Achievement Medal

Iraq Campaign Medal

C3C Calan Tobias Eastman

United States Air Force Academy

Cadet 36th Squadron

ACKNOWLEDGMENTS

The following thesis, while an individual work, benefited from the insights and direction of several people. First, my Thesis Chair, Dr. Mark Abel exemplifies the high-quality scholarship to which I aspire. Thank you for taking me on as a graduate student, I am forever grateful for the opportunity to work with you. In addition, Dr. Beth Rous provided timely and instructive comments and evaluation at every stage of the thesis process, allowing me to complete this project on schedule. Next, I wish to thank the complete Thesis Committee, and outside reader, respectively: Dr. Phillip Gribble, Dr. Nick Heebner, and Dr. Rosie Lanphere. Each individual provided insights that guided and challenged my thinking, substantially improving the finished product.

Dr. Emily Langford, I have learned so much from you and I am in constant awe of your tenacity and drive. Your accomplishments are well deserved and earned. I am forever thankful for your friendship. Isabelle Gillis, Mariana Jacobs, and Clara Mitchinson, I am forever thankful for your friendship. Thank you for the constant support. I am so excited to see everything each of you accomplish.

To my parents, Robin, and Robert Eastman, thank you for always believing in me. From all the years playing soccer to my academic endeavors, thank you for always being my support system. To my brother, Calan Eastman, I am so incredibly proud to be your sister. I am so proud of you and your accomplishments thus far at the United States Air Force Academy. To Ben, thank you for being my resident physical therapist throughout this whole project and for all of your support.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1. INTRODUCTION

1.1 BACKGROUND

Firefighting requires numerous occupational demands that may compromise firefighters' safety. Firefighting involves the performance of rigorous occupational tasks in unpredictable, dynamic, and hot environments which expose firefighters to a variety of physical and psychological stressors (Frost et a., 2015; Szubet & Sobala, 2002). In addition, firefighters' work schedules often result in deleterious sleep patterns (Dobson et al., 2013; Sullivan et al., 2017). These occupational demands may, in part, predispose firefighters to an increased risk of injury (Lyon et al., 2017; Teyhen et al., 2015). Injuries are common in the Fire Service, as the National Fire Protection Association (NFPA) reported that approximately 60,000 injuries are incurred by U.S. firefighters annually (Campbell and Evarts, 2020). Furthermore, the type and cause of injury are of interest given future efforts to create appropriate countermeasures. To that end, the NFPA has identified musculoskeletal injuries (e.g., sprains and strains), as a significant cause for both non-fireground and fireground injuries, accounting for 56% and 41% of these injuries, respectively (Campbell and Evarts, 2020). These injuries incur substantial direct and indirect costs to the municipality and firefighter and result in a $9 billion cost to U.S. fire departments annually (Zhuang et al., 2017). Injuries typically occur in the back and shoulder (Campbell and Evarts, 2020). Regarding injury cause, overexertion or strain is the leading cause of injury, and is responsible for 29% of all fireground injuries, however the prevalence of overexertion-related injuries has not been described in non-fireground injuries (Campbell and Evarts, 2020).

Firefighters must maintain adequate physical fitness levels to promote occupational readiness and decrease risk of injury while responding to emergencies (Poplin et al., 2012). To promote physical fitness, it is important that firefighters participate in a physical training program. Ironically, physical training is the most common cause of firefighter injuries, accounting for one-third of all injuries and is responsible for 41% of post-injury absence from work (Frost et al., 2015; Poplin et al., 2012; Szubert and Sobala, 2002). The most common anatomical locations of these non-fireground injuries are the knee, ankle, shoulder, and back (Frost et al., 2015). However, additional information is needed to provide context regarding the risk factors and mechanisms of exercise and occupational injuries.

Researchers have attempted to predict injury occurrence via physical fitness outcomes (Butler et al., 2013; Poplin et al., 2014). Specifically, aerobic fitness, the deep squat and push-up components of the Functional Movement Screening, and the sit-and-reach assessments have been found to be correlated to injury occurrence or risk (Butler et al., 2013). Although these data are informative and indicate that greater physical fitness and movement proficiency are related to lesser injury risk, they present non-causal relationships with injury. Thus, it is critical to identify specific musculoskeletal injury mechanisms during physical training and other occupational tasks to reduce injury prevalence. An alternative approach to identifying firefighter injury mechanisms is to survey health care practitioners that regularly treat firefighter injuries. As common practice, health care practitioners typically interview injured firefighters to gather contextual factors that may be associated with the injury occurrence and assess potential physical limitations that may have predisposed the firefighter to injury. This methodological approach may provide critical information regarding identification of firefighter injury mechanisms and risk factors. Therefore, the purpose of this study was to utilize health care practitioners to identify prevalent injury types and anatomical locations, as well as common injury mechanisms and risk factors during exercise and other occupational tasks. The findings from this investigation will provide key focus areas for future research and programmatic interventions.

CHAPTER 2. LITERATURE REVIEW

2.1 INTRODUCTION

The following sections provide a brief review of several content areas including physiological demands of firefighting, commonly incurred musculoskeletal injuries, the impact of exercise programs on injury risk and potential outcomes, injury costs, and review of phenomenological research methodology. This literature will provide a foundation to explore health care practitioners' experiences regarding firefighter injury risk factors and mechanisms of exercise and occupational injuries.

2.2 PHYSICAL AND PHYSIOLOGICAL DEMANDS

The occupational demands of firefighting require adequate fitness for performance, safety, reduced risk of sudden cardiac death, as well as musculoskeletal injury. Previous literature has provided a thorough description of the physiological demands of firefighting tasks. Firefighter tasks require all three energy systems depending on the activity and duration performed. For instance, tasks that require the phosphagen system often include advancing a charged hose line, forcible entry, ladder raise, and lifting/lowering objects (Abel et al., 2015). Tasks that typically utilize the phosphagen system are short in duration (≤10 s) and require strength and / or power (Gastin, 2001). Tasks that utilize the glycolytic energy system are of moderate duration (30-120 s) and may include victim rescue and load carriage tasks (Abel et al., 2015; Gastin, 2001).). Tasks that utilize the oxidative energy system are of longer duration (i.e., >120 s) and include stair climb, hose operations, confined space maneuver, salvage, and overhaul tasks (Abel et al., 2015; Gastin, 2001). It is important to note that often these energy systems overlap with each other, and each task is typically not supported by a singular energy system. This requires firefighters to have adequate aerobic and anaerobic fitness and possess suffient levels of strength, power, muscular endurance, and cardiorespiratory endurance.

2.3 GEAR AND MUSCULOSKLETAL INJURIES

The weight of the gear takes a toll on firefighters' bodies. Firefighter gear includes a self-breathing apparatus (SCBA), turnout gear (coat and pants), gloves, hood, and steel toed boots (Kollock et al., 2021; Park et al., 2015). Park et al. (2015) and colleagues have found that turn out gear and SCBA requires greater oxygen uptake, greater blood lactate, greater mechanical work production, and results in lower running speeds when tasked with completing a 10-meter walking protocol. Park et al. (2015) found that the weight and bulkiness of the gear can reduce range of motion in the sagittal and transverse planes of the lower body. Specifically, there was an increased risk of ankle sprains and reduced range of motion in the ankle and ball of the foot in firefighters in full turnout gear (Park et al., 2015). The gear has also contributed to fall-related injuries due to gait imbalances and changes in the center of mass which leads to an elevated risk of slipping (Park et al., 2015). The limitations of the gear and nature of occupational tasks lead to firefighters putting greater strain on their body. Kollock et al. (2021) examined the effect of firefighter gear and equipment on posture stability in fire cadets. Kollock et al., (2021) assessed dynamic postural stability index, limits of stability, and normal stability with and without gear and equipment. Kollock et al., (2021) found that cadets with less body mass had trouble maintaining stability when donning gear. There is evidence that the gear will contribute to immobility and dynamic balance which potentially could be risk factors for musculoskeletal injuries during occupational tasks and Kong et al., (2013) indicates in a review article that gear may be an extrinsic risk factor that contributes to firefighter injuries.

2.4 ANATOMICAL INJURY LOCATIONS

Frost et al. (2015) and Poplin et al. (2012) identified physical training as the most common setting for injury. Frost et al. (2015) examined the injuries sustained by firefighters with injury surveillance data. Injuries reported in this study were described by type, body part affected, job duty, and movement pattern (Frost et al., 2015). Specifically, Frost et al. (2015) identified that the most common injury locations included the back, knees, ankles, and shoulders. Furthermore, 64% of musculoskeletal injuries were sustained while working at the fire station or during physical training-related activities and only 15% were related to fireground injuries (Frost et al., 2015). Similarly, Poplin and colleagues (2012) identified the primary injury sites to be lower extremity and spine. In addition, Orr, and colleagues (2019) performed a systematic review and noted that the lower extremities, specifically the knee, are a common site for injury among firefighters. However, the risk factors during physical training have not been clearly identified. In previous literature, physical therapists have worked towards developing a series of tests that predict injury in firefighters during physical training (Butler et al., 2013). Butler et al. (2013) implemented a series of tests including functional movement screening (FMS), sit and reach, push-up test, pull up test, 1.5-mile run, tower test, and fundamental movement pattern test. Utilizing injury surveillance, Butler et al. (2013) found that all of the test injury, the primary cause of musculoskeletal injuries has not been identified.

2.5 INJURY RISK FACTORS EXPLORED

Kong et al. (2013) conducted a review, identifying several intrinsic and extrinsic factors attributed to slips, trips, and falls in firefighters. Intrinsic factors included balance, age, experience, muscular strength and fitness, body mass, as well as fatigue (Kong et al., 2013). Extrinsic factors include personal protective equipment, additional equipment mass, reduced vision, footwear, surface condition, and heat. Kong and colleagues (2013) indicated that the load of gear combined with poor balance exasperates the risk of slipping and falling, which aligns with previous literature. While many of the intrinsic factors can be addressed through appropriate testing and physical training, the effects of the environment and protective garments on slips, trips, and falls remains unknown (Kong et al., 2013). Hong et al. (2012) implemented a survey-based study that was distributed to various fire stations across the United States to identify risk factors of occupational injuries in firefighters. Previous studies have cited gender, age, race, years of service or tenure, job title, rank, obesity, premature removal of safety devices, call volume, workload, presence of civilian injury or fatality, and work environment as risk factors for sustaining an injury (Hong et al., 2012). Specifically, Hong et al. (2012) found that firefighters with longer tenure and have less perceived organizational commitment are more likely to sustain an injury compared to firefighters who are less tenured. This contradicts previous studies that have found that firefighters who are less tenured are more likely to sustain a musculoskeletal injury (More-Merrell, 2008 & Seabury & Sobala, 2002). Hong et al. (2012) reported that more than half of their responses noted that they have sustained more than three injuries during their career. Walton et al. (2003) examined 1,343 worker compensation claims from 1992 to 1999 which contain detailed information including the cost of the injury and details about the causation of injury (Walton et al., 2003). Walton et al. (2003) found that over 33% of all injuries and over 80% of overexertion injuries resulted in strains and sprains to the firefighters.

Conrad et al. (1994) implemented focus groups with firefighters and fire chiefs to better understand risk factors associated with musculoskeletal injuries in firefighters. Conrad et al. (1994) identified factors that were attributed to musculoskeletal injuries. These factors were categorized personal, workplace, and external environmental factors as well as solutions for these potential risk factors. Fire chiefs attributed 50% of the relative contribution of musculoskeletal injuries to persons, 21.8% to workplace, and 28.2% to the external environment (Conrad et al.,1994). Firefighters attributed 26.1% of relative contribution of musculoskeletal injuries to persons, 33.4% to workplace, and 40.4% to the external environment (Conrad et al., 1994). Conrad et al., (1994) listed several factors within person, workplace, and the external environment that could influence musculoskeletal injuries. Potential person factors include commitment to job and team, skill and knowledge level, lifestyle practices, age, experience, pre-existing conditions, physical fitness level, fatigue, mental preparedness, stress- physical, mental emotions (Conrad et al., 1994). Potential workplace factors include job tasks, staffing levels, work schedule, equipment, safety training, budget, fitness program, medical services, health culture/environment (Conrad et al., 1994), Potential external environment factors include number of runs, weather, structural conditions, unpredictability, rescue operations, how far situation has progressed, heat, and water (Conrad et al., 1994). In addition, Conrad et al., (1994) provides a list of solutions to address these factors. Some of these solutions included lifestyle alterations, health promoting culture, budget, facilities, physical fitness and wellness programs, and occupational health and safety programs (Conrad et al., 1994).

Much of the literature has focused on physical risk factors related to musculoskeletal injuries. However, there may be psychosocial risk factors that are related to musculoskeletal injuries. Kim (2013) administered a survey to 35,155 workers regarding symptoms of depression. 904 of the 35,155 responses suffered an occupational injury and a follow up survey was conducted to capture incidence rate of depression. Occupational groups were divided into white collar, service, farm, and blue collar. Blue collar accounting for 42.9% of occupational injuries (Kim, 2013). 41.0% of occupational injuries were described as musculoskeletal injuries with 62.7% of injuries accounted for being related to falls (Kim, 2013). Kim (2013) concluded that workers with an occupational injury were more likely to experience symptoms of depression compared to workers with a non-occupational injury.

2.6 COST OF INJURIES

Injuries cost the federal government approximately nine billion dollars per year (NIST). Worker compensation injuries are estimated to cost fire departments $50,000 to $200,000 USD per year and $1000 to $5,500 per firefighter per year. A big push for firefighter safety and injury prevention is the goal to reduce workers' compensation and time loss due to injury. Griffin et al. (2016) implemented an exercise intervention that led to a reduced cost in injury claim costs by $33,000. The cost of the exercise intervention program was $32,192 and the return on investment after one year was 2.4% (Griffin et al., 2016). The return on investment after one year would likely increase annually leading to a greater return on investment. This is important because it has been cited in previous literature that the median number of days absent from work is about two times greater for an individual with a musculoskeletal injury in a public sector (Seabury & McLaren, 2010). In the private sector the ratio is only 1.25 (Seabury & McLaren, 2010). In the public sector, individuals must go through workers' compensation for treatment. This often delays access to treatment. This creates a cascading of costs for the fire department in the form of resources, personnel, and capability costs. In addition, Orr et al. (2019) indicated that injury caused by a strain or sprain has the potential to cost up to US $57,106 in just medical costs. The cost of injuries becomes an important conversation with fire departments who are considering implementing programming to reduce injuries with buy-in from executive leadership and labor unions.

