WHAKARATONGA IWI

FIRE EMERGENCY NEW ZEALAND

FATIGUE IN FIREFIGHTING AND ASSOCIATED SUPPORT ROLES

Sleep/Wake Research Centre, Massey University

October 2020

This report is a review of literature examining:

- The impact of fatigue on firefighting and associated support roles within Fire & Emergency New Zealand that involve shift work (e.g., communications centre) or potentially long hours (e.g., deployments).
- Interventions that have been used with firefighters/on-call shift workers to improve fatigue management.

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MASSEY UNIVERSITY
TE KUNENGA KI PŪREHUROA
UNIVERSITY OF NEW ZEALAND

RAPID REVIEW:

FATIGUE IN FIREFIGHTING AND ASSOCIATED SUPPORT ROLES

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INTRODUCTION

This report has been generated in response to a request from Fire & Emergency New Zealand for the Sleep/Wake Research Centre to conduct a rapid review of the literature on fatigue that is of direct relevance and interest to Fire & Emergency New Zealand. Specifically, we have conducted a review of the literature examining:

- the impact of fatigue on firefighting and associated support roles within Fire & Emergency New Zealand that involve shift work (e.g., communications centre) or potentially long hours (e.g., deployments).
- interventions that have been used with firefighters/on-call shift workers to improve fatigue management.

Occupational fatigue is a broad term, often used to describe a wide range of symptoms. For this reason, there can be confusion about what constitutes 'fatigue', and its causes and consequences. For the purposes of this report, we have framed our review using an internationally accepted definition of occupational fatigue:

> *Fatigue is a physiological state of reduced mental or physical performance capability resulting from sleep loss or extended wakefulness, circadian phase or workload (mental and/or physical work) that can impair an individual's alertness and ability to safely perform their work-related duties" (International Civil Aviation Organisation, 2016).*

In light of the definition of fatigue provided above, we have aimed to select literature that explicitly measured fatigue; included measures of work patterns that are likely to lead to fatigue (i.e., shift work); or included measures of physiological factors that contribute to fatigue (i.e., sleep loss, extended wakefulness, circadian disruption, workload). To examine the impact of fatigue, we have selected literature that has investigated fatigue and its contributors in relation to outcomes such as physical health, mental health, physical performance and cognitive performance.

The rapid review of the literature has been used to:

- comment on the relevance of the reviewed literature for Fire & Emergency New Zealand.
- identify critical areas for future research relevant to Fire and Emergency New Zealand.
- identify issues relevant for the review of Fire and Emergency's fatigue management policy.

METHODS

We conducted several searches to identify available academic literature relevant to the review aims. Using the EBSCO Discovery Service, the PubMed, Medline, psycINFO, Web of Science and CINAHL databases were searched simultaneously. Additional searches were run in the Scopus and Cochrane Reviews databases (using the same key words and limiters) to identify relevant literature. In all cases searches were limited to peer-reviewed literature published between January 2010 and May 2020 (10-year period).

The search terms used were optimised with the help of a Massey University librarian. The final search terms were:

1. (firefight* OR "fire fight*" OR firemen*) AND (tired* OR fatigue* OR sleep* OR shiftwork* OR "shift work*")

2. (firefight* OR "fire fight*" OR firemen*) AND (tired* OR fatigue* OR sleep* OR shiftwork* OR "shift work*") AND (interven* OR manag*)
3. (fatigue* OR sleep* OR tired*) AND (shiftwork* OR "shift work*") AND "on call"
4. ("emergency dispatcher*" OR "911 dispatcher*" OR "9-1-1 dispatcher*") AND (fatig* OR tired* OR sleep* OR "shift work*" OR shiftwork*)
5. dispatcher* AND (fatig* OR tired* OR sleep* OR "shift work*" OR shiftwork*)
6. (emergency OR emergencies OR crisis OR crises) AND ("call centre*" OR "call center*" OR "contact centre*" OR "contact center*" OR dispatch*) AND (fatig* OR tired* OR sleep* OR "shift work*" OR shiftwork*)
7. ("emergency reporting" OR "emergency communication*") AND (fatig* OR tired* OR sleep* OR "shift work*" OR shiftwork*)

Results from these searches were exported into EndNote X9 software where duplicates were first removed using the 'Find duplicates' function. Owing to differences in the formatting of references, this function removed most, but not all, duplicates. As such, records were then manually checked for duplicates, which were in turn removed. Once duplicates had been removed, records were checked to ensure they met the criteria agreed by the research team: abstracts, editorials, legal matters and articles for which the full text was not in English were excluded. The number of duplicates removed, and records identified for screening, is provided in Figure 1.

