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# Descriptive Analysis of Injuries Sustained by Wildland Firefighters

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# DESCRIPTIVE ANALYSIS OF INJURIES SUSTAINED BY WILDLAND FIREFIGHTERS

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Descriptive Analysis of Injuries Sustained by Wildland Firefighters

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**Objective:** To develop a better understanding of the types of injuries Wildland Firefighters (WLFFs) sustain during Physical Training (PT) and while out on the fire line, and if there are any discernible trends or patterns that can be addressed through the implementation of a more focused PT program.

**Methods:** This study is a web-based cross-sectional questionnaire titled *Injury Surveillance of Wildland Firefighters* (ISWLFF). We utilized a snowball sampling technique to reach seasonal and fulltime WLFFs of the US Forest Service. 360 WLFFs responded to the questionnaire, but were not required to answer every question. While 112 of the respondents did not report an injury in the past 5 years, 248 WLFFs did. Of the 248 participants whose injury data was utilized, there were 218 males, 29 females and 1 identified as other. Quantitative data from the questionnaire was analyzed using Microsoft Excel to determine WLFFs demographics, types of injuries sustained and the potential influence environmental factors have on injuries sustained. Thematic analysis was conducted on open-ended questions where WLFFs could offer further explanation to a closed ended question.

**Results**: Most WLFFs (n=248) sustained at least one injury in the past 5 fire seasons with 91% (n=226) of those injuries occurring on the fireline on rocky mountainside terrain. Nearly half (n=209) of the injuries reported were sprains and strains occurring to the lower back, knee and ankle. 76% of injuries reported by WLFFs (n=343/453) directly impacted their ability to continue with normal duty.

**Conclusions**: Most of the injuries reported by WLFFs were to the lower extremity and occurred while working on the fireline. Therefore, a more targeted, job-specific injury prevention program that focuses on the lower extremity should be considered.

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# Chapter 1

## Introduction

### Statement of the Problem:

As the number and severity of wildfires increases every year, more is asked of today's Wildland Firefighters (WLFFs) than ever before.[1] The task of wildfire suppression is incredibly arduous, and as the physical demands of the job continue to rise, so too will the risk of injury.[2] As the environment for WLFF becomes increasingly more dynamic, it is imperative to look towards optimizing physical performance through injury prevention.[3,4]

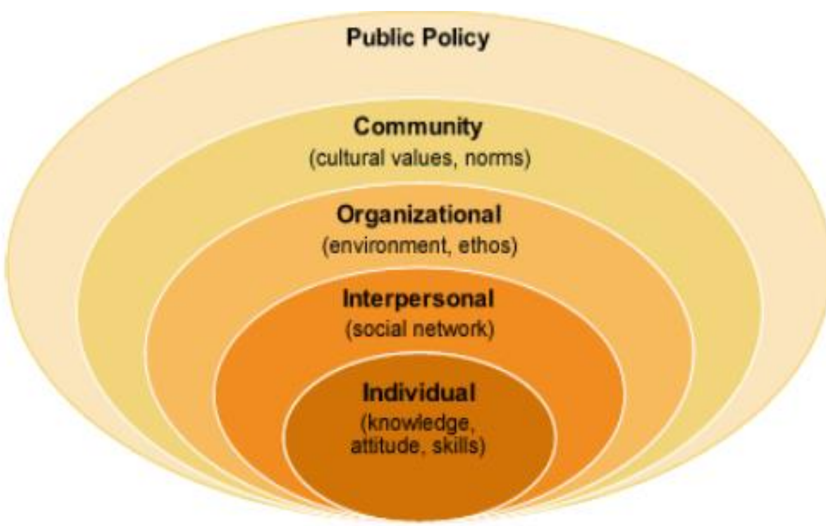
The most important component of injury prevention is first identifying the types of injuries sustained by WLFFs through prior research. In order to accurately assess the types of injuries suffered by WLFFs, an in-depth evaluation of external factors, such as terrain, equipment availability, and duration of work shifts is necessary to address the most prominent threats to the safety of all WLFFs during physical training (PT) and out on the fireline.

Unfortunately, the amount of data on WLFF injuries is underwhelming, and research shows that injuries by WLFFs are often underreported.[5] The reality of the present situation is that today's Wildland Firefighters, regardless of crew type or physical fitness, are suffering injuries at an alarming rate. Whether assigned to an incident or during PT, the time lost from these injuries and the subsequent financial burden that the United States Forest Service (USFS) faces as a result of these injuries is an issue that needs to be addressed.[3]

### Theoretical Framework

Wildland Firefighters, by nature, are incredibly tough when dealing with injuries. While this may be seen on an individual basis, there are multiple levels of influence that ultimately shape the behaviors of the entire community, as noted by Glanz et al.[6] The Social Ecological Model (see Figure 1),[6] helps us better understand what factors affect WLFFs behavior patterns by laying out the framework necessary to design programs that benefit the group as a whole. These levels of influence include individual, interpersonal, organizational, community, and public policy. In the WLFF environment, this model thrives because it allows for change and growth on an individual level with the potential for change and growth throughout the WLFF community through beneficial changes in public policy.[6]

**Figure 1.** Social Ecological Model Diagram as illustrated in *Health Behavior and Health Education: Theory, Research, and Practice*[6]




## Purpose of Study

In the Wildland Firefighting community, there is a growing realization of the need to develop a better understanding of the types of injuries WLFFs sustain during PT and while out on the line. After collecting and analyzing this injury data, we hope to identify possible patterns or discernible traits that may present a problem for certain demographics of WLFFs. The aim of this study is to identify the types of injuries WLFFs sustain on the job, the factors leading up to the injury, and how best to address these areas of concern. With a solid understanding of injury rates and how they pertain to WLFFs, the next logical step in addressing these injuries is through simple injury prevention strategies, or through the implementation of a more job-specific PT program.

**Quantitative Research Question(s)**

1. What type of injuries do WLFFs sustain while completing physical training?
2. What type of injuries do WLFFs sustain while working on the fireline?
3. Are there specific factors that influence types of injuries sustained by Wildland Firefighters?

**Quantitative Hypothesis**

1. The majority of injuries sustained by WLFFs while completing physical training will consist of injuries to the knees and ankles.
2. The injuries sustained on the fireline by WLFFs will manifest primarily in the low back, knees, and ankles.
3. Specific factors that influence types of WLFF injuries will be time of day, amount of days into work shift, and the type of terrain.

**Significance of the Study**

While efforts have been made to research injury rates among structural firefighters, policemen, and military personnel, the unfortunate truth is that these studies do not translate to WLFFs because the physical demands and varying terrain experienced by WLFFs cannot be replicated outside of Wildland Firefighting. To further exacerbate the problem of limited research, the data on WLFF injuries that does exist is outdated, and does not accurately portray today's WLFF.

Therefore, the aim of this study is to identify what parts of the body are most commonly injured during PT and when assigned to an incident, what demographics or specific factors place WLFFs at the greatest risk for injury, and how to take all of this information and apply it towards a more job-specific PT program in order to reduce injury rates amongst Wildland Firefighters.

## **Definition of Terms**

For the purposes of this study, the following definitions were used.

*Wildland Firefighter (WLFF)*. Wildland Firefighters are any employee of the U.S. Forest Service, Bureau of Land Management, National Park Service, Bureau of Indian Affairs, and U.S. Fish and Wildlife Service, state and volunteers, seasonal or full-time, tasked with battling, preventing, or cleaning up wildland fires through the use of specific tools and specialized techniques.[7] For the sake of this study, the term WLFF refers only to employees of the U.S. Forest Service.

*Physical Training (PT)*. Physical training is any physical activity program, either preseason or in-season, that is prescribed to or undertaken by a WLFF crew in order to improve or maintain the levels of physical fitness necessary to perform the duties of a WLFF for the duration of the wildland fire season.[8]

*Fireline.* A fireline is the designated strip of land WLFFs clear by digging down to mineral soil in order to arrest a forest fire and prevent further burning.[7]

*Assigned to Incident.* When a WLFF Crew is designated for duty on an active wildfire, as determined by the U.S. Forest Service.[9]

*Type I.* A Type I Crew consists of highly trained and specialized WLFFs that undertake the most severe wildfires. Type I Crews are incredibly self-sufficient, and often work in isolated areas without further WLFF assistance.[7,10]

*Type II.* A Type II Crew consists of a wide variety of WLFF positions that cover initial attacks on wildfires, to constructing firelines, as well as mop-up of previously burned areas.[7,10]

*USFS.* The United States Forest Service is one of many agencies of the United States Department of Agriculture, and whose mission is to "sustain the health, diversity, and productivity of the Nation's forests and grasslands to meet the needs of present and future generations."[11]

**Delimitations**

This study was delimited to permanent and seasonal WLFFs employed by the U.S. Forest Service (USFS). Participation in the online survey was completely voluntary, and the data recorded was all self-reported.

**Limitations:**

The tool for collecting data for this study was a self-administered online questionnaire. Participants recalled and listed injuries over the previous five years, which limits the results to the sample and eliminates the possibility of randomization when recruiting participants for the study. Other limitations to self-administered questionnaires include incomplete questionnaires, qualitative explanations that cannot be categorized, and individuals participating in the survey more than one time. Another limitation is that there is no available data that lists the number of Wildland Firefighters actively employed during the fire season, making it all but impossible to determine if our sample is representative of the entire Wildland Firefighter population.

**Threats to Internal Validity:**

When designing a research study, it's important to control as many conditions of the experiment as possible to maintain the highest degree of validity. Internal validity, than, indicates the amount of confidence a researcher possesses in regards to causal relationships between two variables.[12–14] The nature of snowball sampling and distribution of the survey raises the concern of experimental mortality, or the failure of subjects within the population to respond to or complete the questionnaire.[13,15] Yiannakis[15] notes that selection bias, especially in survey research, is a constant threat to internal validity once it is introduced and should be heavily considered when designing a research study.

