

# National Wildfire Coordinating Group

## Risk Management Committee Days Off Task Group:

### Summary Of Wildland Firefighter Fatigue Research

#### Background

Fatigue is a complicated construct that is difficult to measure. Fatigue can only be measured indirectly based on factors thought to cause fatigue (e.g., prior sleep/wake, time-of-day or time-on-task) or inferred from behaviors that fatigue influences (e.g., eye movement, response times, error rates, subjective assessments).<sup>1</sup> There is a general lack of consensus on the definition of fatigue among the scientific community. Though no concise definition exists; fatigue of any dimension (e.g., burnout, cognitive fatigue – both task- and sleep-related, physical fatigue, emotional fatigue, perceptual fatigue) is linked to worker health, wellbeing, and performance.<sup>2</sup>

Fatigue has been broadly described by the National Institute for Occupational Safety and Health as “a feeling of weariness, tiredness or lack of energy.” It can also be defined as a reduction in physical and mental work capacity, resulting from physical or mental load(s), that is reversible with rest.<sup>3</sup> In workplace settings, it is commonly associated with nonstandard schedules, which disrupt or shorten sleep. Fatigue can also be associated with other workplace factors such as stress, physically or mentally demanding tasks, or working in hot environments. It can stem from several different factors and its effects go beyond sleepiness. Fatigue can slow down reaction times, reduce attention or concentration, limit short-term memory and impair judgment.<sup>4</sup> Long work hours may also increase the risk of injuries and accidents. They can also result in increased levels of stress both at work and home, poor eating habits, lack of physical activity, and illness.<sup>5</sup> Because of these detriments of fatigue, it is important to identify the sources of fatigue, learn the associated risks, and use strategies to manage fatigue in the workplace.<sup>4</sup>

Wildland firefighters' work tasks and schedules are known to cause fatigue. Managing this fatigue is one part of the risk management framework. Management of fatigue-related risk in operations that use long hours and night work requires multiple levels of control from the organizational level to the individual level. One organizational strategy to manage fatigue is through work-to-rest standards. For wildland firefighters, work-to-rest ratios span across multiple time spans, from breaks during shifts, maximum shift lengths, and a maximum number of shifts before days off.

Days off from work after assignments to wildfire incidents are one of the specific work-to-rest standards. This standard is written into the Interagency Standards for Fire and Fire Aviation Operations. The word fatigue is mentioned 17 times overall in the document. Fatigue is an important topic in Fire and Aviation Management, especially when it comes to safety and risk management. In chapter 7 when outlining standards for both work/rest and days off, the section begins with the words “To mitigate fatigue” and “to assist in mitigating fatigue” and then continues to outline the various standards.

In 2021, the USDA Forest Service implemented a change in the days off standard from 2 days to 3 days off for fire resources after the completion of a 14-day assignment on an incident and upon return to the home unit. There are many different reasons the Forest Service changed this policy and one of them is to further assist in mitigating the fatigue of wildland firefighters by providing them an extra day off from work.

Any shift schedule that increases consecutive days off can potentially positively affect multiple outcomes related to fatigue such as:

- Sleep recovery
- Stress levels
- Physical activity and task performance
- Mental and emotional health
- Cognitive performance
- Work-life balance and increased productivity
- Safety outcomes
- Job satisfaction

The following summary will explore research findings on the topic of fatigue and the various outcomes listed above.

## Fatigue Research Summary

### Introduction

Fatigue management strategies for wildland firefighters should be evidence-based and practical to implement. The following summary of relevant scientific research is intended to provide some background and insights into how fatigue and sleep are assessed, what is known about fatigue and fatigue management in wildland firefighting, and how this may relate to days off policies as well as other strategies for managing fatigue in wildland fire. The research mentioned below is not an exhaustive summary of studies on the subject but does cover an overview of the evidence available.

Information was obtained from 35 studies, 12 of which were review papers. The research examined various aspects of fatigue among wildland firefighters and related populations. Study populations included wildland firefighters (33), emergency medical service providers, structure firefighters, other first responders (8 collectively), and the general population (1). Of the 21 original research studies (not review papers) that focused exclusively on wildland firefighters 12 were conducted in Australia, 5 studies were in Canada, and 4 in the United States. Much of the research on this topic comes from Australian and Canadian wildland firefighters.

Both quantitatively and qualitatively measuring fatigue levels, as well as evaluating mitigation techniques that reduce fatigue, is challenging. However, research on wildland firefighters, structure firefighters, and other first responders generally supports a robust fatigue management framework. Work schedules and days off are a part of this framework. Due to the unique and variable nature of wildland firefighting schedules and work tasks, it is difficult to extrapolate conclusions from studies on other first responders, but these studies can still provide valuable insight. In addition, there is no existing quantitative evidence directly comparing the differences between 2 and 3 days off for wildland firefighters; however, some studies suggest that both 2 days and 3 days off are not sufficient time for wildland firefighters to recover from fatigue. Research indirectly suggests that time off beyond 48 hours after long work assignments and multiple consecutive shifts will reduce fatigue.