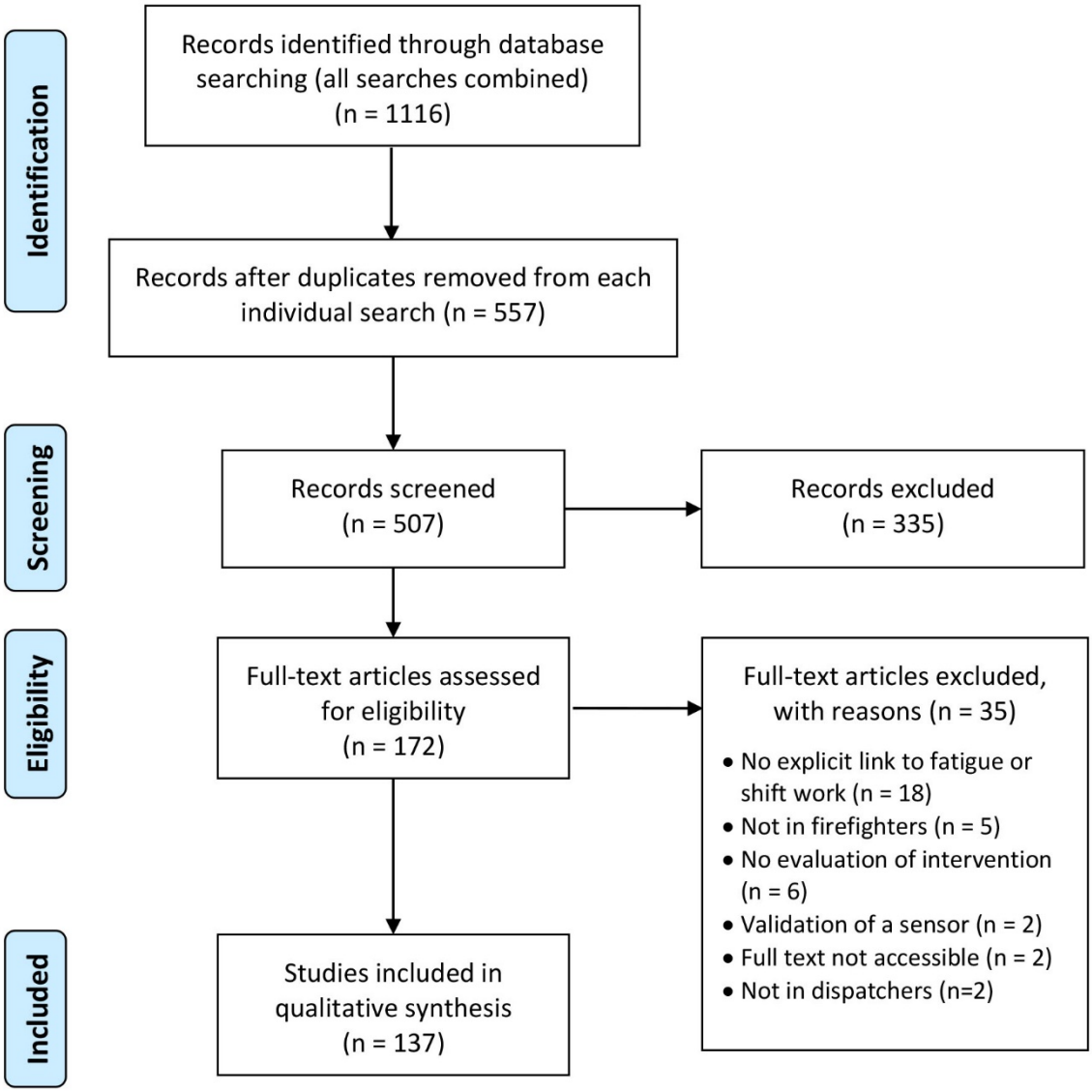
Records for screening were divided equally between three researchers (KO, JZ, LS) with each allocated a set number of abstracts to review. During this process, we identified records:

1. for which the full text would need to be assessed for inclusion,
2. that could be excluded based on the abstract (i.e., records that did not pertain to the review aims),
3. for which we were unsure about whether to include.

All of the records for which we were unsure about inclusion were then reviewed by a second researcher and either noted for reading of the full text or excluded. Records relating to case studies, validations of measures or sensors, and studies of 9/11 first responders were excluded. Additionally, for the searches relating to search terms 1 & 2, studies which included non-firefighters only were excluded. Similarly, for the search using search terms 3, studies which did not include an intervention were excluded. This process led to 172 records being identified for further assessment (Figure 1).

There was overlap in the search results. For example, eight records identified in the emergency communications searches (searches 4-7) had already been identified in the firefighting and fatigue searches (searches 1 &2), while five records identified in the on call interventions search (search 3) had already been identified in either the firefighting and fatigue or the emergency communications searches (searches 1, 2, 4-7). These records have only been included once in Figure 1.

FIGURE 1: PRISMA FLOW DIAGRAM OF THE PHASES OF THE RAPID REVIEW



RAPID LITERATURE REVIEW

SLEEP AND SHIFT WORK

Sleep in firefighters has been investigated in a number of ways, including using actigraphy[1] and sleep diary to capture sleep characteristics, and questionnaires to assess sleep quality and the presence of sleep disorders. These studies have generally investigated differences in sleep characteristics in those who worked shift work compared with those who did not; the relationships between having a sleep disorder or poor sleep quality and health and well-being outcomes; and the impact of short sleep on performance and health outcomes. It is clear that short sleep and poor quality sleep are experienced by firefighters as a result of their work patterns, and that a concerning proportion of firefighters have sleep disorders (Aisbett et al., 2012, Vincent et al., 2018a, Larivière et al., 2016).