**Threats to External Validity:**

The reality of validity is that the degree to which one type develops has an inverse effect on the other. For non-experimental research, the emphasis is placed primarily on external validity. External validity focuses on generalizability, or the ability to use results from the selected study sample and apply it to the larger population.[13–15] An important obstacle to navigate when designing a research questionnaire is bias. Unfortunately, bias can impact the validity of a study from the perspective of the researcher, as well as the subject. Sampling bias is the subsequent error that results from surveying a non-random sample from a given population.[13,14,16] Seeing that the method of data collection utilized was snowball sampling, it is nearly impossible to obtain a random sample of the entire population. Self-report bias is difficult to monitor amongst research participants because some subjects may forget certain details necessary for the data collection, or may even curtail their responses to appear more socially desirable to the researcher.[13–16]

The first step in addressing injuries sustained by WLFFs is understanding the types of injuries most commonly seen throughout the population. However, the lack of data on WLFFs demonstrates the need for an in-depth look at injury rates and injury prevention strategies and programs across a cohort similar to Wildland Firefighters.[5] The job demands placed on tactical athletes, particularly military personnel, most closely reflect what is seen throughout the WLFF community and provide the necessary information for injury rates and prevention strategies that are critical to reducing injury rates across the entire population.[5,17–19]

# Chapter 2

## Review of the Related Literature

### Overview:

The United States averages around 80,000 wildland fires each year, burning upwards of 6.5 million acres of federal, state, and private land.[5,20] Suppression of these fires falls across multiple agencies and crew types, where the severity of the wildland fire season dictates the amount of time spent on a given job. The arduous nature of work seen in wildland firefighting leads to an increased risk of injuries. In order to assist WLFFs in identifying and preventing these injuries, it is imperative to develop a more comprehensive understanding of the physical demands of the job, the types of injuries WLFFs sustain, as well as the mechanism of the injury, and how to best address these areas of concern in the offseason, as well as throughout the wildland fire season. Using research focused on injuries sustained by tactical athletes and the prevention strategies and programs that are in place for those occupations, we can transpose those findings into strategies and programs for WLFFs that may help decrease the rate of injury seen during physical training and while working out on the fireline.

### The Tactical Athlete:

The lack of literature on WLFF injuries dictates that most of the research must come from occupations with similar physical demands.[3,21] Military personnel, structural firefighters, policemen, and WLFFs all fall under the term of *tactical athlete*.[22] Scofield & Kardouni[18] define the tactical athlete as anyone whose occupation demands methods of physical training that are necessary to maintain an appropriate level of physical performance compulsory with the profession.[18] These athletes must overcome not only the physical demands of their occupations, but also the dynamic environmental factors that may impact job performance.[17,18,21]

Although each occupation carries with it unique challenges specific to the job for tactical athletes, it's difficult to ignore the similarities between professions.[23] Military personnel, law enforcement, and WLFFs all adhere to physical fitness guidelines in order to remain eligible for employment.[24] These physical fitness standards provide the foundation from which the tactical athlete can modify their fitness to match the demands of the job.[17,18,25] The lack of data on WLFFs dictates that comparisons must be drawn from a similar population, and in the case of tactical athletes, military personnel are the most logical option. Both groups experience adverse terrain, packs loaded down with equipment, shift rotations with arduous work duty, and physical demands not seen in other professions.[2,3,17,18,21,25–28]

The difficulty in making these comparisons between groups is that the factors that make them similar are also what make them different. While both military personnel and WLFFs experience adverse terrain, the discrepancy is in the amount of time spent and jobs performed on that terrain. Although the operation style, crew types, and work shifts between these groups appear very similar in a broad sense, they actually vary a great deal upon closer examination.[17,18,25] This information is important to remember so that conclusions aren't drawn from military personnel and incorrectly applied to WLFFs.

**Military Injuries:**

Much like athletes preparing for competition, military personnel must build up and maintain a high level of fitness in preparation for training and missions.[29] Far and away, the most common injuries sustained by military personnel are musculoskeletal injuries.[26,28,30,31] The difficulty in collecting injury data throughout the military is the rate of underreporting, a point most attributable to the culture of all branches of the military.[30] To combat this lack of injury data, de la Motte et al[32] developed a screening tool to establish baseline normative values of functional movement patterns for new military recruits before they shipped out to basic training. They monitored the recruits for the duration of basic training in order to observe and record musculoskeletal injury outcomes and determine if certain injury-screening tools are capable of predicting injuries in a large cohort.[32] Utilizing a similar approach, one study found that 1-mile run times predicted both acute and overuse musculoskeletal injuries in soldiers of the US Army entering initial training.[33] This movement towards a more proactive approach in identifying potential risk factors that may lead to injuries in tactical athletes is arguably the most critical piece of the injury prevention puzzle.

Musculoskeletal injuries can occur across multiple environments in the military, yet most injuries occur as a result of physical training.[25,26,28–30] Almeida et al[34] reports that the injuries most commonly reported amongst military personnel are lower extremity sprains, particularly ankle sprains.[34] Range of motion at the ankle joint, especially dorsiflexion, is a reliable tool when looking at factors that contribute to the risk of injury.[35,36] When analyzing ankle dorsiflexion amongst Army recruits, Pope et al[36] found the risk of ankle injuries increased as range of motion decreased.[36] Conversely, Lovalekar et al[26] found that Naval Special Warfare Operators commonly reported upper extremity and shoulder injuries.[26] The discrepancies reported throughout the data, while frustrating, illustrate the impact that environment and training requirements have on the separate branches of the military, as well as different populations within each branch.[25,29,30]

While knowing the most common types of injuries military personnel sustain is important, understanding the mechanism of injury is another critical piece of the puzzle. When determining intrinsic factors related to injuries, Jones and Knapik[29] found that low cardio-respiratory endurance was the most documented risk factor amongst populations within the U.S. Army.[29] Extrinsic factors that have the potential to impact the risk of sustaining an injury across all demographics of military personnel include terrain, type of equipment, and type of training program.[19,28,29,31] Throughout the literature, physical training programs and equipment loads were cited as the predominant influences on injuries in the military.[17,27–29,37] Furthering this sentiment, Almeida et al[34] states that most injuries sustained are attributable to overexertion related to the amount of time spent on physical training, as well as the amount of equipment carried throughout the process of physical training.[34] The difficult aspect of physical training is that research shows it contributes to injuries, yet it is crucial for the success of the military. Understanding the nature of military personnel and their potential risk for injuries, comprehensive prevention strategies are necessary to address these risks and limit the amount of time lost due to these injuries.[29]

**Injury Prevention Programs:**

To combat the incidence of physical training injuries sustained by tactical athletes, multiple programs with varying strategies have been explored by the military, law enforcement, and structural firefighters.[17,18,25,27,29,38] The majority of the research revealed two approaches to injury prevention: injury screening tools[31,39–45] and PT program modifications.[17,25,27–30] Injury screening tools aim to address the individual, while physical training modifications address the program. These principles are not independent of one another, and when used in conjunction with each other, have produced positive results relating to injury reduction.[38,46,47] Although both of these approaches aim to reduce injuries, the means by which they attain these goals are incredibly different.

Tactical athletes work in environments that require dynamic and functional movement patterns.[48] The Functional Movement Screen (FMS) is a tool utilized in identifying an individual's potential risk of sustaining a musculoskeletal injury.[31,39] The FMS is graded on a scale of 0-21, and tests seven different movement patterns, including deep squat, hurdle step, in-line lunge, shoulder mobility, active straight leg raise, trunk stability push-up, and rotary stability.[40,49] Schneiders et al[50] found that participants in athletic populations who score less than 14 may be at an increased risk of sustaining a musculoskeletal injury.[50] Some studies have found that military personnel with FMS scores ≤14 are at an increased risk of injury when compared to similar participants with FMS scores ≥14.[31,44,46,47] It's important to note, however, that the developers of the Functional Movement Screen™ designed it as a screening tool, not a diagnostic assessment.[40,49] Even with these screening tools available, a well-documented injury history is still one of the best predictors when determining potential risk of injury.[17,28,31,32,40,51–55]

Given the job requirements of tactical athletes, a physical training program is unavoidable.[18,56] Many PT programs for tactical athletes are founded in aerobic principles, where the primary focus is building endurance through distance running.[18,27,29,57] This emphasis on distance running during physical training, combined with on-job physical activity, can lead to overtraining and increased injury rates.[17,27,28] Bell et al[58] found that as the physical demands of the occupation in the U.S. Army increased, the risk of injury increased as well.[58] Recent literature suggests implementing progressive overload strategies into physical training programs in order to mitigate the risk of injury due to overtraining.[17,19,27,28] This is achieved by manipulating the frequency, intensity, and type of training sessions, as well as the recovery periods, early on in the physical training process.[17,27,28]

Analysis of these injury prevention strategies reported mixed results in terms of the effectiveness of the program. Bullock et al[17] found six different strategies that should be implemented across all branches of the military to reduce injuries, with "preventing overtraining" identified as the most strongly recommended approach to reduce injuries.[17] Some researchers actually found that PT programs designed to improve fitness levels also helped to reduce injuries amongst study participants.[25,59] Although the research is varied in terms of results from injury prevention programs, there are indications that these programs may have a positive impact on both physical fitness and the rate of injuries. While much of the research into these injury prevention programs is rooted in the military, it's essential to understand that these findings are relevant and applicable to all tactical athletes, including law enforcement, structural firefighters, and WLFFs.

## **Organization and Personnel Associated with Wildland Fire**

Wildfire suppression is an incredibly complex process that, depending on fire size and location, may require the help of multiple agencies. These government agencies include the U.S. Forest Service, Bureau of Land Management, National Park Service, Bureau of Indian Affairs, and U.S. Fish and Wildlife Service.[60] While the roles and responsibilities of each agency differ, collectively, they each play a pivotal role in managing and suppressing wildfires across the United States. The Bureau of Land Management houses and maintains the largest aviation program within the Department of Interior, and is responsible for providing aircraft support for wildfire operations.[61] With roughly 400 permanent employees and 600 seasonal employees, the

National Park Service employs both Type I and Type II WLFFs across multiple crews, much like the U.S. Forest Service, but on a drastically smaller scale.[62,63] The Bureau of Indian Affairs states: “Our Mission is to execute our fiduciary trust responsibility by protecting lives, property, and resources while restoring and maintaining healthy ecosystems through cost-effective and creative fire-management programs, collaboration, and promoting Indian self-determination.”[64] For wildfires that threaten sovereign land and Native American Reservations, the Bureau of Indian Affairs, with more than 200 WLFFs, coordinates and consults with local tribes to assist in wildfire suppression and forestry management.[64,65] Of all of the agencies within the Department of Interior responsible for wildland firefighting, the U.S. Fish and Wildlife Service protects the most land management units at 150 million acres. Included within the Fish and Wildlife Service’s fire management teams are experts in the science and ecology of wildfires, range conservation, and smoke management.[66] Together, these federal agencies make up the National Wildfire Coordinating Group, a consortium of WLFF agencies that are responsible for standardizing safety and training protocols for all wildland firefighters.[8,67]