### Measuring Sleep and Fatigue

Accurately assessing fatigue and sleep is an essential first step to managing fatigue at all levels and evaluating the effectiveness of fatigue management strategies. There is a multitude of assessment techniques to measure aspects of fatigue. The appropriate measures for any given research question depend on aspects of the study

such as if it takes place in a lab or the field, the specific factors of fatigue researchers desire to evaluate, or the fatigue mitigation or prevention actions that can be implemented based on the results of the study.

Sleep is closely related to and a measurement of fatigue. When measuring sleep specifically, the two overarching aspects that are commonly quantified are sleep quantity and sleep quality. A typical adult should obtain at least 7 hours of sleep per night for optimal health and functioning.<sup>6,7</sup> Sleep quality consists of factors including sleep efficiency, sleep latency, sleep duration, and wake after sleep onset.<sup>6</sup>

The three primary methods for measuring sleep in laboratory or field studies include polysomnography, activity monitoring (also known as actigraphy), and subjective (self-report) measures. Polysomnography measures brain, cardiac, and muscle activity as well as eye movement. Through this monitoring, researchers can measure the aspects of sleep quality. Activity monitoring provides an objective, non-invasive and practical alternative to polysomnography. When compared to activity monitors, sleep diaries have similar dating for sleep timing, duration, onset and offset, but not for sleep latency, awakenings, and the number of naps.<sup>6</sup> Self-report measures are the least accurate when relied on alone but the accuracy of objective sleep assessments using activity monitors can be improved when analyzed in conjunction with subjective self-report measures.<sup>6</sup>

Yung et. al completed a scoping review of fatigue measures and risk assessment tools for first responder fatigue risk management. The authors sought to answer the question “How can organizations and personnel measure or detect fatigue-related hazards and assess the risk of an adverse outcome?” The scoping review describes 60 unique measures and tools across 403 papers, 156 of which focused specifically on firefighters. The measures were categorized into five different dimensions of fatigue across all first-response occupations.<sup>2</sup> These dimensions are burnout, cognitive, physical, emotional, and perceptual fatigue. For burnout, there were 13 measures total and 9 were used for firefighting research. The most common tool used is the Maslach burnout inventory. For cognitive tools, the authors found 34 tools of which 20 were used for firefighters. The most popular tools for cognitive fatigue were non-specific questionnaires which can add difficulty to consistent measurements of fatigue, but this was followed closely by the Pittsburgh sleep quality index which is a standardized tool. For the physical dimension, studies on firefighters used 13 of 15 tools and among firefighter research heart rate and heart rate variability was the most common followed by perceived exertion/force using Borg’s rate of perceived exertion scale. For the emotional and perceptual dimension only 4 tools were found, of which firefighter researchers used 2. The most common is the professional quality of life scale.<sup>2</sup>

In another study of 88 Australian volunteer firefighters put through a multi-day firefighting simulation, researchers assessed multiple objective and subjective measures of fatigue and found that the Psychomotor Vigilance Task (PVT) was the most sensitive for objective fatigue, and the Samn-Perelli fatigue scale was the most sensitive for subjective fatigue.<sup>8</sup> The study concluded these are both good measures of cognitive fatigue in the lab and field-like conditions, especially in the presence of physical work tasks.<sup>8</sup>

Because fatigue of each dimension is prevalent in first responder work we must identify and understand the proper tools to assess fatigue as well as how accurate, reliable, and consistent these tools are. It is important to select the right fatigue measures and tools to assess the desired aspects of fatigue in each unique occupational situation. Yung et. al’s paper is an excellent resource to refer to when studying wildland firefighter fatigue or assessing the results from studies of fatigue.

## Review Papers on Fatigue

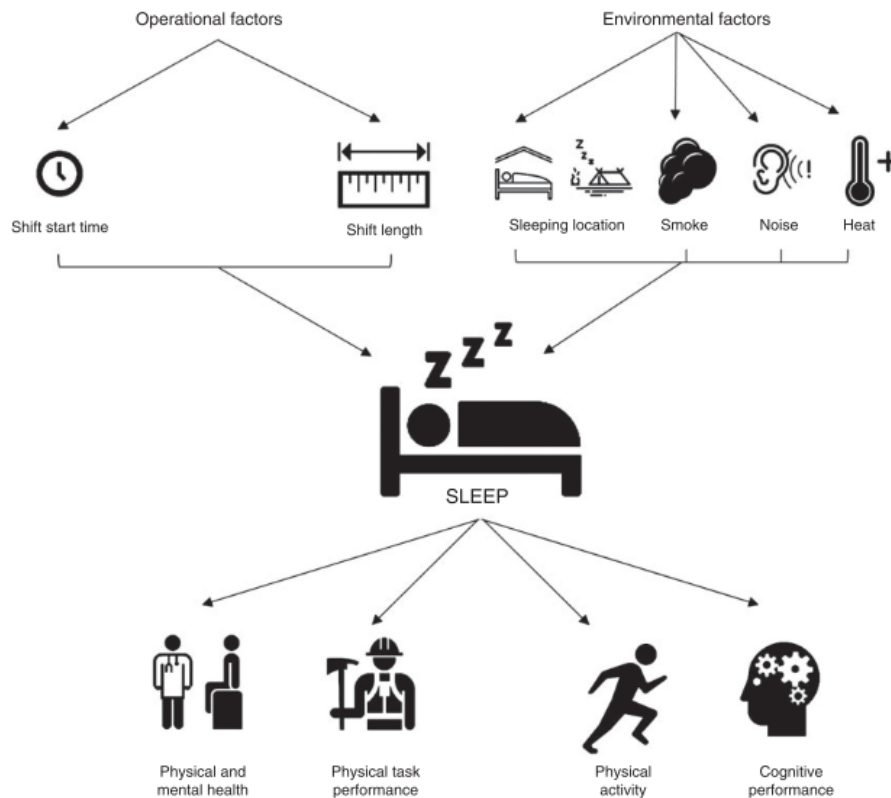
Twelve review papers ranging from scoping to systematic reviews contribute overarching and combined insight into various aspects of fatigue and fatigue management in emergency occupational settings, including a large body of work on wildland firefighting.