An examination of actigraphic sleep among 363 Korean firefighters found no difference in sleep characteristics between shift workers and day workers, when working day work (Jeong et al., 2019). However, sleep efficiency and total sleep time was lower, and wake after sleep onset was higher, among those who worked shift work (both during night shifts and rest days), compared to those who only worked day work. In those who worked shift work, mean total sleep time per 24 hours was 5.8±1.5hr during day work, 4.5±1.4hr during night work and 5.7±1.7hr on rest days. Studies including focus groups and interviews with fire personnel support these findings. Sleep difficulties were an area of concern among firefighters while at work due to disruptions from calls and anticipatory effects on sleep due to the potential for call (Jahnke et al., 2012). These disruptions had flow-on effects for sleep while at home.

Sleep quality has been measured in firefighters and emergency communications personnel using the Pittsburgh Sleep Quality Index (PSQI)[2] (Buysse et al., 1989). In firefighters, greater PSQI global scores have been observed in those working shift work, compared with those working day work only (Abbasi et al., 2020, Lim et al., 2014). A study of 657 urban Korean firefighters found that 48.7% had poor sleep quality and that shift workers were more likely to report poor quality sleep (OR 1.58) (Lim et al., 2014). Poor quality sleep was less prevalent among those who were older and had more work experience, but was more prevalent among those experiencing depression, and psychosocial and occupational stress. A survey of 109 shift working career firefighters found that 73% reported poor quality sleep and mean PSQI scores were above 5 (indicating poor sleep quality) regardless of shift work schedule (i.e., 24/48[3], 48/96[4] or Kelly[5] schedules) (Billings and Focht, 2016). A study of 45 career firefighters showed that sleep quality was perceived to be worse on-duty than off-duty (Stout et al., 2020). Contrary to these findings, a survey of 427 fire and rescue personnel in Iran found that although 70% of respondents reported poor quality sleep, there were no significant differences in the prevalence of poor sleep between shift workers and non-shift workers (Mehrdad et al., 2013). In this study, shift work was not an independent predictor of having poor quality sleep, but the likelihood of poor sleep quality increased with increasing work experience and was increased among those with a second job. A study of a small group of Brazilian dispatchers (n=20) who are part of the

[1] Actigraphy is a method of monitoring human rest/activity cycles. An actigraph is usually a wristwatch-like device worn on the wrist. They may be worn for several weeks at a time and are useful for determining patterns in sleep and wake.
[2] The Pittsburgh Sleep Quality Index is a 19-item questionnaire assessing 7 components of sleep quality. A global score is calculated from the responses on a scale of 0-21. Scores above 5 indicate poor sleep quality.
[3] The 24/48 schedule has a 24-hrs on/48-hrs off pattern.
[4] The 48/96 schedule has a 48-hrs on/96-hrs off pattern.
[5] The Kelly schedule is a 9-day schedule that follows the pattern: 24-hrs on, 24-hrs off, 24-hrs on, 24-hrs off, 24-hrs on, 96-hrs off.

Military Fire Brigade of Recife found that the majority (60%) of those dispatchers had poor sleep quality (based on the PSQI) and a small proportion (15%) experienced sleep disturbances (de Carvalho Dutra, 2017).

Sleep disorders have been examined in firefighters using validated scales to assess excessive sleepiness (Epworth Sleepiness Scale[6] (Johns, 1991)), insomnia (Insomnia Severity Index[7] (Bastien et al., 2001); Athens Insomnia Scale[8] (Soldatos et al., 2003)), obstructive sleep apnoea (Berlin Questionnaire[9] (Netzer et al., 1999)), and restless legs (Restless Legs Epidemiology, Symptoms and Treatment Questionnaire[10] (Allen et al., 2005)). Obstructive sleep apnoea has also been examined among firefighters using objective measures of polysomnography[11] and oximetry[12] (Jay et al., 2016). A large survey (n=6,933) of (99% career) US firefighters, which examined the relationship between having a sleep disorder and reporting a motor vehicle accident in the last month, found that 37.2% screened positive for a sleep disorder (Barger et al., 2015, Weaver and Barger, 2019). Firefighters who screened positive for a sleep disorder were significantly more likely to report a motor vehicle crash (OR 2), a near crash (OR 2.49), and feeling drowsy or falling asleep while driving (OR 2.41). They were also more likely to report having cardiovascular disease, diabetes, depression, and anxiety, and have lower health status.

Surveys of insomnia prevalence and severity in firefighters have varied in their quality. Some have included small samples of shift working firefighters (Choi et al., 2020, Jeong et al., 2015, Wolińska et al., 2017). These studies have shown that validated insomnia scales are reliable tools to measure insomnia among firefighters (Jeong et al., 2015), but they have not always been able to demonstrate relationships between work characteristics and insomnia prevalence or severity (Jeong et al., 2015, Wolińska et al., 2017). Choi et al. (2020) examined insomnia severity among 276 participants, of which 60 were firefighters working 24hr every-other-day schedules. Insomnia severity was more severe among shift workers and was correlated with depression and anxiety severity in firefighters. A large survey of all Korean firefighters (n=9,100, 21% response rate) found that the prevalence of

[6] The Epworth Sleepiness Scale (ESS) is an 8-item questionnaire, where respondents are asked to rate, on a 4-point scale (0-3), their usual chances of dozing off or falling asleep while engaged in eight different activities. The ESS score (the sum of the 8 item scores) can range from 0-24. The higher the ESS score, the higher that person's 'daytime sleepiness'. Sleepiness is considered excessive at 11 or above on the scale.