In order to coordinate and mobilize resources to combat and manage wildfires more efficiently, an interagency plan was designed and implemented to divide the United States into 10 geographic areas, known as Geographic Area Coordination Centers (GACC).[8,68] While beneficial in terms of divvying up resources and man power to areas of the United States that are heavily impacted by wildland fire season, the major challenge that these GACCs pose is that some regions span hundreds of miles across multiple states. This runs the potential of GACCs with large areas to cover being unable to respond as quickly as desired in urgent fire situations.[68]

**Wildland Firefighters:**

During the peak of fire season, WLFFs are deployed on work shifts called rolls, a shift rotation that can span 14 consecutive days, and work for as much as 24 hours a day during initial responses.[1,2,4,5,9,21,69,70] Found within *Type I* and *Type II* Crews are smaller crews with specific roles for wildland fire suppression, including Hand Crew, Fuels Crew, Engine Crew, Hotshot Crew, Helitack Crew, Smokejumpers, Wildland Fire Module and Prescribed Wildland Fire Crews.[2–4,7,71] Although all of these crews contribute to wildland fire suppression efforts, their roles within the process can differ greatly, from preventative actions like line digging, chainsaw work and prescribed burns to clearing debris and mop-up of areas previously burned by fire.[7,8,10] Hand Crews are used for multiple operations on wildland fires, consisting primarily of fireline construction with hand tools and chainsaws and mop-up duty of previously burned areas.[8,10,60,71] The primary responsibility of Fuels Crews is to manage the risk of wildfires through thinning and felling of timber with chainsaws, reducing fuels through prescribed fires, monitoring prescribed burns, and even fire suppression.[8,60] Engine Crews are often present for the initial attack of fires, as well as project work. This project work is accomplished through the use of specialized equipment, and includes laying hose, line digging, mopping up hotspots, and mobile attack with the fire engines.[8,10,60] One of the more comprehensively trained WLFF crew is Hotshot Crews. While their roles vary depending on the mission, their primary duties are similar to that of Hand Crews, but with more extensive specialty training and greater physical fitness demands. Hotshot Crews are tasked with navigating difficult terrain while suppressing the most severe wildfires, and will travel anywhere in the country where they are needed.[8,60,72,73] Fighting fires from the sky, Helitack Crews are transported on-site by helicopter for initial attack, with some crewmembers even trained to rappel from the helicopter, and suppress wildfires through the use of hand tools and chainsaws.[8,60] Arguably the most experienced and highly trained crew type, Smokejumpers are WLFFs who provide rapid response to new and ongoing fires by parachuting out of airplanes to reach the most remote wildfires. Once on site, Smokejumpers begin wildfire suppression through initial attack efforts and fuels reduction, when necessary, to minimize the risk of wildfire growth. Along with Hotshot Crews, Smokejumpers are incredibly self-sufficient and are capable of fighting wildfires for extended periods of time with minimal resources and support.[2,8,60,63,67,72]

With some background information into the tasks and responsibilities associated with each crew type, the next critical piece of information is to understand the physical demand that each of these tasks places on the body. Budd et al[74] noted that during wildfire suppression, WLFFs expend approximately 7.5 kcal/min while performing common tasks like hiking, brush removal, and line digging.[69,75] To break this information down further, line digging at a normal pace would expend 9.4 kcal/min, while urgent line digging, as seen in initial attacks, expends 14.4 kcal/min. Chainsaw work results in 5.0 kcal/min expended, brush removal at 6.4 kcal/min, and walking at 6.6 kcal/min.[74–77] Although this information is incredibly beneficial in understanding the physical toll associated with WLFF suppression efforts, Ruby et al[69] note that calculating energy expenditure in this manner does not factor in the periods of rest that WLFFs commonly take throughout these bouts of arduous work.[69]

Understanding these job demands and environmental factors surrounding WLFFs and how they contribute to the varying injuries seen throughout the wildland fire community provide a solid foundation for designing and implementing a job-specific injury prevention program.

**WLFF Injuries:**

At the peak of wildland fire season, there are roughly 20,000 WLFFs employed by the USFS.[1,10] However, there are thousands more WLFFs employed by other federal agencies, as well at the state level, local Volunteer Fire Departments and privately contracted organizations. The population of WLFFs ranges in age from 18-65+, made up primarily of males at a ratio of roughly 9:1.[2,4,9,70] There are eight different crew types[10] spread out across ten Geographic Area Coordinating Centers.[71] Although limited, previous research indicates that the demographic at the greatest risk for injury are male WLFFs between the ages of 25-45 assigned to a Type II Crew while working out on the fireline.[4,5,9,78]

The impact that environmental factors play into injury rates is difficult to analyze, yet still provides a critical piece of information in the scheme of WLFF injuries. The mechanism of injury most commonly reported amongst WLFFs is attributed to slips, trips, and falls, resulting in joint sprains and muscle strains.[4,5,9,78] Due to the limited amount of data, discrepancies exist across the WLFF injury studies. Britton et al[5] reports injury rates as high as 70% in the lower extremity, while Mangan[4] reports injury rates closer to 50% in the lower extremity. These studies give a wide variation amongst common variables over a relatively small sample size, making conclusions difficult to surmise. However, both studies reveal that a majority of injuries sustained by WLFFs occur in the lower extremity, with three specific areas affected: the ankles, knees, and low back.[4,5]

With the knowledge of which demographic of WLFFs is at the greatest risk of injury, coupled with the areas of the body most commonly injured and the mechanism of injury, the starting point for a modified physical training program is much more apparent. It is estimated that the USFS spends more than $35,000,000 annually on lost wages and medical care as a result of WLFF injuries.[79] Exertional illnesses, whether due to heat or fatigue, can put WLFFs and their crew in jeopardy if not recognized and treated immediately.

One of the more serious conditions WLFFs face as a result of overexertion, especially early in the fire season, is rhabdomyolysis.[80] Rhabdomyolysis is defined as the rapid destruction of skeletal muscle tissue due to exertion or trauma, resulting in the release of intracellular contents, such as myoglobin and potassium, into the blood stream.[19,80–82] While the effects of rhabdomyolysis may be felt throughout the body, the primary area of concern is the kidneys, where acute renal failure can occur rapidly if left untreated.[80,81] One report[80] found that of the nineteen cases of rhabdomyolysis reported by WLFFs, eleven occurred during some form of physical training.  Budd et al[75] found that of the heat stress experienced by WLFFs, 70% is attributable to metabolic heat as a byproduct of muscle contractions, while 30% is due to environment, which includes the climate and the environment of the fire.[75] To help mitigate the potential for early-season cases of rhabdomyolysis and heat stress, researchers[55,80,83] suggest an acclimatization period at the beginning of the fire season, followed by a gradual transition into strenuous activity and exercise that incorporates the appropriate work/rest cycle necessary during WLFF physical training.

Given the battery of risks associated with wildland firefighting, the threat of a fatal injury is always present.  Mangan[70] reported that between 1990-2009, a total of 359 WLFFs suffered a fatal injury on the job, with the four leading causes listed as aviation accidents, vehicle accidents, heart attacks/medical causes, and burnovers.[70] Unfortunately, there is not a program available capable of preventing these fatal injuries.  However, the benefits of a PT program designed specifically with WLFFs in mind creates the opportunity to decrease injuries throughout the

WLFF community, decrease the amount of time lost due to injury, as well as to decrease the amount of money spent on medical care for injured WLFFs.

**WLFF Injury Reporting:**

Combating and suppressing wildland fires is a massive undertaking. To ensure these suppression efforts are swift and effective, WLFFs have emerged across multiple agencies at the federal, state, tribal, and local levels.[84] Similar to wildfire suppression, the task of collecting injury data from these agencies is a difficult task spread out across multiple groups, including the National Institute for Occupational Safety and Health, United States Fire Administration, Census of Fatal Occupational Injuries, Department of Interior Safety Management Information System, National Fire Protection Association, and the US Bureau of Labor Statistics.[67,78,84] Unfortunately, not all of these groups delineate between WLFFs and structure firefighters, and if they do, they only report on fatal injuries. While research has been published on WLFF injuries, many of these studies focus on respiratory conditions due to environmental exposure[85,86] or variations in energy expenditure.[69,73] This leaves very few agencies reporting non-fatal WLFF injuries, and for the few that do report these injuries, there exists a noticeable difference in the definition of injuries and how those injuries are categorized and reported.[67,84] In order to take the next step towards implementing job-specific injury prevention strategies, an overhaul of the injury reporting systems in place is essential to ensure that the data from WLFF injuries is reported accurately and consistently across all agencies responsible for wildland firefighting.

**Injury Prevention Strategies:**

The unfortunate result of the arduous work environment WLFFs experience is the type of injuries they sustain and the rate at which they sustain them. The varying nature of injuries and the associated risk factors make injury prevention an incredibly complex process to undertake.[87] As it relates to WLFF, Moody et al[3] found three major themes listed by WLFFs for injury prevention strategies: environmental factors, personal characteristics, and physical training. Interventions relating to environmental factors are impossible given the nature of the job, and personal characteristics interventions would not be practical given the sheer volume of WLFFs. This leaves physical training, the piece of injury prevention that is oftentimes overlooked throughout the WLFF community.[3,4,17]

When developing an injury prevention strategy, it's difficult to encompass all of the athletes within the population. WLFFs are incredibly diverse, with multiple crew types and vastly varying fitness levels.[3–5] It appears that the two largest disparities amongst WLFFs manifests in age and fitness levels.[3–5,21] With this in mind, the injury prevention strategy must be broad enough to encapsulate as many WLFFs as possible, yet specific enough that the majority of participants see an objective decline in the rate of injuries sustained during PT and out on the fireline.

The need for physical training modification for WLFFs is abundantly clear, but the direction of this modification is not nearly as apparent. The appropriate progression in this process is to continue collecting and analyzing data to ensure that the PT program stays aligned and consistent in addressing the injuries reported by WLFFs. One of the more obvious approaches to modifying physical training is to move towards more job-specific, functional movement exercises.[38,40,42,56] The benefit of these exercises is that they incorporate movement patterns that work through a functional range of motion consistent with movement patterns seen in a work environment similar to WLFFs. By focusing on the muscle groups most commonly used in WLFF, functional movement exercises can be implemented across all crew types, which captures the specificity WLFFs want while still encompassing the population as a whole. The implementation of job-specific, functional movement exercises is a simple fix for a growing problem throughout the WLFF community.

Although it may seem bleak, the future is bright for WLFF injury prevention. The process of collecting and analyzing data on WLFFs cannot begin without a detailed layout of the necessary steps to achieve an injury prevention program. Using injury data and prevention strategies published on behalf of tactical athletes, the next step is to collect and analyze data specific to WLFFs in order to design the most effective, job-focused injury prevention program.