2.7 IMPLEMENTATION OF EXERCISE PROGRAMS

Exercise intervention programs have shown to reduce musculoskeletal injuries in firefighters. Mayer et al. (2015) implemented a supervised worksite exercise intervention focusing on back and core muscular endurance in firefighters. Ninety-six firefighters were randomly assigned to an intervention or control group (Mayer et al., 2015). The intervention group participated in an exercise program on duty two times per week for 24 weeks (Mayer et al., 2015). The purpose of the intervention was to increase muscular endurance to protect against lower back injuries. They found that the supervised exercise program increased muscular endurance of the back by 12% and core muscular endurance by 21%. Mayer et al. (2020) continued looking into core and back muscular endurance with comparing supervised and telehealth delivery of worksite exercise for prevention of low back pain in firefighters. The purpose of this study was to determine how effective telehealth intervention is to on-site supervised exercise for prevention programs. This is the only study to examine telehealth exercise for injury prevention to be administered to firefighters. Mayer et al. (2020) found that telehealth was more effective in preventing musculoskeletal injuries compared to both the control group and worksite supervised program. In addition, previous literature has found that exercise intervention programs improve body mass, fat mass, and body mass index (Pawlak, et al., 2015). Pawlak et al. (2015) implemented a 12-week circuit training intervention to improve both aerobic and anaerobic fitness levels. Poston et al. (2013) evaluated ten fire departments that already have a health and wellness program implemented. Participating fire departments completed a self-report physical activity survey where VO_{2max} was predicted and they were prompted to rate their level of physical activity on shift (Poston et al., 2013). In addition, body composition was assessed using a portable stadiometer (Poston et al., 2013). Poston et al. (2013) found that fire departments with established wellness programs were overall healthier in terms of body mass and predicted VO_{2max}. However, behavior health issues such as, alcohol and tobacco use need to be addressed (Poston et al., 2013). Although not directly related to injury risk, improved aerobic capacity improves overall health outcomes.

2.8 DIRECT ACCESS CARE MODELS

There is limited literature regarding best practices with implementing direct access care models within the fire service. The International Association of Fire Fighters does have peer support training for behavior health awareness and crisis intervention. However, there is limited fire departments in the United States that have direct access to health care practitioners. There is no current literature that discusses direct access care models in the fire service or tactical field. A review article discusses the approach of utilizing direct access care models to treat musculoskeletal injuries in the general population (Piano et al., 2017). Piano et al. (2017) proposes that the direct access care model can be an effective and efficient model for managing patients who have been diagnosed with musculoskeletal injuries. Direct access care provides an avenue for patients to bypass bureaucratic steps to directly access the health care professional (Piano et al., 2017). Piano et al., (2017) cited numerous studies with primary outcomes such as health care costs, number of visits, patient outcomes, pain, and restricted workdays. In addition, the sports world has implemented and utilized direct access care models for decades.

2.9 PHENOMENOLOGICAL RESEARCH IN PUBLIC SAFTEY

Several studies have applied the phenomenological approach in a public safety population (Nord-Ljungquist et al., 2021; Gazzale et al., 2019; Broomé et al., 2019; Carleton et al., 2018; McFarlane, 1988; Sinden et al., 2013). Although previous literature has identified musculoskeletal injuries as a leading cause of injury in firefighters, (Frost et al., 2015; Poplin et al., 2012) the perspectives of health care providers have not been investigated surrounding musculoskeletal injuries. Furthermore, firefighter perspectives of how they obtain musculoskeletal injuries have not been investigated. Phenomenological research provides an avenue of qualitative research that focuses on the shared aims of lived experiences within a specific group (Groenewald, 2004). In phenomenological research, semi-structured interviews take place with individuals who have lived experiences of the event being studied (Groenewald, 2004). Previous papers have utilized phenomenological research with firefighters (Broomé et al., 2019; McFarlane, 1988; Sinden et al., 2013). Broomé et al. (2019) examined the experience of surviving a structural fire when a building collapses. Interviews were conducted with three firefighters who had experienced a building collapse in South Australia (Broomé et al., 2019). Sinden et al. (2013) implemented semi-structured interviews to furthermore investigate the experiences and perspectives of four female firefighters. In addition, McFarlane, (1988) implemented semi-structured interviews to investigate post-traumatic stress disorder in fifty structural firefighters. The phenomenological approach has not been applied to injury causation and mitigation in firefighters. Furthermore, the phenomenological approach has been applied to a wide range of public safety professions (Nord-Ljungquist et al., 2021; Gazzale et al., 2019;

Broomé et al., 2019; Carleton et al., 2018; McFarlane, 1988; Sinden et al., 2013). A large survey study was conducted in Canada focused on assessing suicidal ideation in public safety personnel (Carleton et al., 2018). Carleton et al. (2018) administered a web based self-report survey to public safety employees across Canada. Public safety works were call center operators, correctional workers, firefighters, police officers, and paramedics (Carleton et al., 2018). The questions were focused on past year and lifetime of suicidal ideation, plans, and attempts with a series of yes/no questions. Carleton et al. (2018) found a substantial portion of Canadian public safety personnel experience suicidal ideation and those additional resources are needed. Gazzale (2019) utilized the phenomenological approach to better understand factors of motivation with volunteer firefighters by using semi-structured interviews with seventeen subjects. Nord-Ljungquist (2021) implemented a descriptive design derived from the phenomenological approach to assess what first aid firefighters are applying while waiting for the ambulance in rural areas where resources are limited. This design was coined the reflective lifeworld research approach which is aimed at describing the focus of the lived phenomenon (Nord-Ljungquist et al., 2021). Nord-Ljungquist (2021) found that training for the time waiting for an ambulance is drastically needed because medics and firefighters rely on each other to provide first aid.

There is a discussion surrounding qualitative research of what is considered enough saturation to form findings from data analysis. Researchers utilizing the phenomenological approach range in what has been considered an adequate number of subjects for saturation. Saunders et al. (2018) discusses the concept of saturation in qualitative research and the core questions regarding saturation levels. The three core questions include in what ways is saturation defined, in what types of qualitative research saturation should be considered, and how do we assess saturation has been reached. To ensure reliability and validity during qualitative research, several processes can be implemented. Member checking is a method of validity, where researchers may return the data to the subject to ensure their responses are representative of their subjective experiences (Carl & Ravitch, 2018). A second process is sharing the final findings with subjects, for them to confirm if the findings are reflective of their subjective experiences (Carl & Ravitch, 2018). In addition, Cohen's kappa can be used to assess reliability between coders when coding a transcript. There are several recommendations of what is considered a reliable instrument. For categorical data, Landis and Koch (1977) suggests that <0.20= poor agreement, .21-.4= fair agreement, .41-.6 moderate agreement, 0.61-0.8= good agreement, and 0.81-1.0= very good agreement. Miles and Huberman (1994) suggest that Cohen's kappa should approach 0.90, however they discuss that the researchers should determine the most appropriate standards for the project.

2.10 CONCLUSION

In summary, the physiological demands of firefighting, exercise interventions within the fire service, and injury surveillance of firefighter injuries has been well described in the literature. However, the risk factors and mechanisms of injury have not been described in detail. Additional research is necessary to explore injury risk factors and mechanisms to enhance firefighter safety.

CHAPTER 3.

MANUSCRIPT #1: ETIOLOGY OF EXERCISE INJURIES IN STRUCTURAL FIREFIGHTERS: A HEALTH CARE PRACTITIONER PERSPECTIVE

3.1 INTRODUCTION

Firefighting requires the completion of vigorous occupational tasks (Soteriades et al., 2011). It is critical that firefighters engage in regular exercise to enhance their health, occupational readiness, and safety. Regarding health, sudden cardiac event is the leading cause of on-duty fatality among firefighters (Campbell & Evart, 2021). Indeed, the prevalence of cardiovascular disease risk factors among firefighters has been extensively described in the literature (Langford et al., 2019). Regular exercise and greater physical fitness levels can attenuate many of these modifiable risk factors (Langford et al., 2019). Regarding occupational readiness, development of various biomotor abilities is required to effectively perform fireground tasks (Rhea et al., 2004; Michaelides et al., 2011; Norris et al., 2021). As such, exercise interventions have been demonstrated to enhance relevant biomotor abilities and occupational physical abilities in structural firefighters (Mayer et al., 2020; Mayer et al., 2015; Pawlak et al., 2015; Poston et al., 2013). Regarding safety, research has indicated that physical fitness is related to incidence of occupational injury (Poston et al., 2013). Collectively, exercise is a critical countermeasure to enhance firefighters' health, occupational readiness, and safety.

Despite the aforementioned benefits of exercise for firefighters, ironically, exercise training is the most common cause of on-duty injuries (Marsh et al., 2017). Specifically, exercise training accounts for one-third of all occupational injuries (Marsh et al., 2017) and for 41% of post-injury absence from work (Campbell & Evarts, 2021). Griffin and coworkers (2016) revealed that an overwhelming amount (33%) of exercise injuries were musculoskeletal in nature and classified as sprains and strains (Griffin et al., 2016). Likewise, Orr et al. (2019) confirmed found that 27% of firefighter exercise injuries were due to sprains or strains. These injuries typically occur at the back, shoulder, and knee (Orr et al., 2019). In addition, these musculoskeletal injuries incur substantial fiscal and personnel consequences. For instance, musculoskeletal injuries have been reported to cost $57,106 USD per incident in medical costs (Orr et al., 2019). This does not account for the costs associated with backfilling the injured firefighter's line position.

To reduce the number of exercise-related injuries in the fire service it is important to identify risk factors associated with exercise injuries. Unfortunately, there is limited research on this topic due to a variety of methodological and logistical reasons. However, one methodological approach is to interview health care practitioners that regularly treat exercise-based firefighter injuries to explore their perspective regarding injury risk factors and mechanisms. These health care practitioners have the educational training to identify etiological factors (i.e., intrapersonal, interpersonal, & institutional) associated with injury occurrence and understand the occupational and exercise environments within the fire departments they serve. Therefore, the objectives of this study were threefold: (1) to describe prevalent injury types and anatomical locations of exercise injuries; (2) to identify common intrapersonal, interpersonal, and institutional risk factors of exercise injuries; (3) to identify mechanisms of exercise injuries from the clinical experiences of health care practitioners who regularly treat firefighter injuries. We hypothesized that health care practitioners would identify that sprain, strain, and muscular pain would be the most prevalent type of injury, and that anatomical injuries would typically be incurred at the shoulder, back, and knee, and finally that resistance training (i.e., lifting) mechanics would be identified as a common reason for exercise injuries.

3.2 METHODS

3.2.1 *Research Design*

The phenomenological research approach was utilized in this study to provide a qualitative mechanism to explore the shared aims of lived experiences within a specific group (Groenewald, 2004). Specifically, semi-structured interviews were conducted with health care professionals who have treated firefighter injuries (Groenewald, 2004). This method has been previously implemented with firefighters (Broomé et al., 2019; McFarlane, 1988; Sinden et al., 2013).

3.2.2 Subjects

A convenience sample of 14 health care practitioners were recruited who had at least one year of experience in treating and rehabilitating firefighter injuries, including experience within the past year, and were currently employed as a licensed health care practitioner (e.g., Athletic Trainer, Physical Therapist, Physician, Nurse Practitioner, etc.). Descriptors of the practitioners' tactical patient experience are provided in Table 1. Collectively, the practitioners in the current study had approximately 85,000 firefighter injury related encounters (weekly patient load x 52 wk/yr x years of experience). Participants were recruited from across the United States via established firefighter health care practitioner groups (e.g., American Academy of Sports Physical Therapy – Tactical and Combat Athlete Special Interest Group, Firefighter Physical Therapy and Rehabilitation Consortium), and from fire departments with embedded health care practitioners.

Table 1. Summary of health care practitioners' demographic information and descriptive characteristics.

Subject #	Education	Years of Experience	Years of Experience with Tactical Pop.	Observed Firefighter Tasks	Firefighter Patient Encounters (weekly)
1	Bachelors	15	12	Yes	25
2	Doctorate	10	2	Yes	45
3	Doctorate	5	5	Yes	80
4	Masters	7	3	Yes	30
5	Doctorate	10	8	Yes	8
6	Doctorate	11	4	Yes	5
7	Masters	17	7	Yes	60
8	Doctorate	5	5	Yes	2
9	Doctorate	13	7	Yes	25
10	Masters	5	2	Yes	12
11	Doctorate	42	16	Yes	8
12	Masters	3	1	Yes	-
Mean		11.9	6	-	27.3
SD		10.4	6	-	25.1

3.2.3 Procedures

Semi-structured interviews lasting approximately 45 minutes were conducted with a sample of 14 health care practitioners during the spring of 2022 (Table 1). The interview protocol was drafted in consultation with an external health care practitioner, not included in the study. Pilot interviews were conducted with two health care practitioners (that were excluded from data analysis) to provide feedback and guide revisions to the interview script. Interviews were conducted using video conference technology (Zoom, Version 5.5.2, San Jose, CA). Conrad and colleagues' (1994) conceptual framework were applied and utilized (Figure 1) to develop the script and deductive matrix (Figure 2) for the current study. The interview protocol included four sections. Section one outlined the purpose of the study, obtained verbal informed consent, addressed issues of confidentiality, and established trust with health care practitioners.

Section two included the interview questions that explored the health care practitioners' experience in treating and rehabilitating firefighter injuries. Section three included open-ended questions related to injury mechanisms and environmental factors associated with exercise. Follow-up questions and probes were included as needed. Section four was composed of closing questions that allowed the participants to add additional information not covered in other sections.