[7] The Insomnia Severity Index (ISI) is a 7-item assessment tool designed to evaluate insomnia severity in the last two weeks. Items are rated on a 5-point scale (0-4). Total scores range from 0-28, with higher combined scores indicating worse insomnia severity.

[8] The Athens Insomnia Scale (AIS) is an 8-item assessment tool designed to diagnose insomnia according to ICD-10 criteria. Items are rated on a 4-point scale (0-3). Total scores range from 0-24, with 0 denoting absence of any sleep-related problem and 24 representing the most severe degree of insomnia.

[9] The Berlin Questionnaire is a 10-item screening tool (grouped into three categories) used to identify the risk (low to high) of obstructive sleep apnoea (OSA). Respondents are scored as being at high risk for OSA if they have a positive score on two or more categories, while those who do not are scored as being at low risk.

[10] The Restless Legs Epidemiology, Symptoms and Treatment Questionnaire is a 3-part assessment tool used to assess whether a person has Restless Legs Syndrome (RLS) and the severity of their condition. Part 1 collects information on recent medical consultations and current diagnoses. Part 2 includes four diagnostic questions for RLS, which are based on standard diagnostic criteria, and collects information about the frequency of RLS symptoms and the degree of associated distress. Part 3 is administered only to those who respond positively to Part 2 and is designed to collect more detailed information on the frequency, nature, and impact of RLS symptoms, consultation rates, diagnosis, and treatment.

[11] Polysomnography is a multi-signal sleep study that records at a minimum electroencephalography (EEG; brain waves), electrooculography (EOG; eye movements) and electromyography (EMG; muscle tone) to be able to determine sleep stages. In addition, breathing, muscle movements, oxygen levels and heart activity (ECG) may be recorded.

[12] Pulse oximetry is used to measure the oxygen level (oxygen saturation) of the blood.

mild-severe insomnia using the Insomnia Severity Index was 41.8%, and the prevalence of moderate-severe insomnia was 9.1% (Jang et al., 2020). Those with insomnia were more likely to report experiencing more fatigue on the Fatigue Severity Scale, as well as experiencing depression and anxiety. Firefighters involved in fire suppression work or emergency medical services/rescue work were more likely to report insomnia, than those involved in administration roles. Firefighters worked a range of 3-, 6-, 9- or 21-day shift cycles. There was no association between work schedule type and the likelihood of insomnia. However, as the frequency of emergency callouts per week and off duty work (overtime) per month increased, the likelihood of experiencing insomnia increased. A recent review of literature pertaining to mental and physical health challenges experienced by emergency service call-takers and dispatchers indicated that insomnia was a common complaint associated with shift work and that both exposure to traumatic calls and the need to exhibit emotional neutrality when responding to calls resulted in nightmares and difficulties sleeping (Smith et al., 2019a).

Studies examining excessive sleepiness among firefighters using the Epworth Sleepiness Scale have found that firefighters who report excessive sleepiness are more likely to report insufficient sleep in general and while on duty (Haddock et al., 2013). Reporting excessive sleepiness while on duty was associated with problems with sleep at home (i.e., initiating and maintaining sleep, and early morning awakening) and at work (i.e., maintaining sleep). Those reporting excessive sleepiness on duty were more likely to work 48-hour shifts and have a second job outside the fire service, worked more hours outside the fire service, and were less likely to report that their departmental sleep quarters were private. A study assessing the impact of changing from a Kelly schedule to a 48/96 schedule found that as the average sleep duration increased, sleepiness (measured using the Epworth Sleepiness Scale) decreased (Caputo et al., 2015).

A robust assessment of sleep among volunteer firefighters has been conducted in a series of studies examining the impact of sleep restriction and heat on sleep characteristics during simulated wildfire suppression (Cvirn et al., 2017, Jay et al., 2016). In relation to sleep, these studies included three conditions in a 3-day/4-night simulation: control, awake, awake/hot. The study involved a baseline night with an 8hr sleep opportunity, and 2 experimental nights with either an 8hr (control) or 4hr sleep opportunity (awake; awake/hot), and a recovery night with an 8hr sleep opportunity. Ambient temperature was kept between 18-20˚C for day and night for the control and awake conditions, and 33-35˚C for day and 23-25˚C for night in the awake/hot condition. Sleep was assessed objectively using polysomnography. Polysomnographic sleep measurements showed that, in the awake and awake/hot conditions, stage N1 (lightest) sleep decreased from baseline by experimental night 2; and stage N2 (light) sleep and REM sleep decreased from baseline over both experimental nights 1 and 2, compared with the control condition (Cvirn et al., 2017). There was no difference in stage N3 (deep) sleep during experimental nights in the awake and awake/hot conditions, compared with the control condition. Those with sleep disordered breathing had more wake after sleep onset and arousals during sleep, and less stage N3 (deep) sleep and REM sleep (Jay et al., 2016).