## Chapter 3

## Methods

### Overview:

Survey questionnaires continue to prove their merit as a viable research tool.[16] This style of data collection gives the researcher the opportunity to view the responses at a fixed point in time, allowing the investigator to note any differences between subjects, and determine if those differences may impact the study's outcome measures.[16,88] Although there are disadvantages with survey questionnaires, their effects can be lessened by paying close attention to the validity and reliability of the survey.[16] This is accomplished through a six step plan of action, which begins with developing a research question, investigating existing literature, clarifying and refocusing the research question, establishing the validity of the survey, determining the appropriate sample, and finishes with acquiring and analyzing the data.[16] As is consistent with all other types of research, it is paramount to understand the reasoning behind the data collection; successful research must always have a purpose.[16]

### Population Size/Characteristics

The current population size for WLFFs is difficult to calculate. The seasonal nature of the job dictates the amount of active crewmembers employed by the U.S. Forest Service. As recently as 2015, of the roughly 30,000 employees of the U.S. Forest Service, there are more than 12,000 permanent year-round WLFFs[1] and around 8,400 seasonal WLFFs hired for peak fire season.[10] The U.S. Forest Service is divided into ten regions, known as Geographic Area Coordination Center's, containing WLFFs across eight different crew types.[10,71]

**Selection-Eligibility Characteristics**

Characteristics for selection-eligibility required that each participant was a permanent or seasonal employee of the USFS and served as a WLFF within the last five years. Participants needed to be at least 18 years old, and must have suffered at least one injury while assigned to an incident or during PT in order to remain eligible for this study.

**Sampling Scheme/Size/Characteristics**

In order to obtain the greatest number of survey responses, a snowball-sampling scheme was utilized.[89] The crew leaders and WLFFs were encouraged to forward the survey link to other WLFFs, ultimately spreading the impact of this survey across a variety of crews and regions and increasing the amount of data necessary to further this research effort. Although this sampling style makes it difficult to obtain a truly random sample of the population, allowing the subjects to dictate the extent to which this survey reached offered them the chance to participate in a study that will benefit the future health and wellbeing of WLFFs for years to come.

**Quantitative Instruments:**

A self-administered online questionnaire was designed and distributed to capture injury data amongst WLFFs (see Appendix A). The survey is titled *Injury Surveillance of Wildland Firefighters*, and consists of 20 open and closed ended questions. The questions were adapted and developed from previous research.[3–5,21] The survey was designed to capture accurate injury data amongst WLFFs to better understand the types of injuries sustained during PT and while out on the fireline. This information will help lay the groundwork to develop research-backed PT programs and injury prevention strategies for the benefit of all WLFFs.

The first block of the survey contains 5 questions that ask the participants basic social and job-specific demographic questions. The next block of the survey contains 12 questions that ask the participants to narrow down the timeframe of their injury, environmental factors surrounding the injury, and mechanism of injury. The final block of the survey contains 3 questions that ask the participants to address what level of treatment they sought after the injury, time lost due to the injury, and whether or not they felt the injury could have been prevented with better physical training.

**Developers/Administrators/Administration of Instrument**

Utilizing previous research[3–5,21] related to injuries sustained by WLFFs, the researchers developed a survey through *Qualtrics*, an online data collection platform. Before distributing the survey, twelve panelists, consisting of WLFFs, academic faculty, and athletic trainers, reviewed the survey to provide feedback regarding clarity, readability, and completion time. Through an anonymous online link, *Qualtrics* administered the survey and recorded the participants' responses.

**Development Procedures for Injury Surveillance of WLFFs**

Designing a research project, particularly a survey, is a difficult task. The challenge is figuring out how to phrase questions so that the greatest amount of data is captured, yet allows the researchers to quantitatively analyze their results. It is critical, then, to develop an outline with specific topic areas that each question from the survey falls under.[16] This survey consists of three specific topic areas: WLFF demographic information, types of injuries sustained, and the potential influence environmental factors play on the injuries sustained. With these three topic areas identified, the wording of the survey questions was manipulated to ensure that they fell within one of the three topic areas.

When writing survey questions, it's important to make sure that the style of question, open-ended or close-ended, is consistent with the needs of the research design. Open-ended questions allow the respondent to answer as they deem fit, whereas close-ended questions allow the researcher to limit the responses to the answers that they deem fit.[16] This survey is comprised primarily of close-ended questions, which is consistent with quantitative analysis. However, within this survey, there are some close-ended questions that allow for open-ended responses to further explain details that may not fall under the given answer choices. The benefit of this style of questioning is that it allows the researcher to gather the data the survey is intended to collect, while allowing the respondent to give context to their answer, something that the researcher would not otherwise be able to extrapolate from a close-ended question.[12,13,16]

## Validation Procedures for Injury Surveillance of WLFFs

Throughout the development of the study, the point of emphasis was that the survey questions fall under the topic areas consistent with the main outcome measures of the study. The validity of a survey makes certain that the instrument is measuring what it is designed to measure.[13,16] Validation of an instrument demonstrates that the survey accurately measures what it is intended to measure, and does so for a given population.[16,90] Validating a survey is determined in four assessments: face validity, content validity, construct validity, and criterion-related validity.[16]

To establish the face validity and content validity of the survey, past and present WLFFs, as well as university researchers with extensive experience collecting data on WLFFs, convened to discuss the content, goals, and outcome measures of the survey. This collaboration made certain that the survey was user friendly and measured exactly what it was intended to measure.[16,90,91]

In order to interpret the data from the survey and objectively apply the results to a specific group or criterion, criterion-related validity must be established. There are two categories of criterion-related validity: concurrent validity and predictive validity.[16] When measuring the same outcomes, concurrent validity establishes that researchers may accurately replace previously exhaustive processes with a more efficient instrument.[16,91] Predictive validity differs in that it provides the necessary rationale when utilizing a measurement to predict a future outcome.[16] Both are essential for establishing criterion-related validity.

## Quantitative Procedures

### Ethical Nature of Data Collection

The use of an anonymous online survey, where participants were free to decline answering a question or decline the survey altogether, posed no ethical dilemma that would delegitimize any of the data collected within the parameters of this survey. The proposal application for the University of Montana IRB was approved, and later amended, to accommodate for survey modifications that opened the survey up to all WLFFs and allowed injury data from the last five years.

### Time Line for Data Collection

Survey availability period lasted two months, opening on September 13, 2016 and closing on November 13, 2016, a total of 61 days.

**Research Paradigm**

Before data collection can begin, researchers must determine why they are addressing a topic and the style in which they want to approach the study. This is a research paradigm, which is defined as, "the set of common beliefs and agreements shared between scientists about how problems should be understood and addressed."[92] Research paradigms provide a foundation when deciding what to study, what questions provide meaningful answers, how those questions should be structured, how to conduct an experiment, and how to interpret the results of a research study.[93] This research project utilized a *positivism paradigm*, meaning the sole goal of the researchers was to obtain unreserved, objective knowledge of WLFF injuries from an impartial point of view. This *positivism* approach is consistent with quantitative analysis research, where objective data is analyzed with the hopes of predicting future outcome measures.[93,94]

**Research Design (with justification)**

This study was designed as a cross-sectional, web-based survey. Cross-sectional research measures these outcomes at a fixed point in time, allowing the researcher to examine differences amongst subjects, and determine if those differences may have a potential impact on any of the study's outcome measures.[88] This research design is primarily used when attempting to identify the prevalence of a measurable outcome across a given population.[88,95] Researchers may also find cross-sectional research designs beneficial when planning, monitoring, and evaluating the public's health.[95,96] Unfortunately, there is one considerable limitation with cross-sectional studies, which is that the single-measurement approach makes it difficult to extrapolate a causal relationship between subject variability and outcome measures.[88,95,96]

**Data Analysis**

Quantitative data from the questionnaire was analyzed using Microsoft Excel to determine WLFFs demographics, types of injuries sustained and environmental factors potential influence on injuries sustained. Thematic analysis was conducted on the open-ended questions where WLFFs could offer further explanation to a closed ended question.

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**Appendix A**

# WILDLAND FIREFIGHTER INJURY SURVEILLANCE SURVEY

***Purpose****: We need your help understanding the types of injuries wildland firefighters sustain during the season. Please complete the following survey for each injury you sustain during the wildland fire season. We are working with the Missoula Technology Development Center-USFS, to use this information to develop an injury prevention program that is based on the best science available.*

***Instructions****: Your participation is voluntary. Please do not put your name anywhere on the survey. All responses are strictly anonymous.*

***When prompted, list the number of injuries sustained over the past five seasons and answer the questions about your injury accordingly.***

**1.** Age:
- ☐ 18-24
- ☐ 25-34
- ☐ 35-44
- ☐ 45-54
- ☐ 55-64
- ☐ Over 64

**2.** Gender:
- ☐ Male
- ☐ Female
- ☐ Other (specify)________________________________________________

**3.** Crew Type:
- ☐ Hand Crew
- ☐ Fuels Crew
- ☐ Engine Crew
- ☐ Hotshot Crew
- ☐ Helitack Crew
- ☐ Smokejumper
- ☐ Prescribed Wildland Fire Crew
- ☐ Wildland Fire Module

**4.** Employment
- ☐ Permanent Year-round
- ☐ Permanent Seasonal
- ☐ Seasonal
- ☐ Other (specify)________________________________________________

**5.** Over the past five fire seasons, how many injuries have you sustained?
- ☐ 0
- ☐ 1
- ☐ 2+

**6.** For your first injury to report, what Geographic Area Coordination Center (GACC) were you assigned to when injured?