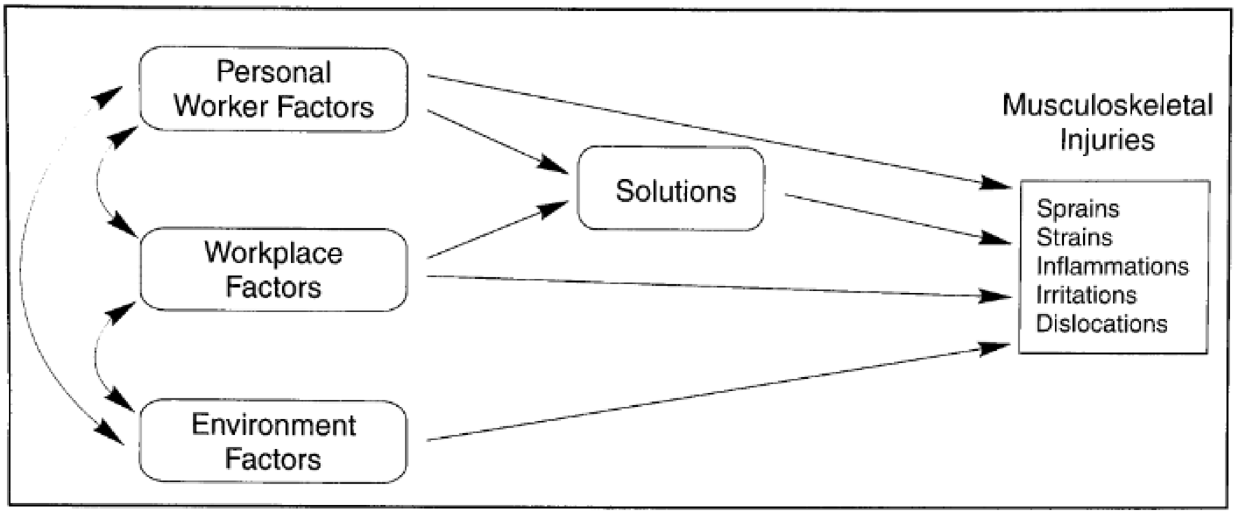

Figure 1. Theoretical Framework Firefighter Injuries. Conrad et al. (1994) displays theoretical framework used to explore risk factors of musculoskeletal injuries in firefighters through focus groups with firefighters and fire chiefs.

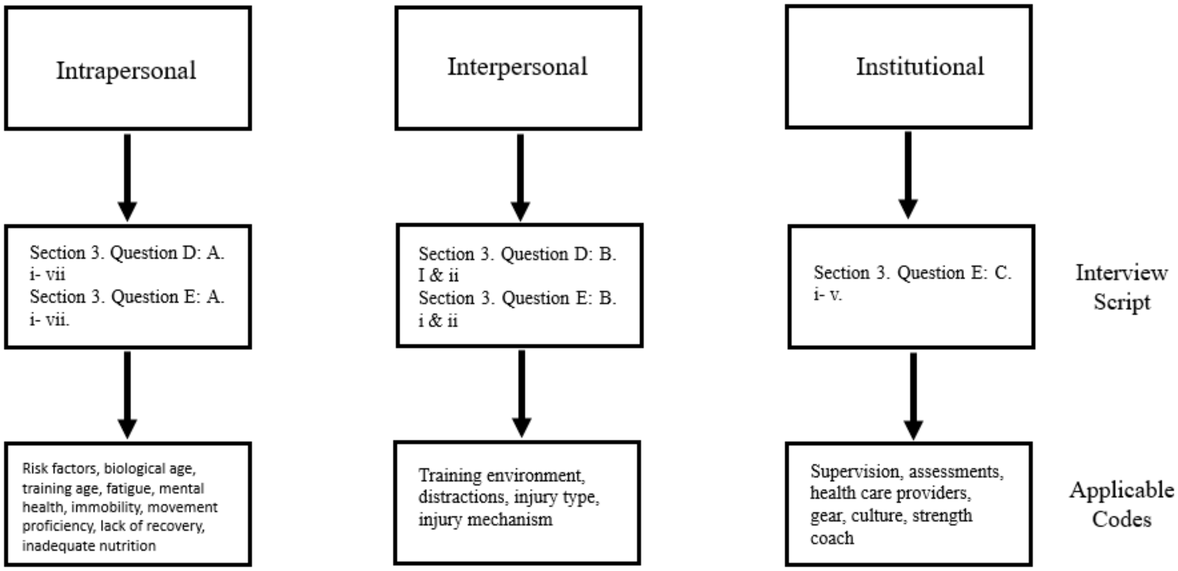

Figure 2. The methodological framework utilized to explore firefighter injuries among health care practitioners.

3.2.4 Data Analysis

The interviews were recorded and saved to a computer for analysis. Field notes were gathered during the interview to capture non-verbal interactions (e.g., facial expressions) to add additional context to responses. Interviews were transcribed and uploaded to a qualitative analysis software program (Dedoose, SocioCultural Research Consultants, LLC, UCLA), for mix-methods research that allows for collaborative data analysis among researchers. Inductive axial coding was conducted to identify categories and themes across participants related to injury mechanisms and environmental circumstances. When analyzing data via code co-occurrence, overlapping of excerpts was not utilized to prevent inflation of the total number of excerpts applied when quantifying code application. To ensure reliability and validity, three methods were implemented. First, two researchers coded the data to reduce inconsistency. Second, the inter-rater reliability of codes and categories across coders was conducted via Dedoose. Specifically, Cohen's Kappa was used to measure the level of agreement among coders (Zhao et al., 2016). which was completed by having a second researcher code two full transcripts at the categorical level. The resultant inter-rater reliability yielded a Cohen's Kappa of 0.81, which has been deemed to be acceptable (Landis & Koch, 1977). Researchers determined that this was sufficient, and they conversed about any inconsistencies in the code book. Third, participation validation was implemented to ensure the accuracy and transferability of the finding with participant responses. Member checking was conducted with each interview which involved sharing the transcript with the participant to verify that their responses were representative of their experiences.

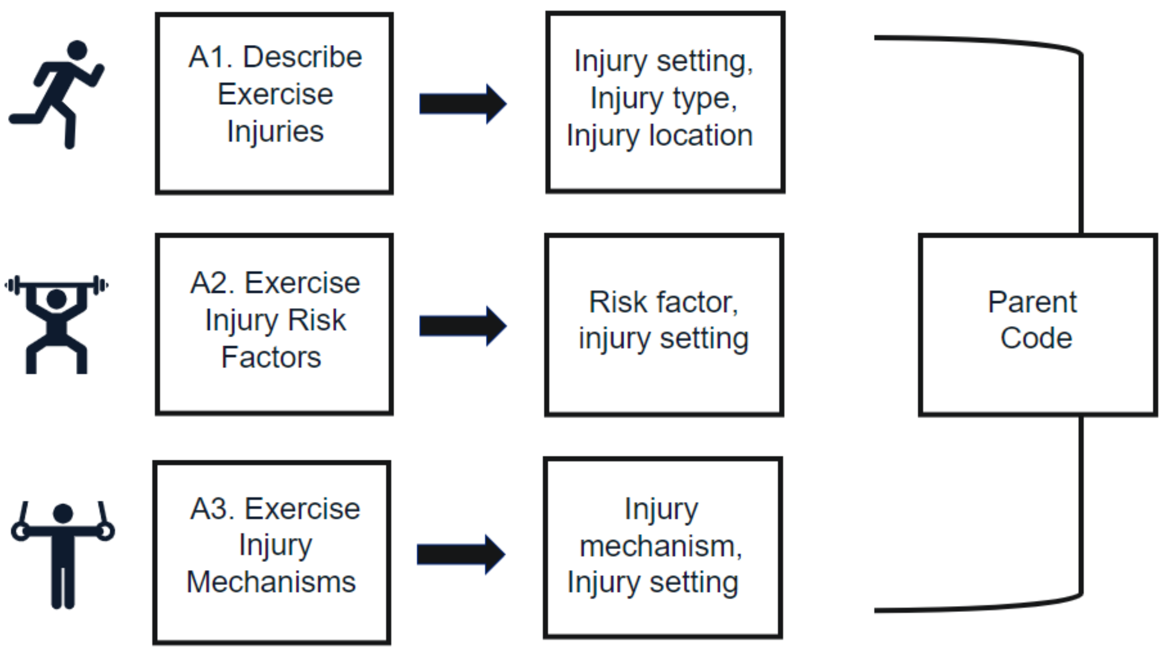

Figure 3. Organization of study aims (A), injury context and respective parent code for data analysis.

3.3 RESULTS

Several anatomical locations were identified as prevalent injury sites for exercise-related musculoskeletal injuries. Specifically, 18 excerpts populated with the code occurrence of injury anatomical location and injury setting. The most prevalent exercise injury locations were the shoulder and back and the most prevalent injury type was chronic in nature and classified as sprains/strains.

3.3.1 AIM #1

When examining the type of injury, the health care practitioners described several instances when both acute and chronic injuries were associated with exercise injuries. One practitioner said "... you're looking at sprains and strains usually and they are typically more acute... A lot of the times what I hear is with them lifting or working out a majority probably relate back to lumbar or even shoulder type sprain/strain injuries" (Subject 11). However, another participant discussed that they often see more chronic exercise injuries. For instance, "During exercise, I'd day for the most part they are chronic, so if these are more non-line of duty, I was doing this on my own, they are chronic. Not even tendonitis, but almost tendinosis that we're mainly seeing because they aren't the type of individuals to seek immediate acute care. You know, they kind of work through a lot of things they're used to being uncomfortable every day and what's an ache or pain? You know? So, we don't really catch those until they've been going on for quite a while" (Subject 6).

Table 2. Prevalence of firefighter injuries occurring during exercise as described by 12 health care practitioners, stratified by anatomical location and type of injury (Objective 1).

Injury Anatomical Location (18 excerpts)				
Shoulder	Back	Knee	Ankle	Elbow
83%	73%	28%	17%	11%
Type of Injury (17 excerpts)				
Sprains/Strains	Chronic	Acute		
65%	53%	29%		

*Values reflect the frequency (%) for which each injury location and type were mentioned by a health care practitioner relative to the total injury excerpts.

3.3.2 AIM #2

The identified exercise injury risk factors and respective prevalence are displayed in Table 3. Specifically, 73 exercise injury risk factor excerpts were identified for data analysis. The five-child code exercise injury risk factors included biological age, movement proficiency, immobility, mental health, and overall fatigue, recovery, and sleep.

Table 3. Prevalence of health care practitioners reported risk factors of exercise injuries in structural firefighters.

Risk Factors	73 Excerpts
Biological age	21%
Fatigue, recovery, sleep	21%
Immobility	19%
Mental health	15%
Movement proficiency	21%

The code biological age was further stratified into two additional child codes (i.e., older, and younger) to describe data trends more clearly. Specifically, health care practitioners had different experiences regarding the influence of age on risk of exercise injury. Furthermore, age was often related to other child codes such as immobility and fatigue. The risk factor of age seems to be related to the length that a health care practitioner was embedded in the respective department. That is, more experienced health care practitioners expressed that the younger firefighters were more likely to sustain an exercise injury compared to older firefighters.

Health care practitioners cited that immobility was often the result of other precursors such as limited range of motion and muscle tightness. Chronic muscle tightness and immobility can lead to poor movement mechanics and lifting techniques. Health care practitioners stated, "Yes, I'd say a lot for shoulder injuries, that's one of the tests that we did was really checking on range of motion for the shoulder because if you don't have the range of motion available, you can't be in the proper mechanics…" (Subject 10). Another participant looped in lifting during their response and said, "Yes 100%. A lot of times, if whether it's due to pain or tightness of the muscles that immobility lends itself to so, uhm, it goes back to improper technique and improper movement, and then you've end up with either an injury there or compensatory injury because you have different structures tasking the brunt of things" (Subject 11).

Health care practitioners' responses suggest a complex relationship regarding mental health and exercise injuries. Specifically, they indicated that chronic psychological and physical stress may impact firefighters' ability to cope with an injury if they are unable to exercise. In addition, the health care practitioners indicated that the accumulation of chronic stress and mental health stressors may be a risk factor to sustain an injury during exercise. One practitioner stated: "Yes, absolutely. Even if it's not just like a diagnoseable… if it's not a DSM [Diagnostic and Statistical Manual of Mental Disorders] 5 characterized thing, yes, chronic stress as well, which is associated, especially job-related stress or just family stress. Stress, it can come from a lack of sleep, things like that. Psychosocial well-being, I would say, is a massive risk factor for pain experience and musculoskeletal injury" (Subject 14). Furthermore, providers revealed that exercise is often used as a coping mechanism to alleviate chronic stress. A health care practitioner stated: "Specifically, exercise. I know a lot of people that have had issues with exercise as kind of a coping mechanism to help them. So, uhm, I'm sure there are some people it does affect there. You know, readiness and willingness to participate in extra exercise, but I find that it's usually helpful" (Subject 10). In addition, one health care practitioner discussed the education surrounding having a psychologist in the fire department and the importance of a strong peer support system. "The mental health component is very big, it's another huge initiative. Our psychologist does work with me quite a bit come in here with a lot of those things and we have a very robust peer support system and things like that. That goes into the mental fatigue of the individual and in the way that they're approaching potentially their training" (Subject 12). Three health care practitioners highlighted the importance of having strong peer support resources and access to chaplains and other mental health services.

Health care practitioners consistently associated poor movement proficiency with poor lifting technique. Health care practitioners discussed that movement proficiency is often coupled with other risk factors such as fatigue, which contributes to increased risk of injury during exercise. One practitioner discussed using movement proficiency as an overall health marker, "...I would say yes, but I also look at it as part of an overall health marker. Your better movers also have better MET scores (aerobic fitness), better VO_2s, probably better relative strength capacity at the gym. So, I look at it as just a marker of being a total athlete or well-rounded athlete. So, I would say, yes" (Subject 13). In addition, another practitioner discussed correcting improper lifts during exercise in order to improve movement proficiency, "Yeah, we've done a lot with retraining specifically with like squat and deadlift and then trying to correct those improper movements and alleviate glute tightness or glute weakness so that things that are triggering the way that they should be, and proper movement is engaged" (Subject 11).