A review by Aisbett et al., 2007 examining the various factors contributing to fatigue including sleep loss, firefighter's work activity, hydration, nutrition, the hot and smoky working environment, physical fitness, and experience, emphasized that the many symptoms of fatigue are a precursor to more serious health and safety risks for the individual and, potentially, their crew.<sup>3</sup> Under sustained or increasing stress, fatigue may quickly lead to impaired work performance and judgment, unsafe behavior, accidents, injuries, and in rare cases death.<sup>3</sup> Another review with the same first author aimed to understand the individual and combined impact of these factors on physical and cognitive work performance. There was little research on the combined effects of sleep loss, smoke, and heat among wildland firefighters.<sup>9</sup> However, one study included in this review did not see an impact of working in hot conditions on measures of sleep.<sup>10</sup> Overall, extrapolations from the available literature suggested that prolonged intermittent work, following shortened sleep in hot and smoky conditions may be associated with greater physiological exertion and compounded degradations in mental performance than when faced with the stressors in isolation.

A systematic review assessing the effects of sleep on firefighters' occupational performance and health found that firefighters with poor sleep measures had worse cognitive performance and overall health, but physical capabilities were not impacted by acute sleep restriction.<sup>11</sup> The authors concluded that to avoid sleep-related declines in occupational performance fire departments should consider the consequences of shift schedules on the performance and health of firefighters. Furthermore, sleep education interventions, the use of wearables to monitor occupational readiness, and sleep health screening appear beneficial based on prior research.<sup>11</sup>

Another review examined sleep among wildland firefighters, the factors that contribute to sleep issues, and well as how sleep impacts work performance and health.<sup>6</sup> The schematic overview (Figure 1 below) provides a helpful visual for the various factors that affect sleep which can change work performance.

**Figure 1:** A schematic of fatigue factors from Vincent GE, Aisbett B, Wolkow A, Jay SM, Ridgers ND, Ferguson SA. *Sleep in wildland firefighters: What do we know and why does it matter?* *International Journal of Wildland Fire*. 2018;27(2):73-84.



**Fig. 1.** Schematic overview: the operational and environmental factors that affect sleep during wildland firefighting, and the ways in which sleep impacts on aspects of firefighters' health and safety.

They found firefighters' sleep is restricted during wildfire deployments, particularly when shifts have early start times, are of long duration, and when sleeping in temporary accommodations. When interviewed post-deployment, firefighters reported an average sleep duration of 3–6 hours. Sleeping location, smoke, noise, and heat all impacted sleep quality and quantity. Shortened sleep impaired cognitive but not physical performance under simulated wildfire conditions. Simulated deployments with sleep restriction revealed acute increases in cortisol among participants.<sup>6</sup> Two studies found that sleep restriction did not moderate physical activity levels. The authors also cited a meta-analysis that estimated sleep problems increase the risk of being injured at work by 62% and this risk increases as working hours increase. So though physical performance may not be negatively impacted by sleep loss, firefighters are at increased injury risk while performing physical activities when fatigued.<sup>6</sup> The longer-term impacts of sleep restriction on physiological and mental health require further research, especially beyond a single fire assignment. Work shifts should be structured, wherever possible, to provide regular and sufficient recovery opportunities (rest during and sleep between shifts).<sup>6</sup>

A review specifically investigated how 1-7 nights of sleep restriction could impact hormonal, inflammatory, and psychological responses among firefighters, law enforcement, defense forces, and ambulance personnel.<sup>12</sup> The available literature suggested that sleep restriction across multiple workdays can disrupt cytokine and cortisol levels, deteriorate mood, and elicit simultaneous physiological and psychological responses. From the factors studied, there was some evidence that partial sleep deprivation impaired immune function and instigated

symptoms of anxiety and depression. Overall, the research was limited and the presence of confounders could have skewed results such as physical work disrupting cortisol levels. Another finding was the strong correlation between psychological self-report measures and physiological responses. If sleep restriction elicits similar responses among both realms, self-report measures could be a simplified non-invasive way to measure fatigue in the field.<sup>12</sup>