- ☐ Alaska (AICC)
- ☐ Eastern Area (EACC)
- ☐ Great Basin (GBCC)
- ☐ Northern California (ONCC)
- ☐ Northern Rockies (NRCC)
- ☐ Northwest (NWCC)
- ☐ Rocky Mountain (RMCC)
- ☐ Southern Area (SACC)
- ☐ Southern California (OSCC)
- ☐ Southwest (SWCC)

**The following questions will help us better understand the type of injury/illness you sustained:**

**7.** At the time of this injury, was it a new or recurring injury/illness?

- ☐ New (this season)
- ☐ Recurring (this season)
- ☐ Recurring (previous season)

**8.** During which month did the injury/illness occur?

- ☐ January
- ☐ February
- ☐ March
- ☐ April
- ☐ May
- ☐ June
- ☐ July
- ☐ August
- ☐ September
- ☐ October
- ☐ November
- ☐ December

**9.** What time of day did the injury/illness occur?

- ☐ 1:00
- ☐ 2:00
- ☐ 3:00
- ☐ 4:00
- ☐ 5:00
- ☐ 6:00
- ☐ 7:00
- ☐ 8:00
- ☐ 9:00
- ☐ 10:00
- ☐ 11:00
- ☐ 12:00
- ☐ 13:00
- ☐ 14:00
- ☐ 15:00
- ☐ 16:00
- ☐ 17:00
- ☐ 18:00
- ☐ 19:00
- ☐ 20:00
- ☐ 21:00
- ☐ 22:00
- ☐ 23:00
- ☐ 24:00

**10.** During which activity did the injury/illness occur?

- ☐ Physical Training
- ☐ Regular duty day, but not Physical Training
- ☐ Assigned to an Incident
- ☐ Not during regular duty
- ☐ Other (specify)___________________________

**11.** If the injury/illness occurred while on an incident, where did the injury/illness occur?

- ☐ Fireline
- ☐ In Camp
- ☐ Not applicable
- ☐ Other (specify) __________________________

**12.** If the injury/illness occurred while on an incident, how many consecutive days had you worked before the injury/illness occurred?

- ☐ 1 day
- ☐ 2 days
- ☐ 3 days
- ☐ 4 days
- ☐ 5 days
- ☐ 6 days
- ☐ 7 days
- ☐ 8 days
- ☐ 9 days
- ☐ 10 days
- ☐ 11 days
- ☐ 12 days
- ☐ 13 days
- ☐ 14 days

**13.** On the day the injury/illness occurred, how many consecutive hours had you worked before the injury/illness happened?

- ☐ 0-3 hours
- ☐ 4-6 hours
- ☐ 7-10 hours
- ☐ 11-14 hours

**14.** If the injury/illness occurred while on an incident, which of the following types of terrain best describes where the injury/illness occurred?

- ☐ Flat, open grassland
- ☐ Rising hill
- ☐ Rocky mountainside
- ☐ Heavily wooded area
- ☐ Other (specify)___________________________________________

**15.** Type of injury/illness sustained?

- ☐ Contusion (bruise)
- ☐ Joint sprain (stretch or tear of ligament)
- ☐ Muscle strain (stretch or tear of muscle)
- ☐ Fracture (broken bone)/Dislocation (joint out of place)
- ☐ Tendonitis
- ☐ Nerve trauma
- ☐ Cut/Abrasion
- ☐ Bite/Sting
- ☐ Muscle cramp/spasm
- ☐ Burn
- ☐ Blister
- ☐ Heat Illness
- ☐ Respiratory Illness
- ☐ Stomach illness
- ☐ Other (specify)________________________________________

**16.** Location of injury/illness sustained?

- ☐ Head/Face
- ☐ Neck
- ☐ Chest
- ☐ Back
- ☐ Shoulder/Arm
- ☐ Elbow/Forearm
- ☐ Wrist
- ☐ Hand/Fingers
- ☐ Abdomen
- ☐ Hip/Thigh
- ☐ Knee
- ☐ Lower Leg/Ankle
- ☐ Foot/Toes
- ☐ Other (specify)______________

**17.** Which of the following best describes how the injury/illness occurred?

- ☐ Slip/Trip/Fall
- ☐ Equipment/Tool/Machinery
- ☐ Struck by/against an object
- ☐ Motor Vehicle/Transport
- ☐ Weather/Environmental
- ☐ Bite/Sting/Poison
- ☐ Fire/Smoke/Flash burn
- ☐ Overexertion
- ☐ Other (specify)____________________

**The following questions will help us understand how your injury/illness was treated and time lost working due to the injury/illness.**

**18.** What was the highest level of treatment sought immediately after the injury/illness occurred?

- ☐ Self-treated
- ☐ Required medical assistance in camp
- ☐ Required transport to a medical facility (emergent)
- ☐ Referral out to a medical provider for further evaluation (non-emergent)
- ☐ Other (specify) _______________________

**19.** How much time was lost working due to the injury/illness?

- ☐ None- I was able to keep working with no restrictions
- ☐ None- I was able to keep working with modified duties
- ☐ Did not work the rest of the day
- ☐ 1 day
- ☐ 2 days
- ☐ 3 days
- ☐ 4 days
- ☐ 5 days
- ☐ 6 days
- ☐ 1 week
- ☐ 2 weeks
- ☐ 3 weeks
- ☐ 1 month
- ☐ 2 months
- ☐ 3 months
- ☐ 4-6 months
- ☐ 7-12 months
- ☐ Season ending
- ☐ Other (specify) ___________________________________

**20.** Do you think the injury/illness could have been prevented with better physical fitness?

- ☐ Yes
- ☐ No
- ☐ If yes, specify how _______________________________________

**21.** For your second injury to report, what Geographic Area Coordination Center (GACC) were you assigned to when injured?

- ☐ Alaska (AICC)
- ☐ Eastern Area (EACC)
- ☐ Great Basin (GBCC)
- ☐ Northern California (ONCC)
- ☐ Northern Rockies (NRCC)
- ☐ Northwest (NWCC)
- ☐ Rocky Mountain (RMCC)
- ☐ Southern Area (SACC)
- ☐ Southern California (OSCC)
- ☐ Southwest (SWCC)

**The following questions will help us better understand the type of injury/illness you sustained:**

**22.** At the time of this injury, was it a new or recurring injury/illness?

- ☐ New (this season)
- ☐ Recurring (this season)
- ☐ Recurring (previous season)

**23.** During which month did the injury/illness occur?

| | | |
|---|---|---|
| ☐ January | ☐ May | ☐ September |
| ☐ February | ☐ June | ☐ October |
| ☐ March | ☐ July | ☐ November |
| ☐ April | ☐ August | ☐ December |

**24.** What time of day did the injury/illness occur?

| | | |
|---|---|---|
| ☐ 1:00 | ☐ 9:00 | ☐ 17:00 |
| ☐ 2:00 | ☐ 10:00 | ☐ 18:00 |
| ☐ 3:00 | ☐ 11:00 | ☐ 19:00 |
| ☐ 4:00 | ☐ 12:00 | ☐ 20:00 |
| ☐ 5:00 | ☐ 13:00 | ☐ 21:00 |
| ☐ 6:00 | ☐ 14:00 | ☐ 22:00 |
| ☐ 7:00 | ☐ 15:00 | ☐ 23:00 |
| ☐ 8:00 | ☐ 16:00 | ☐ 24:00 |

**25.** During which activity did the injury/illness occur?

- ☐ Physical Training
- ☐ Regular duty day, but not Physical Training
- ☐ Assigned to an Incident
- ☐ Not during regular duty
- ☐ Other (specify)___________________________

**26.** If the injury/illness occurred while on an incident, where did the injury/illness occur?

- ☐ Fireline
- ☐ In Camp
- ☐ Not applicable
- ☐ Other (specify) __________________________

**27.** If the injury/illness occurred while on an incident, how many consecutive days had you worked before the injury/illness occurred?

- ☐ 1 day
- ☐ 2 days
- ☐ 3 days
- ☐ 4 days
- ☐ 5 days
- ☐ 6 days
- ☐ 7 days
- ☐ 8 days
- ☐ 9 days
- ☐ 10 days
- ☐ 11 days
- ☐ 12 days
- ☐ 13 days
- ☐ 14 days

**28.** On the day the injury/illness occurred, how many consecutive hours had you worked before the injury/illness happened?

- ☐ 0-3 hours
- ☐ 4-6 hours
- ☐ 7-10 hours
- ☐ 11-14 hours

**29.** If the injury/illness occurred while on an incident, which of the following types of terrain best describes where the injury/illness occurred?

- ☐ Flat, open grassland
- ☐ Rising hill
- ☐ Rocky mountainside
- ☐ Heavily wooded area
- ☐ Other (specify)______________________________________

**30.** Type of injury/illness sustained?

- ☐ Contusion (bruise)
- ☐ Joint sprain (stretch or tear of ligament)
- ☐ Muscle strain (stretch or tear of muscle)
- ☐ Fracture (broken bone)/Dislocation (joint out of place)
- ☐ Tendonitis
- ☐ Nerve trauma
- ☐ Cut/Abrasion
- ☐ Bite/Sting
- ☐ Muscle cramp/spasm
- ☐ Burn
- ☐ Blister
- ☐ Heat Illness
- ☐ Respiratory Illness
- ☐ Stomach illness
- ☐ Other (specify)___________________________________

**31.** Location of injury/illness sustained?

- ☐ Head/Face
- ☐ Neck
- ☐ Chest
- ☐ Back
- ☐ Shoulder/Arm
- ☐ Elbow/Forearm
- ☐ Wrist
- ☐ Hand/Fingers
- ☐ Abdomen
- ☐ Hip/Thigh
- ☐ Knee
- ☐ Lower Leg/Ankle
- ☐ Foot/Toes
- ☐ Other (specify)____________

**32.** Which of the following best describes how the injury/illness occurred?

- ☐ Slip/Trip/Fall
- ☐ Equipment/Tool/Machinery
- ☐ Struck by/against an object
- ☐ Motor Vehicle/Transport
- ☐ Weather/Environmental
- ☐ Bite/Sting/Poison
- ☐ Fire/Smoke/Flash burn
- ☐ Overexertion
- ☐ Other (specify)____________________

**The following questions will help us understand how your injury/illness was treated and time lost working due to the injury/illness.**

**33.** What was the highest level of treatment sought immediately after the injury/illness occurred?

- ☐ Self-treated
- ☐ Required medical assistance in camp
- ☐ Required transport to a medical facility (emergent)
- ☐ Referral out to a medical provider for further evaluation (non-emergent)
- ☐ Other (specify) _______________________

**34.** How much time was lost working due to the injury/illness?

- ☐ None- I was able to keep working with no restrictions
- ☐ None- I was able to keep working with modified duties
- ☐ Did not work the rest of the day
- ☐ 1 day
- ☐ 2 days
- ☐ 3 days
- ☐ 4 days
- ☐ 5 days
- ☐ 6 days
- ☐ 1 week
- ☐ 2 weeks
- ☐ 3 weeks
- ☐ 1 month
- ☐ 2 months
- ☐ 3 months
- ☐ 4-6 months
- ☐ 7-12 months
- ☐ Season ending
- ☐ Other (specify) ___________________________________

**35.** Do you think the injury/illness could have been prevented with better physical fitness?

- ☐ Yes
- ☐ No
- ☐ If yes, specify how _______________________________________

**36.** If you have suffered more than two injuries, please list the number of additional injuries sustained. Please describe the nature of the injury in a similar format to the previous questions, being sure to include the part of the body that was injured, as well as how it was injured.