An additional compelling study has examined sleep in volunteer firefighters during multi-day wildfire suppression using sleep diaries and actigraphy (Vincent et al., 2016a) (n=40, 214 shifts). Sleep has been compared on fire days (work) and non-fire days (non-work). Vincent et al. (2016a) found that time in bed was 1.07±0.19hr less and total sleep time was 0.90±0.25hr less on fire days, compared with non-fire days. Notably, the amount of sleep obtained by firefighters on fire days was very variable (8% <4hr, 35% 4–6hr, 51% 6–8hr and 6% >8hr). Total sleep time was less when sleeping in a tent or vehicle, compared with at home or in a motel. Total sleep time was less when shifts were longer than 14h, compared to all other shift types (<10hr, 10-12hr, 12-14hr). Pre-shift total sleep

time was less when shifts started between 5-6am, compared to all other shift start times (6-7am, 7-8am, 8-9am). Subjective fatigue ratings, measured using the Samn-Perelli Fatigue Checklist[13], were higher pre-sleep compared to post-sleep, on both fire days and non-fire days. On fire days, both pre- and post-sleep fatigue were higher, compared to non-fire days.

A similar study investigated sleep among 21 wildland firefighters (McGillis et al., 2017) and compared sleep during base work, the initial attack and suppression deployments. Total sleep time was lower during the initial attack (mean 4.8±1.2h) than during base work (mean 6.2±1.2h) or suppression deployments (mean 6.2±0.9h). Sleep efficiency was lower during the initial attack than for suppression deployments, but wake after sleep onset did not differ between types of work. It was, however, consistently high for all types of work. The proportion of firefighters who got less than 7 hours of sleep per 24 hours was high for all types of work (base 86%, initial attack 100%, suppression 81%). There were no differences in total sleep time, sleep efficiency or wake after sleep onset when comparing different deployment lengths (short (1-3 days), med (4-7 days) and long (>7 days)) or shift lengths (<12hr, 12-13hr, >13hr). Total sleep time was lowest when shifts started at 5-6am, compared to 6-7am and 7-8am. Reaction times, measured using the psychomotor vigilance task (PVT)[14], were higher during the initial attack, compared with suppression deployments. Interestingly, subjective fatigue on waking was higher for shifts starting at 7-8am than shifts starting at 5-6am and 6-7am. For an excellent review of sleep in wildland firefighters, including articles beyond the scope of this rapid review, please see Vincent et al. (2018a). The articles in Vincent et al.'s review that fall within the scope of this review have been included in this report. The review by Vincent et al. includes literature examining wildfire firefighters' sleep duration and quality, factors that influence sleep during wildland firefighting, and the impact of sleep on health, performance and safety.

Vincent et al. (2016b) has also examined sleep during planned burn operations. Most deployments in this study were for 1-3 days (72%), but the remaining deployments were for up to 9 days. There was no difference in time in bed, actigraphic total sleep time, or subjective total sleep time between burn and non-burn days. There was no difference between burn and non-burn days for sleep efficiency, sleep onset latency, and subjective reports of times woken or sleep quality. Time in bed was on average 33 min less when shifts were >12hr, compared to <10hr and 10-12hr shifts. Total sleep time was on average 28 min less when shifts were >12hr, compared to 10-12hr shifts. Shift start time had no impact on time in bed or total sleep time. In line with the previous study (Vincent et al., 2016a), subjective fatigue ratings were higher pre-sleep compared to post-sleep on both burn and non-burn days, and pre- and post-sleep fatigue were higher on burn days compared to non-burn days.

A study of 61 fire service workers working the Kelly schedule, which included daily mood and sleep diaries and actigraphy, found that increased self-reported total sleep and reduced wake after sleep onset during recovery sleep periods were associated with decreased stress, fatigue and irritability outcomes (Kelly et al., 2019). These relationships were not observed for objective measures of sleep using actigraphy. The amount of sleep obtained did not mediate (i.e., explain) the relationship between emotional regulation and stress, fatigue and irritability. In a study of 115 firefighters completing an online survey, self-reported total sleep time did not correlate to people's beliefs about the origin and consequent outcomes of a situation (locus of control) (Rucas and Miller, 2013).

[13] The Samn-Perelli Fatigue Checklist is a 7-point rating scale that asks a person to rate their current level of fatigue from 1 (fully alert; wide awake) to 7 (completely exhausted; unable to function).
[14] The psychomotor vigilance task (PVT) is a simple reaction time test that requires a person to push a button as quickly as possible in response to a stimulus (usually a numerical counter) displayed at random intervals.

However, those experiencing sleep loss (working more consecutive night shifts) experienced more external locus of control (i.e., success or failure is a result of factors beyond their control) with a higher sleep debt, and then more internal locus of control (i.e., events and outcomes are controlled from their own actions) as sleep time increased.

One study has attempted to examine circadian adaption among firefighters working 4-night/4-day/4-off vs. 7-night/7-day/7-off schedules using overnight salivary melatonin and Karolinska Sleepiness Scale[15] ratings during the last night shift worked before changing to a day shift (Kazemi et al., 2018). The authors suggest that circadian adaptation is greater among those working 7 consecutive night shifts. Unfortunately, this study has some limitations including incorrect reporting of the data. As a result, the findings are not reliable.