A recent scoping review sought to find research gaps related to working hours, sleep, and fatigue in the public safety sector. Nonstandard work hours have been associated with increased risk for on-duty injuries and chronic diseases such as cancer and cardiovascular disease among workers in the public safety sector.<sup>13</sup> In the findings among wildland firefighters, self-reports of sleepiness were significantly greater after rest days compared to initial deployment. During shorter prescribed burn operations, sleep was not compromised. In a multi-day wildfire suppression, sleep quantity was restricted, and pre-and post-sleep fatigue was higher, compared with nonfire days. There was suboptimal sleep quality and quantity more frequently during initial attack, but also during nonfire (base) work periods, and project fires.<sup>13</sup> In a simulated wildfire suppression, imposed sleep restriction and heat did not hurt self-paced physical performance and heat did not impair physiological or perceptual responses. In a 3-day simulated wildfire suppression with hot wildfire conditions, two nights of imposed sleep restriction did not influence task performance or physiological responses. Other sleep restriction studies found associations with inflammatory stress responses and cortisol.<sup>13</sup>

Overall public safety workers had high rates of fatal and nonfatal injuries, some of which may be linked to long hours and fatigue. Adverse psychological symptoms were consistently associated with a lack of support, job demands, job pressure, administrative/organizational pressure, and long working hours. Sleep quality was correlated with PTSD, depression, anxiety, social anxiety disorder, panic disorder, and alcohol use disorder in public safety personnel.<sup>13</sup>

Another systematic review identified health outcomes that were associated specifically with psychosocial stress among firefighters.<sup>14</sup> From 29 studies they found a variety of psychosocial stressors that firefighters regularly experience and that ongoing exposure to these stressors can lead to health-related outcomes in 6 areas, one of them being sleep quality. The other 5 areas can also be indirectly related to fatigue: depression, non-depressive mental health problems, burnout, alcohol use disorders, and physiological parameters/somatic disorders. Psychosocial stressors can cause fatigue, burnout, slower recovery, and a variety of chronic diseases within a workforce.<sup>14</sup>

Though physical performance was not negatively impacted across the included studies, factors in all dimensions of fatigue were consistently negatively affected.

## Review Papers and Studies Evaluating Fatigue Management

Risk assessment tools and controls include fatigue-proofing strategies, policies, standards, guidelines, and programs. Canada is working to implement a fatigue risk management system framework, which is a science-based, data-driven process that is subjected to continuous improvement, and designed to improve organizational and personal outcomes. Two reviews by Yung et al. worked to define the scope of the Canadian fatigue risk management standard for first responders.<sup>2,15</sup> In Canada, a national occupational standard on fatigue risk management is being developed for first responders (police, firefighters, and paramedics/EMS personnel). A team of researchers and professionals conducted a review on fatigue and fatigue management in each of these three occupations. They found that burnout, cognitive fatigue, and physical fatigue were associated with adverse health and performance outcomes. The recommendation was a fatigue risk management standard for

first responders that considers managing fatigue of any type and includes both work and personal/social/cultural risk factors to prevent both short- and longer-term adverse outcomes.<sup>2,15</sup>

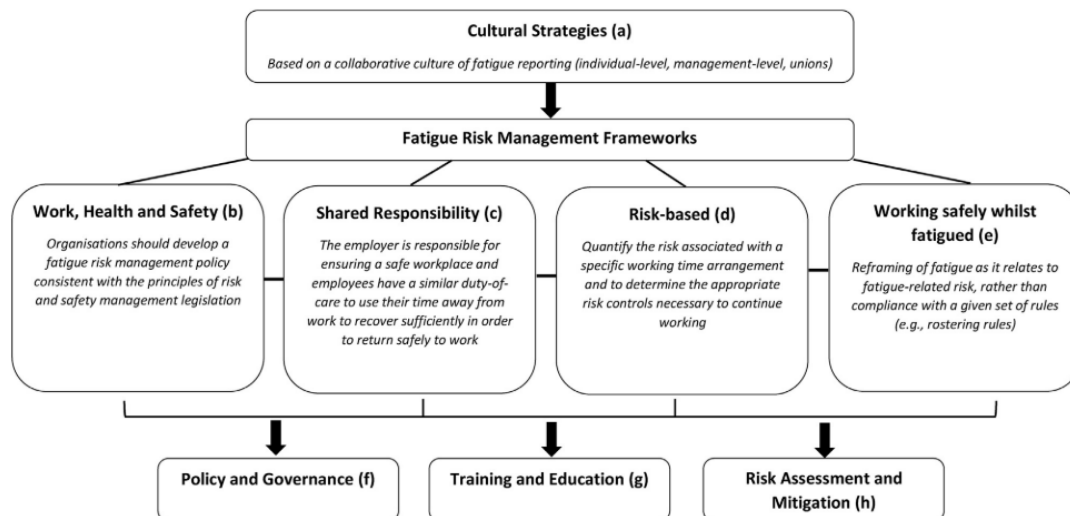
Among studies that investigate the effectiveness of fatigue risk management programs for first responders, the findings indicated that these programs can result in positive outcomes.<sup>15</sup> Firefighters reported increased sleep quantity and quality in a trial and Royal Canadian Mounted Police improved sleep satisfaction, better management of insomnia symptoms, and fewer headaches when assigned to a fatigue management training program. The authors also found an evidence-informed guideline for fatigue risk management system is under development for emergency service personnel in the United States.<sup>15</sup>