**Thank you for your participation and feedback.**
**This information will be analyzed for the benefit of all wildland firefighters.**

**Chapter 4**

**Manuscript**

**Title:** Descriptive Analysis of Injuries Sustained by Wildland Firefighters

**Short Title:** Injuries Among Wildland Firefighters

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**Objective:** To develop a better understanding of the types of injuries Wildland Firefighters (WLFFs) sustain during Physical Training (PT) and while out on the fire line, and if there are any discernible trends or patterns that can be addressed through the implementation of a more focused PT program.
**Methods:** This study is a web-based cross-sectional questionnaire titled *Injury Surveillance of Wildland Firefighters* (ISWLFF). We utilized a snowball sampling technique to reach seasonal and fulltime WLFFs of the US Forest Service. 360 WLFFs responded to the questionnaire, but were not required to answer every question. While 112 of the respondents did not report an injury in the past 5 years, 248 WLFFs did. Of the 248 participants whose injury data was utilized, there were 218 males, 29 females and 1 identified as other. Quantitative data from the questionnaire was analyzed using Microsoft Excel to determine WLFFs demographics, types of injuries sustained and the potential influence environmental factors have on injuries sustained. Thematic analysis was conducted on open-ended questions where WLFFs could offer further explanation to a closed ended question.
**Results**: Most WLFFs (n=248) sustained at least one injury in the past 5 fire seasons with 91% (n=226) of those injuries occurring on the fireline on rocky mountainside terrain. Nearly half (n=209) of the injuries reported were sprains and strains occurring to the lower back, knee and ankle. 76% of injuries reported by WLFFs (n=343/453) directly impacted their ability to continue with normal duty.
**Conclusions**: Most of the injuries reported by WLFFs were to the lower extremity and occurred while working on the fireline. Therefore, a more targeted, job-specific injury prevention program that focuses on the lower extremity should be considered.

*Key words:* fireline, injury, wildland firefighter, physical training, wildfire

## Introduction

As the number and severity of wildfires increases every year, more is asked of today's Wildland Firefighters (WLFFs) than ever before.[1] The United States averages roughly 80,000 wildland fires each year, burning upwards of 6.5 million acres of federal, state, and private land.[2,3] Suppression of these fires falls across multiple agencies and crew types, where the severity of the wildland fire season dictates the amount of time spent on a given job. This dynamic work environment, paired with the arduous nature of wildland fire suppression, places today's WLFFs at an increased risk of sustaining an injury while on the job.[4] Whether assigned to an incident or during physical training (PT), the time lost from these injuries and the subsequent financial burden incurred by these federal agencies demonstrates the need to optimize physical performance through the implementation of WLFF-specific injury prevention strategies.[2,5,6]

In order to address the most prominent threats to the safety of all WLFFs during PT and out on the fireline, members of the WLFF community are invested in developing a better understanding of the types of injuries sustained and how to minimize the risk of injury through job-specific injury prevention strategies.[5] In the interest of identifying and preventing these injuries, it is imperative to develop a more comprehensive understanding of the environmental factors leading up to the injury, the physical demands of the job, the types of injuries WLFFs sustain, and the mechanism of those injuries. This comprehensive approach to understanding the nature of these injuries hinges on identifying environmental factors surrounding the injury incident, which includes terrain, equipment availability and duration of work shifts, and determining how these factors may contribute to the increased risk of injury seen throughout the WLFF community.[5]

Unfortunately, due to the limited amount of injury data, discrepancies exist across the WLFF injury studies largely because of reporting issues. Very few agencies report non-fatal WLFF injuries, and for the few that do report these injuries, there exists a noticeable difference in the definition of injuries and how those injuries are categorized and reported.[7,8] However, previous research is consistent in noting that the most common mechanism of injury reported amongst WLFFs is attributed to slips, trips, and falls, resulting in joint sprains and muscle strains of the low-back, knees and ankles.[2,9–11] To address these injuries, it is imperative to understand all of the environmental factors surrounding the injury and determine what role they may have in contributing to the incidence of injury. Therefore, the aim of this study is to identify the types of injuries WLFFs sustain on the job, the environmental factors leading up to the injury, and how best to address these areas of concern. With a solid understanding of injuries sustained and how they pertain to WLFFs, the next logical step in addressing these injuries is through simple injury prevention strategies or through the implementation of a more job-specific PT program.

**Methods**

STUDY DESIGN

This study was designed as a cross-sectional, web-based questionnaire that utilized a mixed-methods approach. The self-administered questionnaire is titled *Injury Surveillance of Wildland Firefighters* (ISWLFF), and consists of 20 open and closed ended questions. Quantitative data from ISWLFF was analyzed using Microsoft Excel to determine WLFFs demographics, types of injuries sustained and environmental factors potential influence on injuries sustained. Thematic analysis was conducted on the open-ended questions where WLFFs could offer further explanation to a closed ended question.

SUBJECTS

Characteristics for selection-eligibility required that each participant was at least 18 years old, a permanent or seasonal employee of the United States Forest Service (USFS) and served as a WLFF within the last five years. A total of 360 participants responded to the questionnaire, but were not required to answer every question. Of the 248 respondents who reported at least one injury, 218 were males, 29 were females and 1 identified as other, reporting a total of 453 injuries sustained over the previous five years. These participants represented all eight WLFF crew types (Hand, Fuels, Engine, Hotshot, Helitack, Smokejumper, Prescribed Wildland Fire, Wildland Fire Module) and spanned across all ten Geographic Area Coordinating Center's (Alaska, Eastern Area, Great Basin, Northern California, Northern Rockies, Northwest, Rocky Mountain, Southern Area, Southern California, Southwest). Demographic descriptors included: age, gender, crew type, and employment status (Table 1).

**Table 1** Demographic characteristics of Wildland Firefighters

| **Gender** | | **Age** | | **Crew Type** | | **Employment** | |
|---|---|---|---|---|---|---|---|
| Male | 87.4% | 18-24 | 3.7% | Hand | 13% | Permanent Year-round | 67% |
| Female | 11.9% | 25-34 | 30.2% | Fuels | 2% | Permanent Seasonal | 19% |
| Other | 0.7% | 35-44 | 40.3% | Engine | 58% | Seasonal | 12% |
| **Total** | **285** | 45-54 | 20.5% | Hotshot | 9% | Other | 2% |
| | | 55-64 | 4.9% | Helitack | 9% | **Total** | **284** |
| | | Over 64 | 0.4% | Smokejumper | 5% | | |
| | | **Total** | **268** | Prescribed WLF | 1% | | |
| | | | | WLF Module | 3% | | |
| | | | | **Total** | **256** | | |

STUDY DATA

Utilizing previous research[2,5,9,12] related to injuries sustained by WLFFs, we developed ISWLFF through *Qualtrics*, an online data collection platform. ISWLFF was designed to capture accurate injury data amongst WLFFs to better understand the types of injuries sustained during PT and while out on the fireline. To establish and ensure the validity of ISWLFF, past and present WLFFs, as well as university researchers with extensive experience collecting data on WLFFs, convened to discuss the content, goals, and outcome measures of ISWLFF, as well as provide feedback regarding clarity, readability, and completion time. Through an anonymous online link, *Qualtrics* delivered the self-administered questionnaire and recorded the participants' responses.

Participants were asked to answer 20 open and closed ended questions covering three specific topic areas: WLFF demographic information, types of injuries sustained, and the potential influence environmental factors play on the injuries sustained. To obtain the greatest number of questionnaire responses, we utilized a snowball-sampling scheme.[13] This approach encouraged crew leaders and WLFFs to forward the ISWLFF link to other WLFFs, ultimately spreading the impact of this questionnaire across a variety of crews and regions and increasing the amount of data necessary to further this research effort.

The use of an anonymous online questionnaire, where participants were free to decline answering a question or decline the questionnaire altogether, posed no ethical dilemma that would delegitimize any of the data collected within the parameters of this questionnaire.

## DATA ANALYSIS

Quantitative data from ISWLFF was analyzed using Microsoft Excel to determine WLFFs demographics, types of injuries sustained and environmental factors potential influence on injuries sustained. To better quantify some of our open-ended responses, a thematic analysis was performed to best categorize those qualitative responses into one of the categories we listed for that specific question. A descriptive data analysis was performed and frequency counts for each question were calculated. To extrapolate any significant factors that may influence types of injuries sustained by certain demographics within the WLFF community, a Chi Square test for Homogeneity was performed in SPSS version 22, comparing reported injuries to a variety of possible combinations of factors, such as time of day the injury occurred, number of days into roll before the injury occurred, and type of terrain where the injury occurred. Significance determined by alpha was set *a priori* at 0.05 and a Cramer V was used to determine effect size using SPSS version 22. With a Cramer V value of 0.1, the magnitude of effect size is small. With a Cramer V value of 0.3, the magnitude of effect size is medium. For a Cramer V value of 0.5, the magnitude of effect size is large.[14,15]

**Results**

The WLFFs comprising this study represented eight different crew types and all ten GACC's, reporting a total of 453 injuries sustained over the previous five wildland fire seasons. The primary areas of focus within these results are the key demographic information as they relate to injuries sustained by WLFFs and the influence of environmental factors on WLFF injuries.

DEMOGRAPHIC DATA

Breaking down the demographic information and analyzing each group in terms of total number of injuries reported, the WLFF most likely to sustain an injury in this study were males (88%)(n=398/453) between the ages of 35-44 (38%)(n=171/453) working on an engine crew (53%)(n=240/453) (Table 2).

**Table 2** Percentage of injuries sustained by demographic group

| Gender | Percentage (n/453) | Age | Percentage (n/453) | Crew Type | Percentage (n/453) |
|---|---|---|---|---|---|
| Male | 87.9% | 18-24 | 3.3% | Hand | 11.3% |
| Female | 11.9% | 25-34 | 29.1% | Fuels | 1.3% |
| Other | 0.2% | 35-44 | 37.7% | Engine | 53.0% |
| **Total** | **100%** | 45-54 | 21.6% | Hotshot | 7.7% |
| | | 55-64 | 3.5% | Helitack | 10.2% |
| | | >64 | 0.2% | Smokejumper | 4.2% |
| | | Unidentified | 4.4% | Prescribed Wildland Fire | 1.1% |
| | | **Total** | **100%** | Wildland Fire Module | 4.0% |
| | | | | Unidentified | 7.3% |
| | | | | **Total** | **100%** |

When each demographic variable was run through a Chi Square test for Homogeneity, the variables of age (P= .005) (Cramer V=0.310) and employment status (P= .000) (Cramer V=0.345) were significantly correlated with report of injury. Employment status is categorized as Permanent Year-round, Permanent Seasonal or Seasonal. Gender (P= .978), crew type (P= .424) and whether or not the injury was a new or recurring injury (P= .553) were not statistically significant.