> Firefighters commonly experience short sleep and poor sleep quality as a result of their work patterns, and a concerning number of firefighters have sleep disorders. Sleep opportunities should be a primary consideration in the design of work schedules and pathways provided for screening for sleep disorders, and diagnosis and treatment, as needed.

PHYSICAL AND COGNITIVE PERFORMANCE

A review by Aisbett et al. (2012) examined the impact of sleep restriction, smoke inhalation and exposure to heat on performance. The authors highlighted that the wider scientific literature provided insight into the effect of individual stressors on performance among firefighters and it could be concluded that these individual stressors impacted on performance. However, they also concluded that very little was known about the interactive effects of these stressors on performance in the wider literature and specifically among firefighters. This gap in the literature has been capitalised upon in a protocol investigating sleep and performance in control, sleep restricted and hot conditions during simulated wildfire suppression with volunteer and career firefighters. The findings in relation to sleep were reported above (Cvirn et al., 2017).

Further examination of the impact of these control, sleep restriction and hot conditions on performance have been reported in a number of articles (Ferguson et al., 2016, Smith et al., 2016, Vincent et al., 2018b, Vincent et al., 2015). The findings from this study have demonstrated that heart rate, core temperature and perceived ratings of exertion were unaffected by sleep restriction, but that sleep restricted firefighters were less active during the simulation compared to controls (Vincent et al., 2015). Similar findings have been observed under hot conditions. Sleep restriction under hot conditions did not impact physical task performance or physiology, but ratings of perceived exertion were slightly elevated in sleep restricted firefighters, compared to those who had an 8hr sleep opportunity (Vincent et al., 2018b). In these studies, reaction speed was slowest in firefighters exposed to the combined effects of hot ambient temperatures and sleep restriction, than either effects alone (Smith et al., 2016). The ability to predict one's own performance varied greatly across experimental conditions and between individuals. Predictions of performance were worst in those who were exposed to both sleep restriction and hot ambient temperatures. As the study progressed, the reliability of predictions of performance worsened with each experimental day and within each experimental day as fatigue increased. Using this experimental protocol, Ferguson et al. (2016) has determined that the PVT is the most sensitive objective measure of fatigue and the Samn-Perelli Fatigue Checklist is the most sensitive subjective measure of fatigue under these conditions. They have also concluded that despite the possibility of masking (i.e., concealing the signs,

[15] The Karolinska Sleepiness Scale is a 9-point rating scale that asks a person to rate their current level of sleepiness from 1 (extremely alert) to 9 (extremely sleepy – fighting sleep).

symptoms and effects of fatigue), physical activity does not prevent fatigue-related decrements in performance.

A qualitative study of Australian rural volunteer firefighters has highlighted that firefighters are often working while fatigued during wildfire suppression (Dawson et al., 2015). Firefighters identified that fatigue affected physical performance by negatively impacting balance and hand-eye coordination; increasing slips, trips and falls; and occasionally leading to damage of firefighting equipment and assets. Cognitive performance was affected by fatigue with a loss of situational awareness, impaired memory, difficulties with decision making and ineffective communication.

Using semi-structured group interviews, Paterson et al. (2016) have conducted an important study that investigated the risks associated with the alarm response for Australian metropolitan career and retained firefighters (retained firefighters are paid a retainer fee and then paid an hourly rate when responding to calls and usually also have another part- or full-time job). The work patterns of salaried firefighters are similar to those of New Zealand career firefighters (4 days on, 4 off; 2x10hr day shifts and 2x14hr night shifts) and during work hours they are normally located at the fire station with access to rest facilities during the night hours. However, despite access to rest facilities, many reported going to bed late, if at all, and that their sleep was lighter due the expectation of an alarm, and often disturbed by calls for other appliances. Retained firefighters also reported their sleep being lighter when they were on call and both groups noted difficulties returning to sleep after a call due to the perceived effect of “adrenaline”. Many firefighters reported feelings of grogginess and disorientation on waking suddenly to an alarm, with these feelings sometimes lasting while travelling to an incident and the driver sometimes requiring assistance with navigation and remaining alert. This may also pose a particular risk to retained firefighters while they travel to the station. Both groups reported that sleep inertia (the feelings of grogginess and disorientation on waking) dissipated more quickly if the call was deemed urgent. Firefighters also reported feelings of anxiety and worry in response to an alarm as well as physical symptoms such as an increased heart rate, shaking hands and headache, with the duration of the response equating to the urgency of the incident. Work-life balance and fatigue were reported as concerns by retained firefighters, with conflicts with other employment and limited time with family and friends noted. Fatigue was felt to influence the quality of time with family and pose a serious health and safety risk in their non-fire-service employment.