The second scoping review was covered in the section on measures and tools for measuring fatigue and the effectiveness of fatigue management actions. The results of that scoping review provide a starting point for organizations to assess fatigue, of any dimension, using the measures and tools they outlined.<sup>2</sup>

Two related review papers from Australia sought to provide an overview of fatigue risk management for regulators, policymakers, and organizations in the emergency services sector, examine policy consensus around managing fatigue, discuss strategies to minimize risks associated with fatigue, as well as identify informal strategies used by firefighters to see how they may be formalized. In Australia, employers are responsible for ensuring employees are provided with a working time arrangement that provides an adequate opportunity for workers to sleep, rest and recover to work safely.<sup>16</sup> According to the National Workplace Health and Safety (WHS) guidelines, working time arrangements are limited to 12 hours in any 24 hours and a sequence of shifts should not exceed a total of 48 hours of work before a rest break of at least 48 hours is required.<sup>1</sup> Firefighters that were interviewed acknowledged there is conflict between service delivery and the WHS guidelines limiting hours of work, and service delivery was the clear priority in this conflict.

When examining various strategies for how emergency services organizations can best manage fatigue-related risk, the authors developed this chart below in Figure 2 (Figure 1 from the study). Days off standards implemented in the United States can have functionality in multiple of the frameworks outlined in the chart. Out of the many strategies assessed, one important practice point the authors emphasized was assessing the work-time arrangements and implementing controls necessary to reduce fatigue by limiting working hours.<sup>16</sup>

**Figure 2:** A schematic of strategies to reduce fatigue-related risk from Dawson D, Mayger K, Thomas MJ, Thompson K. *Fatigue risk management by volunteer fire-fighters: Use of informal strategies to augment formal policy.* *Accid Anal Prev.* 2015;84:92-98.



**Fig. 1.** Strategies to reduce fatigue-related risk in the emergency services sector. Figure adapted from Gander et al. [32]. Letters following headings refer to corresponding sections in the text.

The second Australian review outlined some fatigue impacts in the emergency services sector.<sup>1,16</sup> The impacts included physical as well as cognitive effects, loss of situational awareness, memory troubles, difficulties with decision-making, and communication problems. Various informal fatigue-risk management strategies were analyzed such as awareness of fatigue, reporting of fatigue, cross-checking work/decisions, team monitoring of task performance, food and hydration, task rotation, and estimating sleep. The author's discussed the need for a formal fatigue management system as well as the benefits of formalizing informal risk mitigation strategies to systematically communicate and support fatigue management strategies.

Three individual studies looked at specific fatigue management mitigation techniques.<sup>17-19</sup> The first examined the potential effects of using an optimization approach to shorten seasonal crew travel distances and mitigate fatigue among interagency hot shot crews. The results indicated there is substantial room for improvement in reducing travel distances while still balancing crew fatigue. Coordinating crew dispatching for multiple requests can increase assignment efficiency, particularly when both fatigue mitigation and travel distances are jointly optimized.<sup>19</sup> The new dispatching model considered accumulated fatigue and how transit times also contribute to worker fatigue by building an optimization model that balances travel and fatigue. Accumulated fatigue is included in the model by calculating each crew's total work hours from the preceding 21 days. By running the model across multiple fire seasons and following consistent dispatching policies across regions, the researchers found reduced travel distance, better fatigue mitigation, and increased workload equity.<sup>19</sup>

Two other studies evaluated the effectiveness of glutamine supplementation to help with fatigue and recovery and found that ingesting glutamine before and after firefighter simulations in a heated lab reduced subjective fatigue reports and potentially aided in recovery.<sup>17,18</sup> Specific mitigation techniques such as glutamine could fit within a fatigue management framework but are not as comprehensive and effective as proper work-to-rest standards for recovery.



Another important area of study when it comes to fatigue management is the workforce's perception, interest, and concern level for the particular occupational risk of fatigue. A recent study that aimed to identify the occupational health research priorities of wildland firefighters and related personnel in Canada determined that fatigue and sleep were the second-highest priority only behind understanding and mitigating the effects of smoke inhalation on respiratory health.<sup>20</sup> This study highlights the importance of understanding and mitigating fatigue among the workforce itself.

### Research on Days Off Policies

At this point, no study has directly compared differences in fatigue recovery between differing work schedules of days off for wildland firefighters. Research on the general population, as well as wildland firefighters, does however suggest that both 2 days and 3 days off may not be enough for these workers to recover from work-related fatigue.