Fatigue, recovery, and sleep were often reported by practitioners as risk factors for exercise injury among firefighters as they relate to overall health and wellness. Health care practitioners' responses indicated that general fatigue, sleep, and recovery are a multifaceted risk factor that must be approached with a holistic view. Specifically, practitioners discussed how sleep and recovery are important for injury risk, but also noted how firefighters are more durable than the general population because they "have to be" (Subject 13). In addition, one practitioner discussed that fragmented sleep interrupts recovery because REM sleep is never achieved on shift. In addition, 86% of health care practitioners indicated that firefighters have second jobs and 79% of health care practitioners indicated that these are labor intensive jobs. These labor-intensive jobs may impact accumulation of fatigue, sleep quantity and quality, and lack of recovery.

3.3.3 AIM #3

The prevalence of injury mechanisms reported by practitioners is provided in Table 4. Specifically, 35 excerpts were identified from the twelve interviews. Overall, three child codes were identified as risk factors for exercise related musculoskeletal injuries resistance training technique, overexertion, and overall movement mechanics, with poor exercise technique described as the most prevalent mechanism for exercise injury.

Table 4. Prevalence of health care practitioners' reported exercise injury mechanisms in structural firefighters.

Injury Mechanism	35 Excerpts
Resistance training	51%
a. Poor resistance training technique	44%
Overexertion	20%
Movement mechanics	14%

Poor technique was coded often with resistance training when discussing mechanisms for exercise injuries. Health care practitioners discussed that poor resistance training technique may be related to other risk factors like biological age. One practitioner stated, "… As far as cases that I have seen when guys come in if they describe from lifting, it's been probably well I guess it depends on the age too, a lot of the older guys it's more from poor technique. Whereas some of the younger individuals I've seen I'm just most recently like within the last week they've come in and it sounds more related to fatigue. So, whether that's related to technique or overloading the bar, I don't know. But I would say more related to technique" (Subject 14). Several practitioners discussed poor resistance training technique when discussing resistance training injuries. Health care practitioners described that the lack of education regarding proper technique contributes to injury.

There were two overlapping findings with the code overexertion. First, overexertion was associated with resistance training several times and second, health care practitioners associated overexertion with factors of fatigue, sleep, recovery, and specific types of workouts. Several practitioners agreed that regardless of exercise type, injuries tend to include the mechanism of overexertion. One practitioner tied these findings together in one response, "I think during exercise it might be overexertion or like I would say, like an exacerbation of something that's chronic, like someone who had maybe an old injury that they've never treated, and it kind of gets exacerbated with like a little bit of too intense exercise coupled with like a poor movement pattern. Maybe they haven't slept well, they're not moving well, kind of like a combination of things and work or training related…" (Subject 8). In addition, a health care practitioner described the type of exercise with the type of injury, "…We have a rich history of bicep tendons popping with preacher curls. I've seen multiple ones of those.... The other thing we do see a lot, we do see a lot of deadlifting injuries. Achilles tendon with a jump rope, knees with jump rope, box jumps in another place" (Subject 13). The practitioner went on to indicate that years of exposure to high intensity interval style training may lead to overexertion and overuse injuries.

Health care practitioners indicated that firefighters' general movement mechanics contribute to exercise injuries. Specifically, practitioners indicated that risk factors such as immobility and range of motion, may be associated with general movement mechanics.

3.4 DISCUSSION

The first objective of this study was to describe the practitioners' perspective regarding firefighters' exercise injury location and type. Practitioners indicated that the shoulder and back were the most prevalent anatomical locations of injury, followed by knee, ankle, and elbow. Similarly, Frost et al. (2015) reported that the most prevalent exercise injury locations were the shoulder (22%), ankle (16%), knee (11%), and back (9%). Furthermore, practitioners in the present study indicated that exercise injuries tended to be chronic in nature (53% of excerpts), whereas acute injuries were less prevalent (29% of excerpts). In addition, sprain /strain was the most commonly reported injury type (65%). These findings support previous work by Frost et al.

(2015) and Orr et al. (2019) who reported that sprain/ strain was the primary cause of all musculoskeletal injuries in firefighters.

The second objective of this study was to identify the intrapersonal, interpersonal, and institutional risk factors for exercise injuries among firefighters. The practitioners indicated that the type of injury incurred may be associated with firefighters' age. The biological age factor may have interpersonal and intrapersonal origins. Regarding an interpersonal context, practitioners indicated that some firefighters are competitive in nature and the younger firefighters often want to prove themselves, and therefore may be at a greater risk of sustaining an exercise injury. Specifically, one health care practitioner explained that younger firefighters may compete during exercise and that the competitive environment influences overloading the bar (Subject 11). Another practitioner described that some older firefighters have invested the time, engrained proper exercise movement patterns, and addressed musculoskeletal deficits which may decrease their risk of exercise injuries compared to younger firefighters. (Subject 5). Regarding an intrapersonal context, one practitioner discussed the necessity of modifying exercise selection due to aging, indicating that after so many years of wear and tear, cartilage in the shoulder is gone and so bench pressing is no longer feasible and the type of exercise needs to change (Subject 7). Physiologically, aging is associated with a decrease in the water content of ligaments, cartilage, and skeletal muscle which contributes to increased stiffness and immobility (American Academy of Orthopedic Surgeons, 2020) and subsequently may impact the incidence of chronic exercise injuries.

Immobility and movement proficiency were prevalent intrapersonal injury risk factors reported by the health care practitioners and were often described collectively in their role of exercise injuries. Specifically, health care practitioners discussed that immobility often attenuated movement proficiency (i.e., the ability to perform exercises correctly). This underscores the importance of incorporating proper movement education for firefighters during an exercise program. In support of this assertion, Frost et al. (2015) conducted a longitudinal training intervention among two groups of firefighters that were provided with either a combined fitness training program plus movement education or a fitness training program only. The findings demonstrated that the combined group improved movement proficiency on occupationally relevant tasks and enhanced physical fitness, whereas the training only group decreased movement proficiency following the training intervention. These results indicate that training without an awareness of movement quality may increase risk of exercise and / or occupational injury.

Practitioners indicated that enhanced physical fitness decreases risk of musculoskeletal injuries. These findings are supported by Conrad et al. (1994), who conducted focus groups with firefighters and fire chiefs and found that the level physical fitness was a personal factor that was related to the onset of musculoskeletal injuries. Likewise, Butler et al. (2013) reported that aerobic fitness, the deep squat and push-up components of the Functional Movement Screening, and the sit-and-reach assessments were correlated to injury occurrence or risk. Furthermore, Jahnke et al. (2013) implemented an injury surveillance survey and found that those who exercised were 4.6 times more likely to sustain an exercise injury compared to those who did not exercise on-duty. However, those who reported exercising on-duty, were approximately half as likely to sustain an occupational injury. Thus, an adequate level of physical fitness is crucial for performance and injury risk; however, the current study reveals the importance of utilizing proper movement patterns while developing physical fitness.

The intrapersonal risk factor of fatigue, recovery, and sleep were often described as overall health and wellness by health care practitioners. One practitioner even stated that they believe that fatigue, recovery, and sleep is the biggest risk factor for sustaining a musculoskeletal injury (Subject 12). However, health care practitioners' experiences differed about the sleep factor. That is, one health care practitioner indicated that sleep wasn't as big as a component as other risk factors because firefighters, in their experience, were used to the lack of sleep (Subject 4). However, another health care practitioner described how detrimental fragmented sleep is with disrupted REM cycles and increases in cortisol levels that contribute to chronic stress (Subject 13). However, all the practitioners agreed that the lack of recovery and fatigue impacted the risk of sustaining a musculoskeletal exercise injury.

Interestingly, the intrapersonal risk factor of mental health only occurred in 15% of the excerpts of exercise injuries. However, Conrad et al. (1994) identified chronic stress, which encompassed mental, physical, and emotional health as a risk factor for musculoskeletal injury. In juxtaposition, health care practitioners described that exercise can often be used as a coping mechanism for chronic stress and may cause stress if firefighters become injured and are not able exercise. Furthermore, a seasoned health care practitioner described the importance of mind, body, and spirit when discussing mental health and dealing with chronic stress.

The third objective of this study was to identify potential mechanisms of exercise injuries. The most prevalent injury mechanism was performing resistance training with poor technique. Interestingly, poor technique was commonly associated with the identified risk factors of immobility and movement proficiency. In related research, Wisenthal et al. (2014) assessed injury outcomes in CrossFit participants and associated anatomical injury locations with specific movements. Specifically, the researchers reported that shoulder injuries were commonly linked to gymnastic movements and low back injuries were associated with poor lifting mechanics. In the present study, we sought a clearer understanding of the relationship between anatomical location, type of injury, and exercise performed when the injury occurred. To that end, health care professionals provided some clarification through a few examples. For instance: "We have a rich history of bicep tendons popping with preacher curls. I've seen multiple ones of those… The other thing we do see a lot, we do see a lot of deadlifting injuries, achilles tendon with a jump rope, knees with jump rope, box jumps in another place. And then I won't say [REDACTED], but I'll say you know *ballistic type workouts. I would say years and years of exposure to [REDACTED] and you see a lot of overexertion, overuse injuries there as well (Subject 13). Another health care practitioner discussed the poor bracing of the core during exercise and how that influences injuries as well, they stated, "… improper bracing. They perhaps do not respect bracing and throughout the core quite as much so then when you have like a deadlift type maneuver that type, then it's probably the most common" (Subject 11).

The second mechanism identified was movement mechanics during exercise. This was commonly associated with immobility and movement proficiency for exercise that was not necessarily related to resistance training injuries. Health care practitioners described firefighters as being poor movers. Several health care practitioners discussed using movement screenings to assess overall movement and discussed how they have been able to predict injuries in firefighters. However, a handful of health care practitioners discussed that they have developed their own method for assessing movement and do not utilize the Functional Movement Screening. Several articles have discussed the efficacy of the Functional Movement Screening with firefighters and have found that it can provide general information regarding movement, but a specific screening is needed (Beach et al., 2014; Frost et al., 2012).

Overexertion was the final exercise injury mechanism identified. Overexertion has been cited as a primary cause of fireground injuries (Campbell and Evarts, 2021; Orr et al., 2019; Walton et al., 2003). During exercise, overexertion may predispose a firefighter to an injury because of several risk factors described by Le and colleges (2020). Le et al. (2020) analyzed injury surveillance data and discusses that the risk factors biological age, and physical degradation of joints, cartilage, and connective tissues paired with overexertion contributes to musculoskeletal injuries in the middle-aged population compared to younger ages. Appell (1992) discusses the onset of tissue damage due to overexertion in prolonged exercise bouts. Furthermore, continuous overexertion with acute exercise could contribute to the fatigue factor resulting in injury, however this has not been explored in-depth.

There were several limitations to the present study. Firstly, the population recruited for the present study was composed of a convenience sample inclusive of a select number of health care practitioners who treat musculoskeletal injuries in firefighters. This limited sample had vastly different roles and experiences. For example, health care practitioners may serve in a role as an athletic trainer, physical therapist, strength and conditioning coach, or nurse practitioner. In addition, health care practitioners' connection to the fire service differs, as they may be embedded directly within the department, contracted by the fire department through a company, or employed by the city. Secondly, the number of weekly patients differed between providers. For example, one practitioner had 60+ weekly patient visits whereas another practitioner discussed having two weekly patient visits. Finally, only a select few health care practitioners witnessed firefighters exercising and sustaining an injury. Other providers rely on information from the patient about the injury at the time of injury.

3.5 Practical Applications

The present study indicated that shoulder and back injuries commonly occur during exercise in structural firefighters. These injuries tend to be preceded by tissue tightness, subsequently leading to joint immobility and poor movement proficiency during exercise. Tactical strength and conditioning practitioners and departmental health care practitioners should regularly evaluate firefighter mobility, especially in the thoracic spine and glenohumeral joint. Stability of the spinal erectors and scapulae should also be addressed as part of a comprehensive exercise program. Given the reported risk factor of fatigue, recovery, and sleep practitioners should utilize a subjective (e.g., wellness questionnaire) or objective (e.g., vertical jump, handgrip strength) daily monitoring tool to assess the physiological readiness to train and adapt to the training stimuli. This information should be used to identify trends in physiological readiness and intervene when appropriate. In addition, practitioners should educate firefighters about proper sleep hygiene to enhance sleep quantity and quality. For instance, caffeine use should be limited, perform regular exercise, attempt to maintain a regular sleep schedule on- and off-duty, and avoid screen time prior to sleeping. Fire departments should enhance sleep outcomes by providing resources, including independent sleeping quarters and emergency tones that only wake the appropriate responders. Finally, given the reported exercise injury mechanism of resistance training technique, qualified strength and conditioning practitioners should be utilized to teach and ensure proper mechanics are used to decrease risk of exercise injury. Enhancing firefighters' movement proficiency during resistance training may transfer to use of proper movement patterns on the fireground.

In conclusion, the present study indicated that the most prevalent exercise injuries were chronic in nature and affected the lower back and shoulder. Prevalent risk factors included age, immobility, poor movement proficiency, whereas mechanisms of injury included poor resistance training mechanics. Collectively, these findings provide tactical strength and conditioning practitioners, health care practitioners, and executive departmental leadership with an etiological framework to develop appropriate countermeasures.

CHAPTER 4.

MANUSCRIPT #2: ETIOLOGY OF OCCUPATIONAL INJURIES IN STRUCTURAL FIREFIGHTERS: A HEALTHCARE PRACTITIONER PERSPECTIVE

4.1 INTRODUCTION

Occupational injuries in the fire service occur at a greater rate than other manual labor occupations (The US Bureau of Labor Statistics, 2013). The US Bureau of Labor Statistics (2013) reported the rate of nonfatal occupational injuries and illnesses for firefighters was four times greater than full-time workers for all occupations. These injuries have a substantial impact on personal health, and on personnel and fiscal resources. Specifically, the National Fire Protection Association (NFPA) reported that there were 64,875 on-duty injuries in 2020, with 35% (22,450) of these injuries occurring at the fireground (Campbell and Evan, 2021). Musculoskeletal injuries are the most prevalent type of injury in the fire service with 40% of fireground injuries described as strains, sprains, or muscular pain (Campbell and Evan, 2021). The leading causes of injuries are overexertion or strain (31%) (Campbell and Evan, 2021).