Much of the literature on performance in firefighting has been conducted to examine particular aspects of physical and cognitive performance (Dennison et al., 2012, Giuliani et al., 2020, Airila et al., 2012, Sumińska et al., 2020). A study with a small (n=12) sample of firefighters who had been regularly participating in exercise sessions has shown that in a simulated fireground test, the time to complete search and rescue tasks was longer when experiencing physical fatigue at the start of the simulation, than when well rested (Dennison et al., 2012). There were no differences between conditions in the other tasks examined (i.e., stair climb, hose drag, equipment carry, ladder raise, forcible entry). Absolute and relative heart rate measures, and post simulation ratings of perceived exertion, were greater when physically fatigued at the start of the simulation than not. It has been shown that for every additional minute of light physical activity a firefighter engages in in a shift, there is 0.12 minutes more of light physical activity and 0.46 minutes more of moderate physical activity in the following shift (Vincent et al., 2015). A study of 32 career firefighters has examined changes in peak performance and the relationship with fatigue before and after the five consecutive work shifts in the Kelly schedule (Giuliani et al., 2020). Acute fatigue and chronic fatigue increased, and inter-shift recovery decreased, as age increased. Normalised peak force was not correlated with acute or chronic fatigue or inter-shift recovery, but a greater positive percentage change in peak

force was related to better inter-shift recovery. Sleep problems have been shown to be negatively related to work ability (Airila et al., 2012), whereas physical exercise and work engagement have been shown to be positively correlated with work ability. Sumińska et al. (2020) observed no difference in cognitive performance in firefighters measured after a 24hr shift (morning) and in the morning on a day off, although this is possibly due to study design and the lack of adequte recovery opportunities between measurements.

Increased wake after sleep onset in sleep periods during a work shift has been shown to be correlated with decreased cognitive performance measured using the PVT and RBANS[16] tasks (Stout et al., 2020). A study examining the impact of cognitive performance after a night of normal sleep and exposure to total sleep deprivation has demonstrated that the number of correct responses decreased in the afternoon of the day after total sleep deprivation compared with baseline (Kujawski et al., 2018). The number of errors on cognitive tasks increased after 12 hours of total sleep deprivation and reached its peak in the afternoon of the day after sleep deprivation. However, a learning effect might have been present over the course of the protocol for the more complex tasks in this study and the study design did not take into account time since waking or circadian variation.

Venet et al. (2018) investigated auditory fatigue in a group of French call centre workers (including both customer service and emergency medical dispatch call centres) who use headsets, and found no evidence of objectively measured central or peripheral auditory fatigue at the end of an 8hr shift. They noted that the noise levels measured in these groups (65.7 dBA) were lower than the thresholds for concern (85 dBA) set out in European legislation and similar to the noise levels experienced by administrative workers. The authors posited that the subjective reports of auditory fatigue may be due to cognitive fatigue rather than actual auditory fatigue.

A study of call duration in a French Emergency Medical Dispatch Centre (responding to medical and trauma calls only) found that call duration increased during night shifts and shifts longer than 8 hours (Montassier et al., 2015). In this study, call length was defined as the time from the first word exchanged with the caller to the time at which the call is transferred to the dispatching physician who performs a medical evaluation over the phone to determine the type and priority level of medical response required. Dispatchers were responsible only for caller interrogation and dispatch and worked shifts classified either as day, morning, evening or night shifts. While significant statistical differences in call length were found for both night shifts (call duration increased by ~10 seconds) and shifts longer than 8 hours (call duration increased by ~4 seconds), the authors indicated that these differences were unlikely to have a clinical effect. However, the authors also noted that this difference in call length may impact on call centre efficiency.

A 4-year retrospective examination of a database of calls to a French fire department has shown that there are times of decreased performance during a 24-hour day. Response time to a call was twice as long at 5am than at 4pm (Touitou et al., 2014, Brousse et al., 2011). However, there was no difference in the 24hr curve profiles of the response lag times to either calls for medical help and calls for road accidents in rural or urban areas (Brousse et al., 2011).

[16] The RBANS task measures processing speed, short term visual memory, psychomotor speed and visual motor coordination.

Posture, gait and balance

While the wearing of personal protective equipment (PPE) impacts on various parameters of firefighters' gait and posture, physical fatigue can also lead to alterations of firefighters' gait and posture (Rosengren et al., 2014).

Evidence from a recent study of career and volunteer firefighters indicates that short simulated firefighting activities (14 minute bouts) induce acute fatigue which impacts on different aspects of firefighters' gait (Angelini et al., 2018, Kesler et al., 2016, Park et al., 2018). In particular, this acute physical fatigue leads to changes in step length, step width, stride length (Park et al., 2018), foot clearance when crossing a stationary obstacle (Angelini et al., 2018) and foot clearance when ascending or descending stairs (Kesler et al., 2016). These fatigue-induced changes in gait are suggestive of compensatory behaviours and increased instability and are further amplified by the carriage of an asymmetric load (such as a hose) on one shoulder. Taken together, these findings indicate that firefighters may be at increased risk of slips, trips and falls following firefighting exercise (Angelini et al., 2018, Kesler et al., 2016, Park et al., 2018). Of note, while firefighters in this study completed the simulated exercises in full PPE, they removed their hood and face piece prior to completing the functional task course where their gait was assessed; this is likely to have improved visibility and may have reduced decrements in foot clearances. An earlier study by the same group observed that following 18 minutes of simulated firefighting exercises in full PPE, firefighters' gait was not significantly affected, but movement errors such as stepping out of bounds or making contact with the obstacle increased (Park et al., 2011), suggestive of impaired stability of firefighters following acute exercise. Alterations in gait indicative of shorter strides have also been observed in experienced firefighters following live burn exercises in PPE (Colburn et al., 2017) although these were less pronounced than in the aforementioned studies and were mediated by participants' ability to self-pace during the study.