A large study conducted on the general population concluded that 3 full nights of recovery sleep are insufficient to restore performance to normal levels after 7 days of short sleeping.<sup>21</sup> In mild to moderate sleep restriction conditions, the brain adapted to sleep restriction to stabilize performance, but at a reduced level. The researchers hypothesized these adaptations would restrict brain operational capacity and persist for several days after normal sleep duration is restored. Therefore, these adaptations would delay recovering from sleep deprivation.<sup>21</sup>

Several studies assess the effects of fatigue over multiple days of fire suppression and one begins to include the effects of fatigue from working an entire season of fire. The most relevant studies on the topic of 3 days off examined sleep loss and fatigue in British Columbia Wildfire Service Firefighters over a 14-day fireline deployment, followed by a 3-day rest period. One of these studies used a biomathematical model and concluded that shift duration was the major contributor to fatigue.<sup>22</sup> Prolonged wakefulness over multiple shifts can produce sleep debt (the accumulated difference between the actual number of hours a person sleeps and the ideal nightly hours of sleep a person should be getting) that can have serious effects on performance, judgment, and mood.<sup>22</sup> Models of fatigue such as the one created in this study can help identify scheduling practices that are known to contribute to fatigue and sleep deprivation and in turn promote a safer design of work hours and days.<sup>22</sup>

The second study aimed to gain a better understanding of the effects of the 14-day deployment and 3-day off schedule on fatigue and sleep deprivation. Participants became more fatigued toward the end of the 17 days compared to day 1 and continued to report high levels of sleepiness, fatigue, and poor-quality sleep on their rest days.<sup>23</sup> Participants showed significantly slower reaction times on day 13 compared to day 5 and a significant decrease in reported alertness from day 3 compared to day 13. Firefighters self-reported significantly higher levels of fatigue on day 16 compared to day 5. The average sleep quality was slightly higher during deployment days compared to rest days. Firefighter's subjective sleepiness was higher on day 16 compared to day 1, indicating that subjective sleepiness did not improve at all with 2 days' rest. Total sleep time was below the current recommended guidelines for adults (7-9 hours a night) during both fire and rest days in all participants.<sup>23</sup> Subjective levels of alertness, fatigue, and sleepiness did not return to levels at the beginning of the study following a 3-day rest period. The results indicate that the rest period did not provide the opportunity for wildland firefighters to fully recover from the 14-day work schedule. Poor sleep quality during recovery days may be because the effects of sleep deprivation are not overcome with a few nights' sleep after chronic sleep debt.<sup>23</sup> Overall this study found that over the 14-day assignment, participants experienced progressively higher levels of objective fatigue, poor sleep, poor performance on cognitive tests, and increased reported sleepiness.

None of these levels were able to return to their baselines after 3-days off at the end of the 14-day active deployment.<sup>23</sup>

Another study assessing various measures of fatigue on a British Columbia Wildfire Service fire management team found no significant differences in 3 measures of cognitive performance/reaction time throughout a 14-day deployment.<sup>24</sup> However, subjective fatigue and subjective sleepiness showed a significant increase, and alertness, as well as total sleep time, showed significant decreases.<sup>24</sup> This study highlights the importance of measuring both objective and subjective measures of fatigue.

A study using multiple measures to assess sleep and fatigue among Ontario wildland firefighters across a season while on initial attack, project fires, and at base found that between one-third and two-thirds of the sleep measures collected fell outside recommended ranges for adults for all three types of work.<sup>25</sup> The average sleep duration for initial attack was 4.8 hours and 6.2 hours for both base and project fire days. Regardless of shift duration, sleep measures were suboptimal. These Ontario wildland firefighters' work schedules dictated that they could work up to 14 consecutive days with 2 days of travel at either end before a minimum of 2 days rest is mandated.<sup>25</sup> Changes to the days off standards could be one targeted intervention to improve sleep and fatigue measures. The authors noted that the finding that non-fire work on base was also associated with suboptimal sleep was particularly concerning, as this could increase the risk of pre-deployment sleep debt, furthering fatigue and sleep issues once deployed.

The studies that assessed measures of fatigue related to days off and recovery periods point to the need for longer recovery time between fire assignments and the added benefit of adding an extra day off.

### Original Research on Various Aspects of Fatigue

Many of the articles discussed below are briefly covered in the review papers but each individual study contributes in-depth knowledge to the topic of wildland firefighter fatigue. Research thus far into fatigue and sleep in wildland firefighters has revealed some of the most common fatigue-inducing factors of the job as well as the magnitude of impact these factors may have on fatigue and related health measures.

Multiple studies refer to the association between fatigue and safety outcomes such as injuries.<sup>26,27</sup> A study on emergency medical service (EMS) providers determined the association of poor sleep quality and fatigue with self-reported safety outcomes. From a sample of 547 providers from 30 EMS agencies, there were 1.9 greater odds of an injury and 3.6 greater odds of safety-compromising behavior among fatigued respondents versus non-fatigued respondents.<sup>26</sup> Another study examined the relationship between shift length and occupational injury and found the risk of injury was higher for longer duration shifts and shifts greater than 16 hours in length had a 60% greater risk for injury than those between 8 and 12 hours.<sup>27</sup> Though the work of wildland firefighters differs from that of EMS providers, this preliminary evidence provides relevant insight from related occupations.

Ten research papers, 3 review papers (discussed earlier), and 3 abstract presentations from Australian research groups including Vincent, Wolkow, Aisbett, Ferguson, Main, and others assessed various sleep and fatigue outcomes as well as fatigue's association with other variables such as physical activity, heat, and smoke in wildland firefighting. The results of these studies can inform multiple different areas of fatigue management including standards for days off.