On-duty injuries have significant fiscal consequences. Previous literature has reported that workers' compensation can cost a fire department $50,000-200,000 USD or $1,000 to $5,000 USD per firefighter annually (NIST Report). More specifically, regarding musculoskeletal injuries, Orr et al. (2019) reported that a single sprain and strain injury can cost up to $57,106 USD in medical costs alone. In addition, on-duty injuries impact the utilization and cost of personnel resources. For instance, an injured firefighter may need to be shifted to light-duty and their position must be backfilled with another firefighter, which in turn impacts the latter firefighter's recovery by working overtime, incurs additional personnel costs, and reduces personal (off-duty) time.

Given the deleterious impact of musculoskeletal injuries on fiscal and personnel resources, it is critical to gain insight regarding the risk factors and mechanisms of these injuries in firefighters. Existing research indicates potential injury mechanisms include slip/trip/fall, lifting, bending, and muscle stress (Orr et al., 2019). Although these findings are informative, they lack contextual factors surrounding injury occurrence and risk factors that may predispose the firefighter to injury. In contrast, an alternative approach to obtain a more comprehensive understanding of risk factors and mechanisms of occupational injuries is to interview health care practitioners that are contracted to treat firefighter injuries. Health care practitioners have educational and clinical training to identify potential factors associated with occupational injuries, including movement proficiency, musculoskeletal dysfunction, overexertion, and fatigue. Furthermore, these contracted practitioners are familiar with the occupational demands and personal factors associated with the shift schedule of firefighters, which may impact musculoskeletal injuries. Therefore, the objectives of this study were threefold: (1) to describe prevalent injury types and anatomical locations of occupational injuries; (2) to identify common intrapersonal, interpersonal, and institutional risk factors of occupational injuries; (3) to identify mechanisms of occupational injuries from the clinical experiences of health care professionals who directly treat firefighters. We hypothesized that health care practitioners would indicate that musculoskeletal injuries occurred while performing intense (i.e., overexertion), yet infrequent occupational tasks, and perform compromised movement patterns. These findings will provide critical information to identify appropriate behavioral, programmatic, and institutional countermeasures to enhance firefighter safety.

4.2 METHODS

4.2.1 Research design

A phenomenological design was used in this study to explore the shared lived experiences of health care practitioners treating musculoskeletal injuries in firefighters. The phenomenological design has successfully been applied to the firefighter population to address a variety of research questions (Broomé et al., 2019; Sinden et al., 2013; McFarlane, 1988). Specifically, semi-structured interviews were conducted with health care practitioners who treat firefighter injuries.

4.2.2 Subjects

Fourteen health care practitioners were recruited with at least one year of experience in treating and rehabilitating firefighter injuries, including experience within the past year, and were currently employed as a licensed health care practitioner (e.g., Athletic Trainer, Physical Therapist, Physician, Nurse Practitioner, etc.). Subjects were recruited from across the United States via departments with established direct access providers and tactical practitioner groups. Descriptors of the practitioners' tactical patient experience are provided in Table 5. Collectively, the practitioners in the current study had approximately 85,000 firefighter injury related encounters (weekly patient load x 52 wk/yr x years of experience).

Table 5. Summary of health care practitioners' demographic information and descriptive characteristics. Eastman et al. (*In preparation*).

Subject #	Education	Years of Experience	Years of Experience with Tactical Pop.	Observed Firefighter Tasks	Firefighter Patient Encounters (weekly)
1	Bachelors	15	12	Yes	25
2	Doctorate	10	2	Yes	45
3	Doctorate	5	5	Yes	80
4	Masters	7	3	Yes	30
5	Doctorate	10	8	Yes	8
6	Doctorate	11	4	Yes	5
7	Masters	17	7	Yes	60
8	Doctorate	5	5	Yes	2
9	Doctorate	13	7	Yes	25
10	Masters	5	2	Yes	12
11	Doctorate	42	16	Yes	8
12	Masters	3	1	Yes	-
Means		11.9	6	-	27.3
SD		10.4	6	-	25.1

4.2.3 Procedures

Semi-structured interviews lasting approximately 45 minutes were conducted with a sample of 14 health care practitioners (Table 5) during the spring of 2022. The interview protocol was drafted and reviewed by an external health care practitioner prior to the study. The first two interviews were conducted and utilized to provide feedback and guide revisions to the interview script. These two interviews were excluded from data analysis yielding a sample size of N = 12. Interviews were conducted using video conference technology (Zoom, Version 5.5.2, San Jose, CA). The conceptual framework applied to these interviews was developed by Eastman and colleagues (In preparation; Figure 4) with guidance from Conrad and colleagues (1994).

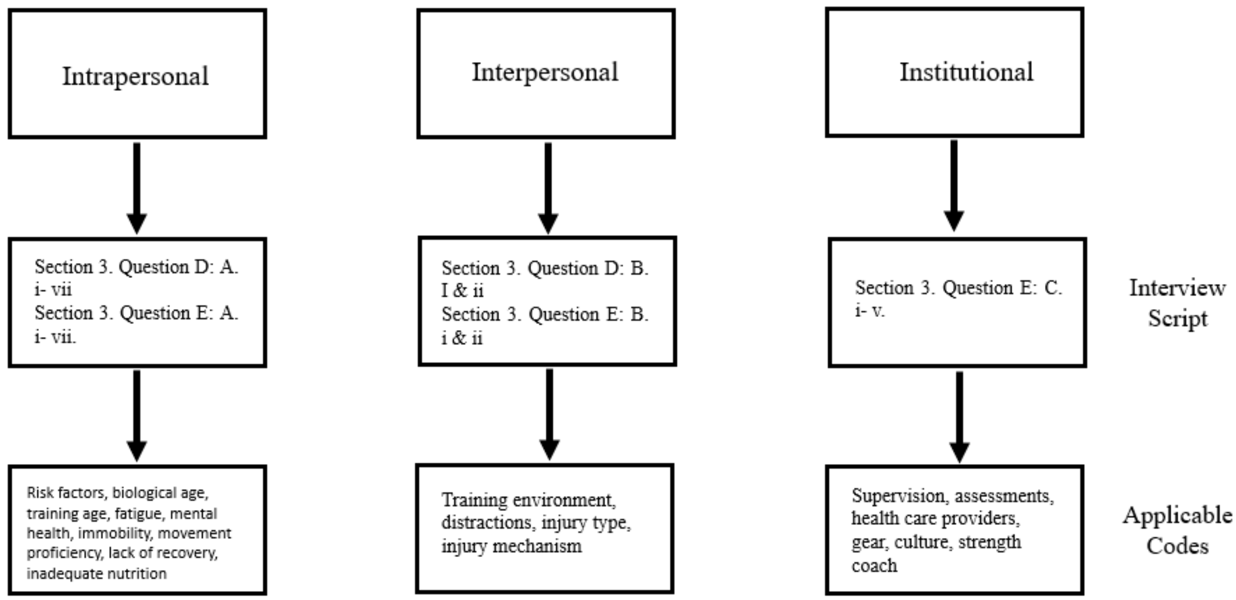

Figure 4. The methodological framework utilized to explore firefighter injuries among health care practitioners (Eastman et al., In preparation).

4.2.4 Data Analysis

Interviews were recorded and uploaded to a qualitative analysis software program (Dedoose, SocioCultural Research Consultants, LLC, UCLA). Field notes were gathered during the interview to capture non-verbal interactions (e.g., facial expressions) to add additional context to responses. Inductive axial coding was conducted to identify categories. When using code co-occurrence, overlapping excerpts were excluded when quantifying code prevalence in excerpts, in order to prevent inflating incidences of code co-occurrence. Three methods were used to ensure the data were reliable and valid. First, two researchers coded the data. Second, inter-rater reliability of codes at the categorical level was determined between the two coders and resulted in adequate reliability (Cohen's Kappa = 0.81). Third, member checking was implemented to ensure accuracy of the data. Specifically, the transcripts were shared with the practitioners to confirm validity of the transcription and the results were shared with practitioners to ensure it was representative of their experiences.

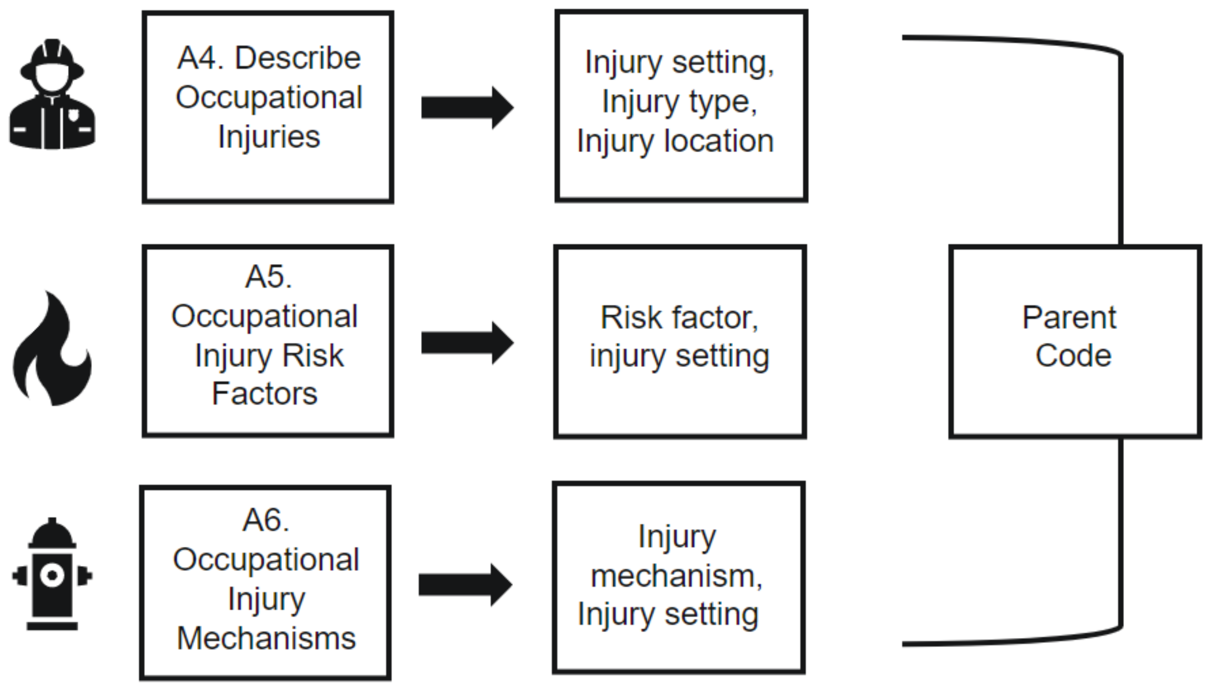

Figure 5. Organization of study aims (A), injury context/risk factor and respective parent code for data analysis.

4.3 RESULTS

4.3.1 AIM #4

Several anatomical locations were identified as prevalent injury sites for occupational musculoskeletal injuries. Specifically, 18 anatomical injury location excerpts populated. The most prevalent occupational injury location was the shoulder and back (Table 6). Regarding type of injury, both acute and chronic injuries were noted by health care practitioners. When being asked to describe occupationally related injuries, one practitioner stated, "…those are all over the board. I mean, it's hard to say if there's, I would say there's a pretty equal distribution between acute and chronic type of injury. And yeah, strains and sprains are typically the most that we're seeing" (Subject 9).

Table 6. Prevalence of firefighter injuries occurring on-duty as described by 12 health care practitioners, stratified by anatomical location and type of injury (Aim #1).

Anatomical Location of Injury (18 Excerpts)				
Shoulder	Back	Knee	Elbow	Ankle
83%	77%	39%	11%	11%
Type of Injury (17 Excerpts)				
Sprains/Strains		Chronic	Acute	
64%		52%	32%	

4.3.2 AIM #5

The identified occupational risk factors and respective prevalence are displayed in Table 7. Specifically, 75 occupational risk factor excerpts were identified for data analysis. The five-child code exercise risk factors included biological age, immobility, mental health, and overall fatigue, recovery, and sleep. The prevalence of these risk factors was similar, but greatest for immobility and general fatigue, recovery, and sleep.

Table 7. Prevalence of health care practitioners' reported risk factors of occupational injuries in structural firefighters.

Risk Factors	75 Excerpts
Biological age	20%
Fatigue, recovery, sleep	23%
Immobility	24%
Mental health	12%
Movement proficiency	16%

The biological age risk factor was further divided into the child codes of older and younger. Specifically, 67% of the excepts related to age was coded as "older" indicating that health care practitioners felt older age was associated with occupational injuries. Furthermore, some health care practitioners indicate that "wear and tear" related injuries tended to occur more so among older firefighters and that younger firefighters are potentially at an increased risk of sustaining an acute injury due to the lack of experience on the fireground. One health care practitioner discussed the concept of "wear and tear" regarding older firefighters. They stated: "These ones are going to be more the degenerative type. The older firefighters that have been doing this for a long time, it's kind of a wear and tear type injury, but age does factor into it" (Subject 11). Practitioners also indicated that the risk factor of age was also dependent on other factors such as training status, which was further detailed in the following response, "Acute injuries, I would say younger because of lack of experience. Chronic injuries, I would say older because of wear and tear, but that again would be dependent upon fitness status and training status" (Subject 14).

Immobility was present in a quarter of the excerpts that coded for occupational injuries. Health care practitioners provided examples of immobility during occupational tasks. One practitioner described the lack of shoulder internal rotation and stated: "The number of guys who I've had say yeah, I have to get someone else to turn on my cylinder. So, like our air pack, I have to get someone else to turn on my cylinder because I can't reach and get it because they don't have the shoulder internal rotation …" (Subject 14). In addition, practitioners agree that the protective gear exacerbates the issue of immobility. When asked to describe the role of gear, practitioners contribute the sheer weight and bulkiness to injury exasperation. One practitioner stated: "I believe it could specifically with like shoulder like wearing the SCBA how it decreases your shoulder mobility. I think that can be a component. Also, the masks that they have to wear kind of decreases their visual fields as well so that can be a contributor" (Subject 9).