## INJURIES SUSTAINED

Table 3 details the types of injuries WLFFs sustained, where the two primary injuries reported were joint sprains (25%)(n=115/453) and muscle strains (15%)(n=69/453). While few in number, the cases of heat illness (3.3%)(n=15/453) are a growing concern within the WLFF community. When analyzing injury data, the body part that sustained an injury (P= .000) (Cramer V=0.470) and the mechanism of injury (P= .000) (Cramer V=0.534) were both found to be significantly correlated with report of injury.

**Table 3** Type of injury sustained by Wildland Firefighters

| **Type of Injury** | **Number of Injuries** | **Percentage (n/453)** |
|---|---|---|
| Contusion | 13 | 2.9% |
| Joint Sprain | 115 | 25.4% |
| Muscle Strain | 69 | 15.2% |
| Fracture/Dislocation | 32 | 7.1% |
| Tendinitis | 23 | 5.1% |
| Nerve Trauma | 12 | 2.6% |
| Cut/Abrasion | 11 | 2.4% |
| Bite/Sting | 7 | 1.5% |
| Muscle Cramp/Spasm | 8 | 1.8% |
| Burn | 6 | 1.3% |
| Blister | 3 | 0.7% |
| Heat Illness | 15 | 3.3% |
| Respiratory Illness | 10 | 2.2% |
| Stomach Illness | 1 | 0.2% |
| Other – Undefined | 67 | 14.8% |
| Incomplete Responses | 61 | 13.5% |
| **Total** | **453** | **100%** |

Table 4 presents the data pertaining to the mechanism of injury reported by the research participants, while Table 5 illustrates nearly half of the total number of injuries reported are attributable to the low back (16%)(n=71/453), knees (17%)(n=78/453) and ankles (13%)(n=60/453). Of the participants who sustained an injury while assigned to an incident, 85% (n=111/131) reported that their injury occurred on the fireline (Table 6).

**Table 4** Mechanism of injury reported for injuries sustained

| **How the Injury/Illness Occurred** | **Number of Injuries** | **Percentage (n/453)** |
|---|---|---|
| Slip/Trip/Fall | 100 | 29.9% |
| Equipment/Tool/Machinery | 11 | 3.3% |
| Struck by/Against an Object | 21 | 6.3% |
| Motor Vehicle/Transport | 4 | 1.2% |
| Weather/Environmental | 20 | 6.0% |
| Bite/Sting/Poison | 6 | 1.8% |
| Fire/Smoke/Flash Burn | 8 | 2.4% |
| Overexertion | 57 | 17.1% |
| Other – Undefined | 107 | 32.0% |
| Incomplete Responses | 119 | 26.3% |
| **Total** | **453** | **100%** |

**Table 5** Body part reported injured by Wildland Firefighters

| Anatomic Region | Number of Injuries | Percentage (n/453) |
|---|---|---|
| Head/Face | 23 | 5.1% |
| Neck | 4 | 0.9% |
| Chest | 12 | 2.6% |
| Back | 71 | 15.7% |
| Shoulder/Arm | 37 | 8.2% |
| Elbow/Forearm | 16 | 3.5% |
| Wrist | 5 | 1.1% |
| Hand/Fingers | 11 | 2.4% |
| Abdomen | 7 | 1.5% |
| Hip/Thigh | 13 | 2.9% |
| Knee | 78 | 17.2% |
| Lower Leg/Ankle | 60 | 13.2% |
| Foot/Toes | 27 | 6.0% |
| Other – Undefined | 31 | 6.8% |
| Incomplete Responses | 58 | 12.8% |
| **Total** | **453** | **100%** |

**Table 6** Location where injuries were sustained

| If Assigned to Incident, Where Injury/Illness Occurred | Number of Injuries | Percentage (n/131) |
|---|---|---|
| Fireline | 111 | 84.7% |
| In Camp | 4 | 3.1% |
| Not Applicable | 1 | 0.8% |
| Other | 8 | 6.1% |
| Incomplete Responses | 7 | 5.3% |
| **Total** | **131** | **100%** |

Understanding the financial impact associated with each type of injury is a critical component of this research. To better quantify this data, participants were asked how much time was lost due to the injury, and to determine whether or not they felt that their injury was preventable. Statistical significance was found (P= .003) (Cramer V= 0.329) as it relates to time lost due to injury, where 24% (n=110) of participants reported that they lost no time as a result of the injury and continued working with no restrictions (Table 7). Factors including hours into shift (P= .154) and number of days into shift (P= .195) were not statistically significant.

**Table 7** Time lost due to injury

| Amount of Time Lost Due to Injury | Number of Injuries | Percentage (n/453) |
|---|---|---|
| None-continued work with no restrictions | 110 | 24.3% |
| None-continued work with modified duties | 60 | 13.2% |
| Did not work the rest of the day | 9 | 2.0% |
| 1 day | 13 | 2.9% |
| 2 days | 9 | 2.0% |
| 3 days | 13 | 2.9% |
| 4 days | 1 | 0.2% |
| 5 days | 10 | 2.2% |
| 6 days | 2 | 0.4% |
| 1 week | 14 | 3.1% |
| 2 weeks | 11 | 2.4% |
| 3 weeks | 6 | 1.3% |
| 1 month | 12 | 2.6% |
| 2 months | 13 | 2.9% |
| 3 months | 7 | 1.5% |
| 4-6 months | 19 | 4.2% |
| 7-12 months | 5 | 1.1% |
| Season Ending | 11 | 2.4% |
| Other | 7 | 1.5% |
| Incomplete Responses | 121 | 26.7% |
| **Total** | **453** | **100%** |

Although the results from number of days into shift were not statistically significant, the data still contained some interesting findings. On a standard 14-day roll, the day with the most reported injuries was the tenth day (15%) (n=18/131), followed by the fourteenth and final day (11%) (n=13/131). Conversely, nearly 40% (n=50/131) of reported injuries occurred within the first five days of a 14-day roll (Table 8).

**Table 8** Number of days into shift before injury

| Consecutive Days Worked | Number of Injuries | Percentage (n/131) |
|---|---|---|
| 1 day | 8 | 6.5% |
| 2 days | 8 | 6.5% |
| 3 days | 12 | 9.8% |
| 4 days | 12 | 9.8% |
| 5 days | 10 | 8.1% |
| 6 days | 6 | 4.9% |
| 7 days | 9 | 7.3% |
| 8 days | 9 | 7.3% |
| 9 days | 2 | 1.6% |
| 10 days | 18 | 14.6% |
| 11 days | 2 | 1.6% |
| 12 days | 6 | 4.9% |
| 13 days | 3 | 2.4% |
| 14 days | 13 | 10.6% |
| Not Applicable | 5 | 4.1% |
| Incomplete Responses | 8 | 6.5% |
| **Total** | **131** | **100%** |

Arguably the most important piece of information was the WLFFs perception of prevention as it related to their injury. Determining whether or not the WLFFs felt their injury was preventable (P= .025) (Cramer V= 0.342) varied depending on where the injury was sustained. For injuries that occurred during physical training, 21% (n=22/106) of participants felt that their injury was preventable. For injuries that occurred on the fireline, 16% (n=17/108) of participants felt that their injury was preventable (Table 9).

**Table 9** Perception of prevention for sustained injury

| | **Injury Occurred During PT (n=106)** | | **Injury Occurred on Fireline (n=108)** | |
|---|---|---|---|---|
| **Preventable** | Yes | No | Yes | No |
| **Percentage** | 20.8% | 79.2% | 15.7% | 84.3% |
| **Total** | 22 | 84 | 17 | 91 |

ENVIRONMENTAL FACTORS

Taking a closer look at the environmental factors surrounding these injuries, two factors appear to contribute in some way to WLFF injuries. These statistically significant factors include terrain where the injury occurred (P= .017) (Cramer V= 0.463) and time of day that the injury occurred (P= .010) (Cramer V=0.469). When analyzing type of terrain where the injury occurred, rocky mountainside was the most common terrain reported, accounting for almost half (47%) (n=57/121) of reported injuries (Table 10). Although terrain is an uncontrollable factor in wildfire suppression, awareness of the different types of injuries (muscle strains/joint sprains) and understanding the common mechanisms (slips/trips/falls) associated with each type of terrain should have an impact in lowering the rates of injury of WLFFs while out on the fireline.

**Table 10** Terrain influences on injuries sustained

| **If Assigned to Incident, Type of Terrain Injury/Illness Occurred** | **Number of Injuries** | **Percentage (n/121)** |
|---|---|---|
| Flat, Open Grassland | 13 | 10.7% |
| Rising Hill | 25 | 20.7% |
| Rocky Mountainside | 57 | 47.1% |
| Heavily Wooded Area | 15 | 12.4% |
| Other | 11 | 9.1% |
| **Total** | **121** | **100%** |

Shift start-times and duration depend largely on fire activity and vary across crew types. Looking at the time of day that these injuries occurred, nearly 14% (n=62/453) of reported injuries occurred during the 10:00am hour. Surprisingly, 35% (n=157/453) of reported injuries occurred between the hours of 9:00am-12:00pm (Table 11).

**Table 11** Time of day injury occurred

| Time Injury Occurred | Number of Injuries | Percentage (n/453) |
|---|---|---|
| 1:00 | 1 | 0.2% |
| 2:00 | 2 | 0.4% |
| 3:00 | 3 | 0.7% |
| 4:00 | 4 | 0.9% |
| 5:00 | 0 | 0% |
| 6:00 | 3 | 0.7% |
| 7:00 | 8 | 1.8% |
| 8:00 | 10 | 2.2% |
| 9:00 | 37 | 8.2% |
| 10:00 | 62 | 13.7% |
| 11:00 | 44 | 9.7% |
| 12:00 | 14 | 3.1% |
| 13:00 | 17 | 3.8% |
| 14:00 | 31 | 6.8% |
| 15:00 | 28 | 6.2% |
| 16:00 | 21 | 4.6% |
| 17:00 | 10 | 2.2% |
| 18:00 | 9 | 2.0% |
| 19:00 | 8 | 1.8% |
| 20:00 | 4 | 0.9% |
| 21:00 | 3 | 0.7% |
| 22:00 | 8 | 1.8% |
| 23:00 | 4 | 0.9% |
| 24:00 | 1 | 0.2% |
| Incomplete Responses | 121 | 26.7% |
| **Total** | **453** | **100%** |

**Discussion**

Given the work environment faced by today's WLFFs and the arduous nature of wildland fire suppression, the risk of injury seems inevitable. The aim of this study was to identify the types of injuries WLFFs sustain on the job, what environmental factors lead up to the injury and how to adequately address these concerns. The data from this study provides some insight into common types of injuries amongst WLFFs and the environmental factors leading up to those injuries. With this information, the next step is to address these areas of concern through the design and implementation of a more job-specific PT program that reduces the risk of injury for all WLFFs.