Two studies looking at prescribed burns had differing results, one found sleep efficiency, and the number of times woken had worse outcomes during prescribed burns than when at home yet a larger study found no differences between sleep measures if prescribed burn shifts were less than 12 hours in duration.<sup>28,29</sup> In a simulated wildfire suppression scenario that restricted the sleep of firefighters, there were no differences in task

performance, heart rate, core temperature, and rate of perceived exertion or effort between the sleep-restricted (given a 4-hour sleep opportunity) and the control group (given an 8-hour sleep opportunity); however, the sleep-restricted group was less physically active in the simulation.<sup>30</sup> An extended field study of 4 weeks analyzed sleep quantity and quality during fire suppression. No differences were found in self-reported sleep quality and times woken, or measures of sleep latency and efficiency, between non-fire and fire days.<sup>31</sup> Total sleep time was lower while pre- and post-sleep fatigue ratings were higher on fire days compared to non-fire days. Sleep was further negatively impacted when the sleep location was a tent or vehicle, shifts were greater than 14 hours, and shifts started between 0500 and 0600. The average time asleep on fire days was 6.1 hours with 43% of days below 6 hours and occurring on successive days.<sup>32</sup> Consecutive nights of sleep restriction and accumulated sleep debt can be partially addressed with longer rest periods after assignments for recovery.

A lab study found two nights of sleep restriction did not influence firefighters' physical task performance or physiological responses during 3 days of simulated wildfire suppression.<sup>33</sup> A field study found no significant moderating effect of total sleep time.<sup>32</sup> Firefighters can maintain and/or increase their physical activity intensity between consecutive shifts, but as stated earlier this could lead to higher injury risk as well as a lowered capacity for recognizing the nonphysical types of fatigue present.

Sleep restriction and physical work are connected stressors faced by firefighters. A study by Wolkow et al. investigated the effect of sleep restriction across a firefighting deployment on the physiological factors cytokine, cortisol, and heart rate, their interactions, and how mood may influence these physiological changes. Four-hour sleep-restricted firefighters had elevated cortisol but no difference in heart rate or cytokine responses above any disturbance caused by physical work alone. The sleep-restricted group showed increases in a negative mood that was also associated with higher cortisol and cytokine level.<sup>34</sup>

In a 3-day simulation of physical firefighting, sleep-restricted firefighters had increases in general fatigue, perceived stress, and depressed mood on the multi-component training distress scale that were related to elevated cytokines. Firefighters who were not sleep-restricted had an inverse relationship between depressed mood and decreasing cortisol and cytokines. The study showed utility in using psychological measures to understand the physiological impacts of fatigue.<sup>35</sup>

Another Wolkow et al. study demonstrated that an 8-hour sleep opportunity between shifts could potentially mitigate rises in evening cortisol which can protect against adverse health effects.<sup>36</sup> In a related study, more research showed that positive associations between negative mood and inflammatory and cortisol levels to physical work and restricted sleep provide useful information to fire agencies about subjective fire-ground indicators of physiological changes.<sup>35</sup>

Lastly, a sleep restriction study based the sleep opportunity on previously reported average rest on the fire ground. When studying the inflammatory responses from acute cytokine levels, researchers determined there could be a non-damaging response to simulated physical firefighting work and that physical work could have been the major stressor in the study compared to sleep restriction.<sup>37</sup> Because of the link between elevated cytokine levels and several diseases though, the authors see the importance of assessing cytokines over longer and more realistic work periods.<sup>37</sup>

The research on fatigue in wildland firefighters spans many measures, factors, and potential areas of fatigue management. Below in Table 1 is a summary of how the studies discussed in this paper measure fatigue and their main findings. Though the findings vary, the evidence has demonstrated the importance of managing and

mitigating fatigue in the wildland firefighting profession. Mitigation strategies on every level can improve health outcomes, safety, performance, and the overall quality of life for wildland firefighters.

**Table 1:** A summary of original research studies measuring fatigue among wildland firefighters

| <b>Study</b>         | <b>Fatigue Exposure</b>                                     | <b>Fatigue Measures</b>  | <b>Main Findings</b>   |
|----------------------|---|--|--|
| Belenky 2003         | Chronic sleep restriction                                   | Psychomotor vigilance task (PVT)                                       | Reduced vigilance, reaction time, and cognitive capacity.  |
| Belval 2018          | IHC Dispatches  | Work time, workload, and travel factors                                | Dispatch optimization can reduce fatigue and travel.   |
| Cvirn 2017           | Sleep restriction, physical activity, heat                  | Polysomnography, activity monitoring                                   | Sleep restriction is more detrimental to firefighters' sleep than heat while working.  |
| Dawson 2015          | Wildland firefighting                                       | Informal fatigue mitigation strategies                                 | Formalizing fatigue mitigation strategies and increased communication can reduce fatigue.  |
| Gaskill 2002         | Wildland Firefighting                                       | Self-reported hours of sleep   | Average sleep was 7 hours a night, and most firefighters were resting adequate amounts   |
| Jeklin 2020          | 14-day deployment and 3 rest days                           | PVT, fatigue questionnaire, actigraphy, sleep questionnaire            | 14-day deployments are associated with suboptimal sleep, objective fatigue, and decreased alertness. 3 days of rest was not adequate for recovery.                                 |
| Jeklin 2021          | Shift parameters of wildland firefighting                   | Actigraphy, sleep diary  | Shift duration was the greatest contributor to fatigue and biomathematical models can provide insight into contributing parameters.  |
| Jeklin, Perrota 2021 | 14-day deployment for incident management personnel and age | Actigraphy, visual analog scale, heart rate variability, reaction time | Heart rate variability can be a practical tool for monitoring and assisting in managing fatigue. Older age was positively associated with increased fatigue and sleep deprivation. |
| McGillis 2017        | A season of wildland firefighting                           | Actigraphy, questionnaires   | 1/3 to 2/3 of sleep measures fell outside optimal ranges during the time at the base, initial attack, and project fires. The initial attack had the worst outcomes.                |
| Moore 2019           | Wildland firefighting simulation in the heat for 2 days     | Perceived fatigue, biological stress                                   | Glutamine supplementation was associated with a small decrease in perceived fatigue.   |
| Nava 2019            | Simulated wildland firefighting for 2 days                  | Subjective fatigue, markers of inflammation, cellular stress           | Gastrointestinal damage, subjective fatigue, and ratings of perceived exertion were lower after glutamine supplementation.   |