Health care practitioners discussed the multifactorial construct of general fatigue, sleep, and recovery and how it may impact injury risk during occupational tasks. Practitioners welcomed the additional factor of nutrition into the construct of general fatigue, sleep, and recovery and contributed the lack of recovery and emergency call volume to increased injury risk. One practitioner stated: "Yes, yes, definitely, and that's if you're looking at a crew that has had run after run throughout the day and then that goes into the night and they're on their second or third run you know, in the wee hours of the morning then there can definitely be some consequences there" (Subject 11). In addition, a second practitioner described an interaction of nutrition, fatigue, and sleep and stated: "Yes, and I don't see it much in the initial like your first bottle. So, let's say like the first 20 minutes on scene breathing air because you're still coursing through with adrenaline,[but] when the adrenaline dies off a little bit, that's when you're truly tired and you're awake in the middle of the night or you haven't had food in a while or you just ate chili cheese dogs that you probably shouldn't have been eating you've already thrown up once in the front yard. That's when injuries happen" (Subject 7). In addition, 86% of health care practitioners indicated that firefighters have second jobs and 79% of health care practitioners indicated that these are labor intensive jobs. These labor-intensive jobs may impact accumulation of fatigue, sleep quantity and quality, and lack of recovery.

4.3.3 Aim #6

Thirty-four excerpts were identified regarding occupational injury mechanisms. Specifically, three child codes were identified as risk factors for occupational musculoskeletal injuries and included awkward positions, lifting, overexertion, with patient transfers commonly coded with lifting (Table 8).

Table. 8 Prevalence of health care practitioners' reported occupational injury mechanisms in structural firefighters.

Injury Mechanism	34 Excerpts
Awkward positions	21%
Lifting	56%
a. Poor lifting technique	15%
b. Patient transfer	24%
Overexertion	29%
Overall movement mechanics	12%

Health care practitioners agreed that firefighters often must maneuver into awkward positions with uneven loads during emergency calls. Health care practitioners' responses indicated that often awkward positions are paired with having to lift a human or object out of a compromised position, putting them at risk of sustaining an injury. One practitioner stated: "…That way from a training standpoint and then as far as lifting patients and gurneys at a house that they've called to trying to lift grandma who's stuck behind a toilet is a common one, believe it or not, and lifting her up with some [REDACTED] position…" (Subject 13). Another practitioner indicated that immobility and operating in awkward positions compounds the risk of injury and stated: "I had one and the guy was trying to hang on the back of an ambulance and didn't have the flexibility to get his arm up you know, trying to close the door and … they have a lot of different odd movements that you can't even practice even in doing the exercise-based stuff and so if you don't have great just general strength or flexibility then you can't do those weird things, trying to get a gurney into the ambulance…" (Subject 12).

Lifting was coded in 56% of the 34 excerpts related to injury mechanisms. 24% of those excerpts included patient transfer and 15% included poor lifting technique. One professional practitioner discussed lifting uneven loads: "Totally and if you think- carrying a human, humans are not- our center of mass is not right in [the] center of our body. So, trying to carry a human is not an easy task and especially if you're short staffed or you know speed is a factor, or if you're trying to get out of a vehicle or whatever, I mean that's where you see the injuries is because people are just trying to move their bodies in ways that aren't designed to be moved" (Subject 12). In addition, another practitioner discussed how hydraulic stretchers have helped alleviate injuries from patient transfers, "Definitely lifting, we have the hydraulic stretchers which significantly decreased injury, but that was an issue, if someone is on a spine board having to lift them or like a second story floor getting someone down…" (Subject 8).

Overexertion was present in 29% of the 34 excerpts assessing injury mechanisms. Practitioners often included overexertion with other injury mechanisms such as lifting, poor form, and technique. One practitioner stated: "Most common is acute rotator cuff strains from on-the-job duties of pulling hose, doing ceiling work, and etc., etc., that they're either excessive amounts of energy that's put into those jobs, or there might be some accident related so rotator cuffs are the biggest one that I see shoulder injuries" (Subject 13). Another practitioner stated, "For the most part, it's probably the overexertion too. So, my knowledge, we don't experience very many slip, trip, fall type things and they are cognizant at least of the weather and how that interacts with things. So, it would probably be overexertion" (Subject 9).

4.4 DISCUSSION

The first objective of this study was to identify prevalent occupational injury types and locations among firefighters. The present study found that occupational injuries tended to be categorized as sprain or strain and were chronic in nature. In relevant research, Frost, and colleagues (2015) analyzed injury reports from a metropolitan fire department and found that 65% of all occupational injuries were classified as sprain or strain. Interestingly, 15% of sprain or strain injuries occurred during fireground operations, whereas 64% of these injuries occurred during physical training or at the fire station (Frost et al., 2015). The classification of chronic and acute injuries has not been well described in the literature. However, in relevant research Nuwayhid and Johnson (1993) identified occupational tasks that were associated with the onset of chronic low back pain. These occupational tasks included operation of a charged hose, cutting structures, ascending, or descending ladders, breaking windows, and lifting heavy objects (Nuwayhid & Johnson 1993). Whereas low risk activities included connecting hydrants, participating in drills, and physical training (Nuwayhid et al., 1993).

Regarding anatomical injury location, the present study indicated that the shoulder and back were the most prevalent injury locations during occupational tasks, followed by the knee, elbow and ankle (Table 6). Likewise, Frost and coworkers (2015) reported that the most prevalent anatomical injury locations during fire suppression operations were the knee (18%), shoulder (14%), back (14%), and ankle (14%) (Frost et al., 2015). Whereas, for non-fire related emergencies, the most prevalent anatomical injury locations include back (21%) and knee (13%). Frost and colleagues (2015) identified the back (21%) and knee (13%) as the most prevalent anatomical injury location. Collectively these findings agree with the injury type and locations of the present study.

The second objective of the present study was to identify intrapersonal, interpersonal, and institutional risk factors associated with occupational injuries among structural firefighters. The risk factors reported by the health care practitioners were intrapersonal in nature and included immobility, biological age, and the collective factor of fatigue, recovery, and sleep. The most prevalent risk factor was immobility. Immobility has been associated with increased risk of injury in geriatric populations (Meijers et al., 2013). There are behavioral and biological mechanisms associated with immobility (Lurati et al., 2015). Specifically, a sedentary lifestyle is associated with an increased risk of premature aging and onset of chronic conditions such as muscle atrophy and joint stiffness (Lurati et al., 2015). In addition, aging is associated with decreased elasticity in tendons and ligaments and ultimately increased musculotendinous stiffness (Lurati et al., 2015; Narici & Maffulli, 2010). Immobility is largely a trainable quality that responds to intervention (Lurati et al., 2015). Thus, it is critical that regular mobility assessments and flexibility training interventions are incorporated at the department and utilized across the career span.

Health care practitioners periodically indicated that firefighter immobility was associated with use of protective gear. The deleterious interaction of immobility and protective gear has been discussed previously. For instance, Park and colleagues (2015) reported that weight and bulkiness of protective gear decreases joint range of motion and contributes to ankle sprains. Although our health care practitioners did not specifically associate the bulkiness of gear to ankle sprains, several practitioners noted that the gear contributes to a decrease in range of motion. In addition, Park, and colleagues (2018) reported that turnout gear has a negative impact on upper body range of motion indicating that fixed length of the self-contained breathing apparatus limits upper body range of motion, especially among shorter firefighters (Park et al., 2019). Park et al.

(2018) reported a decreased range of motion in neck extension and lumbopelvic extension due to wearing the personal protective gear. Park et al. (2019) reported a direct correlation between thickness and size of gear and immobility, which negatively impacts firefighter safety and performance. Collectively, the restrictive nature of the gear and biomechanical requirements of occupational tasks increases firefighters' risk of injury. These findings may indicate the need for protective gear that is ergonomically designed for greater mobility during occupational tasks.

Biological age was another prevalent intrapersonal risk factor reported by health care practitioners that was often associated with occupational degradation of biological systems (I.e., wear and tear) and firefighter experience. These findings are supported by Dropkins and coworkers (2019) who indicated that age is a potential risk factor for musculoskeletal injuries in emergency medical service personnel. Physiologically, increasing age is associated with muscular atrophy and sarcopenia (i.e., decrease in the number of muscle fibers) (Narici & Maffulli, 2010). Sarcopenia is due to the selective loss of type II muscle fibers, which produce greater force per cross-sectional area than type I fibers, although this typically begins at about 60 years of age, after firefighters have retired (Narici & Maffulli, 2010). In aggregate, these factors decrease maximal force production capabilities among older individuals (Narici & Maffulli, 2010), which consequently increases the relative force (i.e., greater strain) required to perform a standardized occupational task and thus may increase risk of overexertion injury. In addition, as noted above, aging is also associated with increased musculotendinous stiffness (Narici & Maffulli, 2010), which may increase injury risk. Collectively, morphological changes in skeletal muscle, tendons and ligaments may have detrimental effects on force production capabilities and tissue stiffness, respectively, that may increase risk of injury among older firefighters. These findings underscore the importance for fire departments to provide comprehensive, guided strength and conditioning programs focused on strength and flexibility development.

According to health care practitioners, aging was often associated with occupational experience. The professionals indicated that younger firefighters may be at a higher risk of sustaining an injury because they are less experienced in performing occupational tasks. Anecdotally, more experienced firefighters have indicated that they have developed efficient methods of performing tasks that may enhance their safety.

In the literature, overexertion is listed as a leading cause of injury among firefighters (Campbell and Evarts, 2021; Orr et al., 2019; Walton et al., 2003). Likewise, in the present study, we noted that fatigue, recovery, and sleep were associated with risk of injury. On a related note, practitioners indicated that the majority of firefighters had second jobs that were comprised of manual labor and may increase fatigue and lack of recovery. Specifically, fatigue may be interpreted like the construct of overexertion, or perhaps a precursor to overexertion related injuries. Indeed, research indicates that exercise-induced fatigue decreases postural stability outcomes in other populations (Clifton et al., 2013). In short, neuromuscular fatigue results in decreased muscular force due to decreased activation of muscle fibers and motor neuron firing rate, alteration in calcium release rates, and inhibition of motor neurons in the peripheral nervous system (Clifton et al., 2013; Kent-Braun, 1999). Furthermore, fatigue increases during exhaustive work and can potentially lead to deleterious changes in kinematics resulting in an increased risk of injury (Clifton et al., 2013).

It is plausible that fatigue, lack of sleep and adequate physical recovery may be associated with risk of occupational injury via reduced mental concentration when performing occupational tasks (Caruso, 2014). Regarding sleep, one practitioner described how continuous sleep disruption prevents rapid eye movement cycles (Subject 13) and that it further impacts their cortisol levels based off the data they have programmatically collected over the years. Indeed, sleep outcomes have been found to be associated with risk of musculoskeletal injury (Lisman et al., 2022). Lisman et al., (2022) discusses that evidence from several studies support that both sleep quality and duration influence musculoskeletal injury in military personnel. To that end, the fire service has implemented several countermeasures to decrease sleep disruption. For example, some departments' emergency tones only go off in specific bedrooms at night with the intention of only waking the responding unit. In addition, these findings highlight the importance for fire departments to provide sleep hygiene resources.

The third objective of this study was to identify prevalent mechanisms of musculoskeletal injury among structural firefighters. The health care practitioners reported that lifting objects was the most common mechanism for occupational injuries (56% of excerpts). More specifically, patient transfer was the most prevalent skill associated with lifting injuries. Interestingly, health care practitioners indicated that patient transfers were a cause for concern regarding injury risk, however, they also discussed how the incorporation of hydraulic gurneys has reduced injury frequency due to patient transfer. In related literature, Poplin et al. (2012) reported that 76% of patient transport injuries resulted in sprain and strain injuries. Furthermore, 46% of injuries incurred by patient transport resulted in lost work time, which demonstrates the substantial financial impact of these types of injuries. Thus, mechanical patient transfer devices should be utilized whenever possible.

In addition, in the present study the mechanism of operating in awkward positions was often associated with lifting. Health care practitioners indicated that occupational injuries tend to occur when firefighters are required to maneuver in confined spaces to gain access to and/or lift a patient. Practitioners described that during these calls, the uneven load of an individual or of the protective gear further exacerbates the issue and likely increases the risk of sustaining a musculoskeletal injury. In relevant literature, Poplin et al. (2012) associated the maneuvering of awkward positions with overexertion. However, practitioners in the present study did not indicate an interaction between operating in awkward positions and overexertion. Rather, overexertion was reported as a prevalent independent mechanism (29% of excerpts). Regardless, to decrease risk of injury from lifting and/or operating in awkward positions, fire departments should emphasize use of proper mechanics while performing occupational tasks and exercising, obtain assistance to lift equipment and patients, and focus on strength development during exercise training.

Interestingly, health care practitioners in the present study did not indicate that slip / trip / fall was a common mechanism of occupational injury (1.5% of excerpts). In contrast, the NFPA 2021 indicates that 21% of occupational injuries that occurred on the fireground are due to slip / trip / fall. Similarly, Frost et al. (2015) and Orr et al. (2019) indicate that slip / trip / fall is a common mechanism of injury and often result in sprain or strain. The discrepancy in findings between these studies may be due to the specific fire departments and participants utilized in each study. That is, it is possible that fire departments with a greater frequency of structure fire responses may incur more slip / trip / fall injuries on the fireground, whereas departments with more EMS calls result in a greater frequency of lifting injuries. It may be that the present sample was biased with health care practitioners that served fire departments with the latter scenario.

There were several limitations to the present study. First, the population recruited were health care practitioners that serve in a role as an athletic trainer, physical therapist, strength and conditioning coach, or nurse practitioner. There are a select number of practitioners who serve in this capacity. In addition, health care practitioners' connection to the fire service differs, as they may be embedded directly within the department, contracted by the fire department through a company, or employed by the city which means that not all practitioners have a shared experience as they serve in relatively different levels, roles, and capacities. A second limitation is that the firefighter patient volume differed between practitioners which may have impacted their responses based on total experience.