## DEMOGRAPHIC DATA

Understanding what demographic of WLFF is most at risk for sustaining an injury provides the necessary foundation for developing and implementing injury prevention strategies that cater to the individual and the WLFF community as a whole. Consistent with previous research[2,9–11] related to WLFF injuries, our findings indicate male WLFFs between the ages of 35-44 working on an engine crew are the most likely to sustain an injury. One difference between our research and previous studies is that we utilized firsthand accounts and descriptions of injuries, while other studies reviewed medical reports that didn't always include the demographic information necessary for developing an accurate representation of the WLFF community.

Looking back at some of the previous studies that analyzed WLFF injuries, some trends in the demographic groups of gender, age and crew type become apparent. In the first published study that examined the severity of specific WLFF injuries and their mechanisms, Britton[7] found that WLFFs aged 17-34 accounted for 75% of the total reported injuries and Engine crews reported one-third (33%) of the total number of injuries.[2,7,16] Due to the nature of data collection, gender information as it relates to injury was not available. Utilizing a similar blueprint, Mangan[9] published a study that focused on WLFF fitness and barriers to physical training. The results from this study found that 91% of WLFFs reporting an injury were male and that the vast majority (72%) of them occurred between the ages of 25-44. Type 2 crews accounted for 38% of the total injuries reported, while Type 1 crews totaled 25% of reported injuries.[9]

While our results mirror some of the demographic data from previous WLFF injury studies, the reality is that three studies is an incredibly small sample size. The lack of literature on WLFF injuries dictates that the research must come from occupations with similar physical demands.[5,12] Military personnel, structural firefighters, policemen, and WLFFs all fall under the term of *tactical athlete*, which is defined as anyone whose occupation demands methods of physical training that are necessary to maintain an appropriate level of physical performance compulsory with the profession.[17,18] In terms of demographic data, structural firefighters share quite a few similarities with WLFFs as it relates to age, gender and experience/crew type.[11,19] Between the years 2010-2012, the U.S. Fire Administration monitored and recorded structural firefighter injuries and found that male firefighters sustained 95% of reported injuries and that more than half (59%) of them occurred between the ages of 25-44.[11] Although they are both firefighters, the difference in work environments and equipment between structural firefighters and WLFFs invariably leads to different types of injuries.

The tactical athlete with the most current and available injury data and whose job demands are most similar to today's WLFFs are military personnel. Demographic information for injured members within the military population is remarkably similar to that of the WLFF community, where males account for 80-90% of reported injuries, with most occurring between the ages of 20-45.[20–23] The operation style, crew types, and work shifts between military personnel and WLFFs are very similar, but it's important to remember that they are in fact different, and that conclusions drawn from injury data collected on military personnel cannot be applied directly to WLFFs.[17,24,25]

INJURIES SUSTAINED

Given the arduous nature of work and physical demands placed on today's tactical athletes, particularly military personnel and WLFFs, the risk of injury is almost certain. Much like athletes preparing for competition, both WLFFs and members of the military must build up and maintain a high level of fitness in preparation for training and missions.[26] As a result of this fitness preparation and training, military personnel may sustain an injury, commonly a musculoskeletal injury.[21,27–29] In our WLFF injury study, musculoskeletal injuries accounted for 57% (n=260/453) of all reported injuries. While musculoskeletal injuries can occur across multiple environments in the military, many occur as a result of physical training.[21,24,26–28] This occurs in the WLFF setting as well, where one study found that 28% of reported injuries occurred during PT[9], while our data revealed that 23% (n=106/453) of our research participants reported that they sustained an injury during PT.

Throughout the literature, physical training programs and equipment loads have been cited as the predominant influences on injuries in the military.[25–27,30,31] Furthering this sentiment, Almeida et al[32] states that most injuries sustained by military personnel are attributable to overexertion related to the amount of time spent on physical training, as well as the amount of equipment carried throughout the process of physical training.[32] Bringing it back to WLFF, the second most common (17%) (n=57/453) mechanism of injury reported in our study was overexertion. Although most WLFF injury data lists slips/trips/falls as the primary mechanism of injury, some researchers state that overexertion is responsible for the majority of firefighter injuries.[11,19,33,34] One serious repercussion WLFFs face as a result of overexertion, especially early in the fire season, is rhabdomyolysis.[35] Rhabdomyolysis is defined as the rapid destruction of skeletal muscle tissue due to exertion or trauma, resulting in the release of intracellular contents, such as myoglobin and potassium, into the blood stream.[35–38] If left untreated, acute renal failure can occur rapidly.[35,36] One report found that of the nineteen cases of rhabdomyolysis reported by WLFFs, eleven occurred during some form of physical training.[35] While slips/trips/falls appears to be the most common mechanism of injury reported by WLFFs, the potential risks associated with overexertion cannot be overstated enough and must be taken seriously.

## ENVIRONMENTAL FACTORS

The unfortunate reality of wildland firefighting is that there are numerous factors that increase the risk of injury that WLFFs are unable to control. Included in this list of factors is type of terrain and mechanism of injury, where our study indicates that nearly half (47%) of the injuries sustained while assigned to an incident occurred on a rocky mountainside, and slips/trips/falls accounted for 30% of total injuries. While definitions of types of terrain vary from study to study, "steep and uneven surfaces" appear to increase the likelihood of slips/trips/falls resulting in injury.[5,7,12,39]

The need for physical training modifications for the safety of WLFFs is abundantly clear. With the data from our research, we can begin moving in the direction of reducing injuries, particularly lower extremity injuries, with a specific demographic in mind. One troubling statistic to emerge from previous WLFF injury research is that upwards of 29% of reported injuries occurred during physical training.[9] Given the battery of risks associated with wildland firefighting, the threat of injury is always present. However, the risk of injury during PT should be significantly reduced compared to the risk of injury observed on the fireline. This can be accomplished through simple injury prevention strategies incorporated into WLFF physical training programs.

The varying nature of WLFF injuries and the associated risk factors make injury prevention an exceedingly complex process to undertake.[40] WLFFs are incredibly diverse, with multiple crew types and vastly varying fitness levels. A successful injury prevention program must be broad enough to encapsulate as many WLFFs as possible, yet specific enough that the majority of participants see an objective decrease in the rate of injuries sustained during PT and on the fireline.[2,5,9] Understanding the physical demands of the job and the injuries associated with fighting wildfires, as well as recognizing the environmental factors leading up to the injury, is essential when designing and implementing a job-specific injury prevention program for the safety and well-being of all Wildland Firefighters.

To combat the incidence of physical training injuries sustained by tactical athletes, multiple programs with varying strategies have been explored by the military, law enforcement, and structural firefighters.[17,24–26,31,41] The majority of the research revealed two approaches to injury prevention: injury screening tools[29,42–48] and PT program modifications.[21,24–27,31] Injury screening tools aim to address the individual, while physical training modifications address the program. These principles are not independent of one another, and when used in conjunction with each other, have produced positive results relating to injury reduction.[41,49,50]

Given the job requirements of tactical athletes, a physical training program is unavoidable.[17,51] Many PT programs for tactical athletes are founded in aerobic principles, where the primary focus is building endurance through distance running, yet tactical athletes work in environments that require dynamic and functional movement patterns.[17,26,31,52,53] This emphasis on distance running during physical training, combined with on-job physical activity, can lead to overtraining and increased injury rates.[25,27,31] One study found that as the physical demands of the occupation in the U.S. Army increased, the risk of injury increased as well.[54] One approach to modifying PT programs is to move towards more job-specific, functional movement exercises.[41,43,45,51] The benefit of these exercises is that they incorporate movement patterns that work through a functional range of motion consistent with movement patterns seen in a work environment similar to WLFFs. By focusing on the muscle groups most commonly used in WLFF, functional movement exercises can be implemented across all crew types, which captures the specificity WLFFs want while still encompassing the population as a whole.

Analysis of these injury prevention strategies reported mixed results in terms of the effectiveness of the program. Some researchers actually found that PT programs designed to improve fitness levels also helped to reduce injuries amongst study participants.[24,55] Although the research is varied in terms of results from injury prevention programs, there are indications that these programs may have a positive impact on both physical fitness and the rate of injuries. While much of the research into these injury prevention programs is rooted in the military, it's important to understand that these findings are relevant and applicable to all tactical athletes, especially today's WLFF.

**Study Limitations**

The tool for collecting data for this study was a self-administered online questionnaire. Participants recalled and listed injuries over the previous five years, which limits the results to the sample and eliminates the possibility of randomization when recruiting participants for the study. Other limitations to self-administered questionnaires include incomplete questionnaires, qualitative explanations that cannot be categorized, and the possibility of individuals participating in the questionnaire more than one time. Another limitation is that there is no available data that lists the number of Wildland Firefighters actively employed during the fire season, making it all but impossible to determine if our sample is representative of the entire Wildland Firefighter population.

Although this study obtained viable data, one caveat is that participants who did not sustain an injury within the past five seasons were excluded from the results, meaning that the injury data presented is that of only WLFFs who have sustained an injury, as opposed to all WLFFs. This is worth mentioning in order to make it abundantly clear that this data is pertinent only to this specific sample group and not the entire WLFF community.

**Conclusions**

Our research indicates that there are multiple environmental factors that play a role in the incidence and severity of injuries sustained by WLFFs. One point that cannot be dismissed is the number of WLFFs who perceived their injury as preventable, both out on the fireline and during physical training. Given the lack of research into WLFF injuries and the limitations of this study, continued research into WLFF injuries is critical in order to develop and implement injury prevention strategies through a job-specific PT program. Future research should focus on identifying WLFFs at the greatest risk of sustaining an injury through injury-screening tools before the season starts. Once these at-risk WLFFs are identified, injury prevention programs need to be implemented in order to improve functional movement patterns and decrease the risk of injury during PT and out on the fireline.

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