|                       |   |   |   |
|-----------------------|---|---|---|
| Patterson 2012        | Emergency medical services work   | 19-item Pittsburgh Sleep Quality Index, 11-item Chalder Fatigue Questionnaire, and 44-item EMS Safety Inventory | Poor sleep quality and fatigue are common among emergency medical service workers and these outcomes are associated with safety outcomes.   |
| Vincent 2015          | Simulated wildland firefighting physical tasks and sleep restriction                                  | task performance, heart rate, core temperature, perceived exertion, and effort sensation                        | 4 hours of sleep restriction did not adversely affect firefighters' performance on physical work tasks but the sleep-restricted group was less physically active.   |
| Vincent 2016          | Multi-day wildfire suppression: shift length, shift start time, incident severity, and sleep location | Sleep/work diaries, actigraphy  | Sleep quantity is restricted, and fatigue ratings are higher during suppression compared to non-fire days. Sleep time is less if the sleep location is a tent or vehicle, shifts are over 14 hours, or shift start time is between 0500 and 0600. |
| Vincent, Aisbett 2016 | Prescribed burning  | Actigraphy, subjective reporting  | Sleep quantity and quality showed no differences comparing non-burn and burn days. Total sleep time was less when planned burn shifts were >12 h. Subjective sleep fatigue was higher on burn days.   |
| Vincent, Ridgers 2016 | Wildfire suppression  | Actigraphy  | Sleep duration did not moderate the association between physical activity and consecutive suppression shifts.   |
| Vincent 2018          | Simulated hot wildfire conditions   | Ratings of perceived exertion, heart rate, core temperature, actigraphy, polysomnography                        | Two nights of sleep restriction did not influence physical task performance or physiology under hot conditions.   |
| Weaver 2015           | Emergency medical service shift length and teamwork factors   | Shift schedules, occupational and illness reports   | Occupational illness and injury are lower for shifts equal to or less than 8 hours.   |
| Wolkow 2015           | 3 days of simulated wildfire suppression work with sleep restriction                                  | Blood samples for cytokine measurements, cortisol measurements  | There is a potential disturbance of a cytokine and cortisol relationship when sleep is restricted.  |
| Wolkow, Ferguson 2015 | 3 days of simulated wildfire suppression work   | Blood samples for cytokine measurements,  | There could be a non-damaging response to the stress of firefighting work but further research is needed  |

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|                                | with sleep restriction   |   | during repeated firefighting deployments.  |
| Wolkow 2016                    | 3 days of simulated wildfire suppression work with sleep restriction | Self-reported psychological factors using the multi-component training distress scale, cytokine and cortisol levels | When sleep was restricted firefighters showed increases in general fatigue, perceived stress, and depressed mood that were related to elevated cytokines.  |
| Wolkow, Aisbett, Reynolds 2016 | 3 days of simulated wildfire suppression work with sleep restriction | Mood Scale II and Samn-Perelli fatigue scale, cytokine and cortisol levels  | Mood and fatigue responses to the scales were related to cytokine levels. Positive associations between negative mood and inflammatory and cortisol levels to physical work and restricted sleep provide useful information to fire agencies about subjective fire-ground indicators of physiological changes. |

## Conclusion

Many of the studies discovered associations between fatigue and factors that were indirectly related to days off and directly related to other areas of work/rest and fatigue management. As fire agencies continue to adapt and adopt policies and standards to improve fatigue measures for wildland firefighters, these factors such as shift start time, shift length, sleeping location, and days on assignment should be considered.

Working extended shifts with little rest between work periods has been shown to result in a reduced opportunity to obtain adequate sleep which in turn can lead to a multitude of health impacts. Previous research done in the field and laboratory has further demonstrated that successive days of sleep loss can result in chronic sleep deprivation and are associated with neurocognitive performance deficits, poor judgment, and poor hazard recognition, which may have serious workplace consequences.<sup>24</sup>

From the currently available research, increased time off has been shown to reduce both short-term and long-term fatigue and improve sleep, which overall can further protect wildland firefighter health.

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