4.5 Practical Applications

The findings of this study indicate that occupational injuries among structural firefighters are multifactorial. Injury reduction countermeasures should occur at the department level and include a comprehensive fitness program for firefighters across the career span with a focus on the development and assessment of mobility and strength, and utilization of proper movement mechanics. In addition, a departmental health and safety program should emphasize proper movement mechanics and provide adequate physical recovery during drills requiring extended periods of greater exertion. Given the apparent relationship of fatigue and overexertion versus occupational injury, it may be advisable to administer brief wellness assessments to identify firefighters who may indicate a reduced readiness to perform occupational tasks safely.

In conclusion, the present study indicated that the back and shoulder are prevalent injury locations and tend to be chronic in nature. Risk factors associated with occupational injuries included age, immobility, and factors associated with fatigue. Whereas, prevalent injury mechanisms included lifting, overexertion, and operating in awkward positions. This exploratory mixed methods investigation confirmed previous findings and provided novel insights regarding injury factors from the perspective of health care practitioners.

APPENDICES

Appendix A: Manuscript #1 - Abstract

BACKGROUND: The National Fire Protection Association reported that musculoskeletal injuries account for 56% of non-fireground. Furthermore, physical training is the most common cause of injury, accounting for one-third of all injuries and resulting in 41% of post-injury absences from work. There is limited research identifying risk factors of exercise injuries among firefighters. However, experienced health care practitioners treating firefighter injuries may provide critical insight regarding contextual information of these injuries. Therefore, the purpose of this study was to query health care practitioners working directly with firefighters to identify potential mechanisms and risk factors associated with musculoskeletal injuries during exercise. METHODS: A phenomenological design was utilized to understand the experiences of health care practitioners when treating musculoskeletal injuries in firefighters. Semi-structured interviews were conducted with 14 health care practitioners. Inclusion criteria included licensed health care practitioners (e.g., Athletic Trainer, Physical Therapist), who had at least one year of experience in treating firefighter injuries. Two interviews were pilot tested with health care practitioners to ensure reliability and validity. Subsequently, 12 interviews were included in the data analyses. Interviews were transcribed and uploaded to a qualitative analysis software program. To ensure reliability and validity of codes and categories, two researchers coded to an acceptable level of agreement (81%). Member checking was used to ensure the accuracy of findings with health care practitioners' responses. RESULTS: Health care practitioners indicated that the back and shoulder were prevalent anatomical injury locations for exercise injuries. Risk factors for exercise injuries included age, immobility, movement proficiency, and factors associated with fatigue. Whereas mechanisms of exercise injuries included poor resistance training technique and overexertion. These findings will guide exercise program design and use of movement assessments to decrease risk of exercise injuries among firefighters.

KEYWORDS: firefighters; musculoskeletal injuries; health care providers; risk factors; exercise

Appendix B: Manuscript #2 - Abstract

BACKGROUND: Firefighting involves the performance of rigorous occupational tasks in unpredictable, dynamic, and hot environments which increases firefighters' risk of injury. Specifically, the National Fire Protection Association reported that musculoskeletal injuries account for 41% of fireground injuries. There is limited research identifying occupational injury risk factors among firefighters. However, health care practitioners that regularly treat firefighter injuries may provide critical insight regarding risk factors and mechanisms of these injuries. Therefore, the purpose of this study was to interview health care practitioners to identify potential mechanisms and risk factors of occupational injuries among firefighters. METHODS: A phenomenological design was utilized to explore the experiences of health care practitioners when treating musculoskeletal injuries in firefighters. Semi-structured interviews were conducted with 14 health care practitioners. Inclusion criteria included licensed health care practitioners (e.g., Athletic Trainer, Physical Therapist) who had at least one year of experience in treating firefighter injuries. Two interviews were pilot tested with practitioners to ensure data reliability and validity. Subsequently, 12 interviews were used in the data analyses and uploaded to a qualitative analysis software program. To ensure reliability and validity of codes and categories, two researchers coded to a level of agreement of 80%. Member checking was used to ensure the accuracy of findings with practitioners' responses by returning the transcriptions back to the participants. RESULTS: Health care practitioners indicated that the back and shoulder were prevalent anatomical injury locations. Occupational injury risk factors included age, immobility, and factors associated with fatigue. Prevalent occupational injury mechanisms included lifting, overexertion, and operating in awkward positions. These findings will inform the implementation of appropriate countermeasures to enhance firefighter safety.

KEYWORDS: firefighters; musculoskeletal injuries; health care providers; risk factors

Appendix C: Interview Script

Interview script is broken up into four of the following sections with informed consent

1. **Section one will outline the purpose of the study, gain consent, address issues of confidentiality, and establish trust with each HEALTH CARE PRACTITIONERs.**

"Good morning/afternoon, ______________.
I would like to formally introduce myself; my name is Ali Eastman. Thank you again for taking time to participate in our study.
I am going share my screen with the consent form I emailed you and review it with you. [Share screen with consent form.]
This interview should take about 45 minutes. I will ask you several open-ended questions. Please answer them based on your experience and current perspective as a health care provider.
With your permission, I would like to record this interview today, audio and video, for analysis. **The interview will be conducted and recorded via Zoom and saved to my computer. The audio recordings will be uploaded to UK OneDrive and to Dedoose, a software program for analysis. After we summarize your responses, we will destroy the recordings.** Also, we will not identify you or your organization if we use any of your quotes; however, some readers may be able to guess who a respondent is. [Confirm they give permission.]
There are no anticipated risks or benefits for participating in the study. Participation is purely voluntary, and there is no penalty to you or your job if you choose not to continue. If you choose to participate, you are also free to withdraw your consent at any time.
Do you have any questions? [Answer any questions.]
Would you like to participate in the study and do the interview with me today?"
IF YES: Great, let us get started. [Proceed to interview questions]
IF NO: Ok, I understand. Thank you for your time. [End call.]

1. **Section two will implement questions which will explore the history of the HEALTH CARE PRACTITIONERs in treating and rehabilitating firefighter injuries.**

A. How many years have you been in your respective profession and treating patients?
A. Are you specialized or hold any certifications through the APTA/NATA?
A. What is your level of education? (BA/MS/DPT/MAT/PhD/MD/etc.)
A. Do you have any other certifications (e.g., CSCS, CPT, ACSM-EP, etc.)?
A. How many years have you been specifically treating firefighters?
  a. How many firefighters are you treating per week? Single patient visits and then are you seeing a patient multiple times per week?
A. Do you belong to a HEALTH CARE PRACTITIONERs group that specifically works with firefighters or other tactical populations?
A. Are firefighters being referred to you? Are you embedded/contracted with a Fire Department?
  a. How does the referral process work?
  a. What is typical duration from onset of injury to treatment?

i. What percentage of firefighters' injuries result in work loss or time away from work?

A. Have you observed firefighters performing occupational tasks?

A. What percentage of your firefighters have second jobs? Are they labor intensive?

1. **Section three will include open-ended questions related to injury mechanisms and environmental factors associated with occupational tasks. Follow-up questions and probes will be included as needed.**

*Questions asked for exercise and non-exercise related injuries.

Exercise: Participation is a physical activity which does not include training operations, but may include lifting, cross fit, aerobic exercises, etc.

Occupational Injuries: Training operations/fire groud

A. What are the most common injuries you are treating? (I.e., sprains/strains; acute vs. chronic) How are they occurring based off your interaction with the firefighter?

- a. Exercise
- a. Occupational injuries (Training operations/fireground?)

A. Anatomically, where do the injuries typically occur (location of injury i.e., back, ankle, knee)?

- a. Exercise
- a. Occupational injuries (Training operations/fireground)
  - i. What is the typical mechanism of injury during exercise and occupational activities?

A. What percentage of injuries would you say are due to exercise versus occupational versus personal?

A. Do you believe exercise is a significant cause of musculoskeletal injuries?

- a. **Intrapersonal**: In your experience does [blank] increase the risk of injuries in firefighters **during exercise.**
  - i. Age
  - i. Immobility
  - i. Lack of movement proficiency **(proper lifting or running technique or proper movement during exercise)**
  - i. Lack of training experience (amount of years' experience lifting or in the gym)
  - i. Lack of sleep/fatigue/lack of recovery
  - i. Inadequate nutrition
  - i. Mental health (I.e., anxiety, depression, PTSD)
- a. **Interpersonal**: In your experience during **exercise**...
  - i. How does the training environment impact injuries during exercise?
    1. Probe: Slip/fall/jump/trip, overexertion/sprain, weather, assault, contact with object, improper form
  - i. Do distractions influence injuries during **exercise**? (i.e., cell phone, each other)

A. Do you believe occupational related activities are a significant cause of MSK injuries?

- a. **Intrapersonal**: In your experience does [blank] increase the risk of injuries in firefighters during **occupational /non-exercise tasks (Fireground, training operations)**.

i. Age
i. Immobility
i. Lack of movement proficiency (Movement during training operations/ or fireground **(i.e.., dummy drag, hose advance, breach & pull)**
i. Lack of occupational experience (years' experience in the profession, actual experience on the fireground/training operations)
i. Lack of sleep/fatigue/lack of recovery
i. Inadequate nutrition
i. Mental health (I.e., anxiety, depression, PTSD)

a. **Interpersonal**: In your experience...
    i. How does the training environment impact injuries during **occupational tasks/non-exercise (Training operations/ fireground)?**
        1. Probe: Slip/fall/jump/trip, overexertion/sprain, weather, assault, contact with object, improper form
    i. Do distractions influence injuries during occupational tasks (training ground/fireground)? (i.e., cell phone, each other)

a. Institutional:
    i. Would supervision during exercise impact the incident rate of injuries?
    i. Do you believe annual fitness assessments may reduce the risk of exercise or occupational injuries?
    i. Would having an AT/PT embedded within the department make a difference from type of injury to treatment?
    i. Do you believe the equipment or protective gear contributes to occupational injuries?
    i. Does the overall culture of the fire station/department/shift affect the attitudes/effort during exercise or occupational tasks?

A. What has been your experience with exercise versus non-exercise injuries?
    a. Based off your experiences do the mechanisms or risk factors of injuries differ from exercise versus occupational tasks.
    b. Probe: What percentage of injuries would you estimate are exercise versus occupational tasks based on your experiences.

1. **Section four will include closing questions that allow the participants to add additional information not covered in the other sections.**
    a. Is there any additional information not covered that you would like to add?

Appendix D: Code Book

Code	Definition
Strength coach	Discusses implementation of strength coach
Assessments	Does the fire department implement assessments to test FF. Annual screening, body composition, FMS, movement screenings, realistic job testing, strength testing.
Culture	The culture of the fire department, shift, personnel is discussed; buy-in, competitiveness, ego, trust.
Education	Discussed implementing education or knowledge of exercise.
Gear	Discussion of the gear worn during occupational tasks. May discuss the bulkiness, cost, and weight of gear.
Distractions	Distraction during exercise or occupational task. Tunnel vision, cell phone usage, distracting each other.
Health care provider	Characteristics of the health care provider. If they are a physical therapist, athletic trainer, contracted, embedded.
*Injury setting	Injury location encumbers exercise-induced, occupationally induced, and personal-induced injuries. Personal-induced injuries include second jobs that may be labor intensive.
*Injury anatomical location	Body part of injury. Ankle, back, knees, elbow, shoulder.
*Injury mechanism	How the injury occurred. Includes, awkward position, compensation, lifting, slip/trip/falls, overall mechanics, overexertion, overreaching, repetitive motion, stability/balance.
*Injury type	The type of injury. Acute, chronic, chronic to acute, sprain/strain, tendonitis/tendinosis.
Access	How the firefighters can see health care providers.
*Risk factor	What contributed to an injury: biological age, fatigue, immobility, lack of recovery, immobility, mental health, movement proficiency, inadequate nutrition, training age.
Supervision	Supervision during drills and training; exercise and occupational.
Environment	The environment during both exercise and occupational activities. Gym, structure falls, training operations, weather.
Treatment	Treatment course for an injury. Anything the health care practitioner does to treat injuries and may include prevention groups.
Volume	How many firefighters the health care practitioners treating.

*Indicates codes utilized for analysis in the current studies.

REFERENCES

Abel, M. G., Palmer, T. G., & Trubee, N. (2015). Exercise Program Design for Structural Firefighters. *Strength and Conditioning Journal*, *37*(4), 8–19. https://doi.org/10.1519/SSC.0000000000000123

Abel, M. G., Sell, K., & Dennison, K. (2011). Design and Implementation of Fitness Programs for Firefighters. *Strength and Conditioning Journal*, *33*(4), 31–42. https://doi.org/10.1519/SSC.0b013e318212f412

Appell, HJ., Soares, J.M.C. & Duarte, J.A.R. Exercise, Muscle Damage and Fatigue. *Sports Medicine* 13, 108–115 (1992). https://doi.org/10.2165/00007256-199213020-00006

Baldwin, S., Bennell, C., Andersen, J. P., Semple, T., & Jenkins, B. (2019). Stress-Activity Mapping: Physiological Responses During General Duty Police Encounters. *Frontiers in Psychology*, *10*, 2216. https://doi.org/10.3389/fpsyg.2019.02216

Beach, T. A. C., Frost, D. M., McGill, S. M., & Callaghan, J. P. (2014). Physical fitness improvements and occupational low-back loading – an exercise intervention study with firefighters. *Http://Dx.Doi.Org/10.1080/00140139.2014.897374*, *57*(5), 744–763. https://doi.org/10.1080/00140139.2014.897374

Broomé, R. E., & Russell, E. J. (2019). What Is It like to Self-Rescue from a Building Collapse as a Firefighter: A Phenomenological Inquiry? *Journal of Phenomenological Psychology*, *50*(2), 225–248. https://doi.org/10.1163/15691624-12341363

Butler, R. J., Contreras, M., Burton, L. C., Plisky, P. J., Goode, A., & Kiesel, K. (2013). Modifiable risk factors predict injuries in firefighters during training academies. *Work*, *46*(1), 11–17. https://doi.org/10.3233/WOR-121545

Campbell, R., & Molis, J. (2019). United States Firefighter Injuries in 2018. *NFPA Journal*, *November*. www.nfpa.org/firefighterfatalities

Carleton, N. R., Afifi, T. O., Turner, S., Taillieu, T., LeBouthillier, D. M., Duranceau, S., Sareen, J., Ricciardelli, R., MacPhee, R. S., Groll, D., Hozempa, K., Brunet, A., Weekes, J. R., Griffiths, C. T., Abrams, K. J., Jones, N. A., Beshai, S., Cramm, H. A., Dobson, K. S., … Asmundson, G. J. G. (2018). Suicidal ideation, plans, and attempts among public safety personnel in Canada. *Canadian Psychology*, *59*(3), 220–231. https://doi.org/10.1037/CAP0000136

Caruso, C. C. (2014). Negative Impacts of Shiftwork and Long Work Hours. *Rehabilitation Nursing: The Official Journal of the Association of Rehabilitation Nurses*, *39*(1), 16. https://doi.org/10.1002/RNJ.107

Clifton, D. R., Harrison, B. C., Hertel, J., & Hart, J. M. (2013). Relationship between functional assessments and exercise-related changes during static balance. *Journal of Strength and Conditioning Research*, *27*(4), 966–972. https://doi.org/10.1519/JSC.0B013E318260B723

Conrad, K. M., Balch, G. I., Reichelt, P. A., Muran, S., & Oh, K. (1994). Musculoskeletal injuries in the fire service: Views from a focus group study. *AAOHN Journal*, *42*(12), 572–581. https://doi.org/10.1177/216507999404201201

Dobson, M., Choi, B., Schnall, P. L., Wigger, E., Garcia-Rivas, J., Israel, L., & Baker, D. B. (2013). Exploring Occupational and Health Behavioral Causes of Firefighter Obesity: A Qualitative Study. *American Journal of Industrial Medicine*, *56*(7), 776–790. https://doi.org/10.1002/ajim.22151

Dropkin, J., Power, P., Rasul, R., Moline, J., & Kim, H. (2019b). Effect of resiliency and age on musculoskeletal injuries and lost workdays in emergency medical service personnel. *International Journal of Industrial Ergonomics*, *69*, 184–193. https://doi.org/10.1016/J.ERGON.2018.11.008

Frost, D. M., Beach, T. A. C., Callaghan, J. P., & McGill, S. M. (2015). Exercise-Based Performance Enhancement and Injury Prevention for Firefighters. *Journal of Strength and Conditioning Research*, *29*(9), 2441–2459. https://doi.org/10.1519/JSC.0000000000000923

Frost, D. M., Beach, T. A. C., Crosby, I., & McGill, S. M. (2015). Firefighter injuries are not just a fireground problem. *Work*, *52*(4), 835–842. https://doi.org/10.3233/WOR-152111

Gastin P. B. (2001). Energy system interaction and relative contribution during maximal exercise. *Sports medicine (Auckland, N.Z.)*, *31*(10), 725–741. https://doi.org/10.2165/00007256-200131100-00003

Gazzale, L. (2019). Motivational implications leading to the continued commitment of volunteer firefighters. *International Journal of Emergency Services*, *8*(2), 205–220. https://doi.org/10.1108/IJES-12-2017-0063/FULL/XML

Griffin, S. C., Regan, T. L., Harber, P., Lutz, E. A., Hu, C., Peate, W. F., & Burgess, J. L. (2016). Evaluation of a fitness intervention for new firefighters: Injury reduction and economic benefits. *Injury Prevention*, *22*(3), 181–188. https://doi.org/10.1136/injuryprev-2015-041785

Groenewald, T. (2004). A Phenomenological Research Design Illustrated. *International Journal of Qualitative Methods*, *3*(1), 42–55. https://doi.org/10.1177/160940690400300104

Jahnke, S. A., Carlos Poston, W. S., Haddock, C. K., & Jitnarin, N. (2013). Injury among a population-based sample of career firefighters in the central USA. *Injury Prevention*, *19*(6), 393–398. https://doi.org/10.1136/injuryprev-2012-040662

Jahnke, S. A. (2016). Injury, musculoskeletal disorders, and ergonomics. *Health Risks and Fair Compensation in the Fire Service*, 209–226. https://doi.org/10.1007/978-3-319-23069-6_10/TABLES/2

Kent-Braun J. A. (1999). Central and peripheral contributions to muscle fatigue in humans during sustained maximal effort. *European journal of applied physiology and occupational physiology*, *80*(1), 57–63. https://doi.org/10.1007/s00421005055

Kim, J. (2013). Depression as a psychosocial consequence of occupational injury in the US working population: Findings from the medical expenditure panel survey. *BMC Public Health*, *13*(1), 1–10. https://doi.org/10.1186/1471-2458-13-303/TABLES/4

Kollock, R., Thomas, J., Hale, D., Sanders, G., Long, A., Dawes, J., & Peveler, W. (2021b). The Effects of Firefighter Equipment and Gear on the Static and Dynamic Postural Stability of Fire Cadets. *Gait and Posture*, *88*, 292–296. https://doi.org/10.1016/J.GAITPOST.2021.05.034

Kong, P. W., Suyama, J., & Hostler, D. (2013). A review of risk factors of accidental slips, trips, and falls among firefighters. *Safety Science*, *60*, 203–209. https://doi.org/10.1016/J.SSCI.2013.07.016

Landis, J. R., & Koch, G. G. (1977). The Measurement of Observer Agreement for Categorical Data. *Biometrics*, *33*(1), 159–174. https://doi.org/10.2307/2529310

Langford, Emily, "Physiological Profile of Rural Structural Firefighters in Southeast Georgia" (2019). Electronic Theses and Dissertations. 1920. https://digitalcommons.georgiasouthern.edu/etd/1920

Le, A. B., Smith, T. D., McNulty, L. A., Dyal, M. A., & Dejoy, D. M. (2020). Firefighter Overexertion: A Continuing Problem Found in an Analysis of Non-Fatal Injury Among Career Firefighters. *International Journal of Environmental Research and Public Health 2020, Vol. 17, Page 7906*, *17*(21), 7906. https://doi.org/10.3390/IJERPH17217906

Lisman, P., Ritland, B. M., Burke, T. M., Sweeney, L., & Dobrosielski, D. A. (2022). The Association Between Sleep and Musculoskeletal Injuries in Military Personnel: A Systematic Review. *Military Medicine*, usac118. Advance online publication. https://doi.org/10.1093/milmed/usac118

Lurati, A. R. (2018). Health Issues and Injury Risks Associated with Prolonged Sitting and Sedentary Lifestyles. *Workplace Health and Safety*, *66*(6), 285–290. https://doi.org/10.1177/2165079917737558

Lyons, K., Radburn, C., Orr, R., & Pope, R. (2017). A Profile of Injuries Sustained by Law Enforcement Officers: A Critical Review. *International Journal of Environmental Research and Public Health, 14*(2), 142. https://doi.org/10.3390/IJERPH14020142

Mayer, J. M., Lane, C. L., Brady, O., Chen, H., Lu, Y., Johnson, B. V. B., & Dagenais, S. (2020). Comparison of Supervised and Telehealth Delivery of Worksite Exercise for Prevention of Low Back Pain in Firefighters: A Cluster Randomized Trial. *Journal of Occupational and Environmental Medicine*, *62*(10), e586–e592. https://doi.org/10.1097/JOM.0000000000001993

Mayer, J. M., Quillen, W. S., Verna, J. L., Chen, R., Lunseth, P., & Dagenais, S. (2015). Impact of a supervised worksite exercise program on back and core muscular endurance in firefighters. *American Journal of Health Promotion*, *29*(3), 165–172. https://doi.org/10.4278/ajhp.130228-QUAN-89

McFarlane, A. C. (1988). The phenomenology of posttraumatic stress disorders following a natural disaster. *Journal of Nervous and Mental Disease*, *176*(1), 22–29. https://doi.org/10.1097/00005053-198801000-00003

Meijers, J. M., Halfens, R. J., Neyens, J. C., Luiking, Y. C., Verlaan, G., & Schols, J. M. (2012). Predicting falls in elderly receiving home care: the role of malnutrition and impaired mobility. *The Journal of Nutrition, Health & Aging*, *16*(7), 654–658. https://doi.org/10.1007/s12603-012-0010-7

Miles, M. and Huberman, A., 1994. *Qualitative data analysis*. Thousand Oaks, Calif.: Sage.

Narici, M. v., & Maffulli, N. (2010). Sarcopenia: characteristics, mechanisms, and functional significance. *British Medical Bulletin*, *95*(1), 139–159. https://doi.org/10.1093/BMB/LDQ008

Nord-Ljungquist, H., Engström, Å., Fridlund, B., & Elmqvist, C. (2021). 'Time is our utmost enemy': First responders' experiences of 'While Waiting for the Ambulance' assignments in rural environments – A phenomenological study. *Nordic Journal of Nursing Research*. https://doi.org/10.1177/20571585211009465

Norris, M. S., McAllister, M., Gonzalez, A. E., Best, S. A., Pettitt, R., Keeler, J. M., & Abel, M. G. (2021). Predictors of Work Efficiency in Structural Firefighters. *Journal of Occupational and Environmental Medicine*, *63*(7), 622–628. https://doi.org/10.1097/JOM.0000000000002197

Nuwayhid, I. A., Stewart, W., & Johnson, J. V. (1993). Work activities and the onset of first-time low back pain among New York City fire fighters. *American Journal of Epidemiology*, *137*(5), 539–548. https://doi.org/10.1093/oxfordjournals.aje.a116707

Orr, R., Simas, V., Canetti, E., & Schram, B. (2019). A profile of injuries sustained by firefighters: A critical review. *Int J Environ Res Public Health*. 16(20):3931. doi: 10.3390/ijerph16203931. PMID: 31623104; PMCID: PMC6843477.

Park, H., Kakar, R. S., Pei, J., Tome, J. M., & Stull, J. (2018). Impact of Size of Fire boot and SCBA Cylinder on Firefighters' Mobility. *Clothing and Textiles Research Journal*, *37*(2), 103–118. https://doi.org/10.1177/0887302X18807753

Park, H., Trejo, H., Miles, M., Bauer, A., Kim, S., & Stull, J. (2015). Impact of firefighter gear on lower body range of motion. *International Journal of Clothing Science and Technology*, *27*(2), 315–334. https://doi.org/10.1108/IJCST-01-2014-0011

Pawlak, R., Clasey, J. L., Palmer, T., Symons, T. B., & Abel, M. G. (2015). The Effect of a Novel Tactical Training Program on Physical Fitness and Occupational Performance in Firefighters. *Journal of Strength and Conditioning Research*, *29*(3), 578–588. https://doi.org/10.1519/JSC.0000000000000663

Piano, L., Maselli, F., Viceconti, A., Gianola, S., & Ciuro, A. (2017). Direct access to physical therapy for the patient with musculoskeletal disorders, a literature review. *Journal of Physical therapy science*, *29*(8), 1463–1471. https://doi.org/10.1589/jpts.29.1463

Poplin, G. S., Harris, R. B., Pollack, K. M., Peate, W. F., & Burgess, J. L. (2012). Beyond the fireground: Injuries in the fire service. *Injury Prevention*, *18*(4), 228–233. https://doi.org/10.1136/injuryprev-2011-040149

Poplin, G. S., Roe, D. J., Peate, W., Harris, R. B., & Burgess, J. L. (2014). The Association of Aerobic Fitness with Injuries in the Fire Service. *American Journal of Epidemiology*, *179*(2), 149–155. https://doi.org/10.1093/aje/kwt213

Saunders, B., Sim, J., Kingstone, T., Baker, S., Waterfield, J., Bartlam, B., Burroughs, H., & Jinks, C. (2018). Saturation in qualitative research: exploring its conceptualization and operationalization. *Quality and Quantity*, *52*(4), 1893–1907. https://doi.org/10.1007/S11135-017-0574-8/TABLES/1

Seabury, S., & McLaren, C. (2010). The Frequency, Severity, and Economic Consequences of Musculoskeletal Injuries to Firefighters in California. *The Frequency, Severity, and Economic Consequences of Musculoskeletal Injuries to Firefighters in California*. https://doi.org/10.7249/MG1018

Soteriades, E. S., Smith, D. L., Tsismenakis, A. J., Baur, D. M., & Kales, S. N. (2011). Cardiovascular disease in US firefighters: a systematic review. *Cardiology in Review*, *19*(4), 202–215. https://doi.org/10.1097/CRD.0B013E318215C105

Sinden, K., MacDermid, J., Buckman, S., Davis, B., Matthews, T., & Viola, C. (2013). A qualitative study on the experiences of female firefighters. *Work*, *45*(1), 97–105. https://doi.org/10.3233/WOR-121549

Sullivan, J. P., Conor, O'brien, S., Barger, L. K., Rajaratnam, S. M. W., Czeisler, C. A., & Lockley, S. W. (2017). A Sleep Health Program for. *SLEEP*, *40*(1). https://doi.org/10.1093/sleep/zsw001

Teyhen, D. S., Shaffer, S. W., Butler, R. J., Goffar, S. L., Kiesel, K. B., Rhon, D. I., Williamson, J. N., & Plisky, P. J. (2015). What Risk Factors Are Associated with Musculoskeletal Injury in US Army Rangers? A Prospective Prognostic Study. *Clinical Orthopaedics and Related Research, 473*(9), 2948–2958. https://doi.org/10.1007/S11999-015-4342-6

Zhao, P., Li, P., Ross, K., & Dennis, B. (2016). Methodological Tool or Methodology? Beyond Instrumentality and Efficiency with Qualitative Data Analysis Software. *Forum Qualitative Sozialforschung / Forum: Qualitative Social Research*, *17*(2). https://doi.org/10.17169/FQS-17.2.2597

Zhuang, J., Payyappalli, V. M., Behrendt, A., & Lukasiewicz, K. (2017). *Total Cost of Fire in the United States FINAL REPORT BY*. www.nfpa.org/totalcost

VITA

Alyssa Quinn Eastman

EDUCATION

University of Kentucky	Master of Science	*08/2022 (expected)*
Lexington, KY	Exercise Physiology	

Thesis Etiology of Firefighter Injuries: A Health Care Practitioners Perspective

Hamline University	Bachelor of Arts	05/2020
Saint Paul, MN	Exercise Science & Public Health Sciences	