In their studies comparing Italian career (full time) and volunteer (part time) firefighters, Pau et al. (2012, 2014) found that both groups exhibited postural balance impairments following a short simulated fire and rescue activity. Although balance may be impacted by age, the career firefighters in this study did not differ in their baseline values of postural sway when compared to their younger volunteer counterparts. By contrast, fatigue had a greater impact on postural sway in the volunteer firefighters than the career firefighters. Compared to baseline, sway area doubled in fatigued volunteer firefighters but was only 38% greater in career firefighters. The authors attributed this difference to the volunteer firefighters being less experienced and having less exposure to challenging balance situations from firefighting activities than their career counterparts.

Injury and accident

Slips, trips and falls are common causes of injuries among firefighters and are influenced by a number of intrinsic and extrinsic factors including fatigue (reviewed in Kong et al., 2013). Studies of French volunteer (and career) firefighters indicate that work-related injury risk and severity are highest during the night (between midnight and 6am) and that this period of increased injury risk maps to a period of slowed response time to medical emergency call outs (Riedel et al., 2019). The relative risk of work-related injuries per hour has been shown to be highest at 2am (Touitou et al., 2014). Work-related injuries were twice as likely to occur during the night than in the morning or afternoon. There also appears to be an interaction of sleep and BMI on injury risk with a study of US male career firefighters finding increased odds of injury in obese firefighters who reported not getting enough sleep compared to obese firefighters who reported getting sufficient sleep (Kaipust et al., 2019). However, this variation in injury risk was not seen in normal weight and overweight individuals.

Exposure to the physical and occupational stressors associated with extraordinary and large-scale fire events such as the Carmel Forest Fire[17] in Israel can have long lasting effects on the firefighters involved in these events. Symptoms, such as fatigue and cough, can persist in the weeks following the event, and in some cases persistent difficulties sleeping and PTSD-type symptoms are observed months after the event (Amster et al., 2013).

> The physical and mental fatigue that arises from the work patterns (i.e., shift work) and workload of firefighters leads to wide-ranging deficits in physical and cognitive performance. These deficits carry health and safety risks.

PHYSICAL HEALTH

MORTALITY

Two studies investigated mortality in firefighters, with both studies mentioning occupational hazards, including shift work, as potentially increasing mortality risk (Farioli et al., 2015, Petersen et al., 2018). However, despite the hazards faced by firefighters, both studies found firefighters had a decreased mortality risk compared to the general population. A study of all on duty US male firefighters working between 1998 and 2012 demonstrated that this population was at decreased risk of sudden cardiac death compared to the general population (Farioli et al., 2015) and a study of 11,775 Danish firefighters working between 1970 and 2014 found lower rates of overall mortality but an increased risk of death from stomach cancer (Petersen et al., 2018). The lower mortality rates are thought to be due to screening at recruitment, on-going health assessments, and firefighters being an active, generally healthy population. An alternative explanation is that firefighters who are predisposed to disease leave the service early.

> Despite the occupational hazards they face, firefighters have lower mortality rates than the general population, perhaps due to a healthy worker effect.

CANCER RISK

There have been two relatively recent meta-analyses of research investigating the risk of cancer in firefighters. The first, in 2006, included 32 studies and looked at 21 different cancer sites[18]. Although this study is outside the timeframe of this review, it is mentioned due to its importance and because it is referred to in multiple more recent publications. This study found a probable risk for four types of cancers: multiple myeloma, non-Hodgkin's lymphoma, prostate and testicular cancer and a possible risk for a further nine cancers. In 2010, the International Agency for Research on Cancer (IARC) undertook a meta-analysis of 42 studies and looked specifically at the four cancers identified in the 2006 study (IARC Working Group on the Evaluation of Carcinogenic Risk to Humans, 2010). IARC concluded that there was a significant excess risk of testicular cancer, prostate cancer and non-Hodgkin's myeloma for firefighters. They also classified firefighting as possibly carcinogenic to humans (group 2B).

Studies conducted since that time have generally supported these earlier findings in relation to an increased risk of prostate cancer (Harris et al., 2018, Pukkala et al., 2014, Barry et al., 2017, Sritharan et al., 2019) and melanoma (Pukkala et al., 2014, Harris et al., 2018). A study by Ahn et al. (2012) was the only one not to find an increased risk of prostate cancer in a study of 33,416 male emergency

[17] The Carmel Forest Fire (2-5 Dec 2010) was the most severe fire in Israeli history due to the intensity and duration of smoke exposure.

[18] Le Masters GK, Genaidy AM, Succop P, et al. 2006. Cancer risk among firefighters: a review and meta analysis of 32 studies. *Journal of Occupational and Environmental Medicine*, 48, 1189-1202.

responders, although they did find an increased risk of colorectal and bladder cancer and non-Hodgkin's lymphoma.

Harris et al. (2018) also found an increased risk of Hodgkin's lymphoma in their study of over 1 million Canadian men that included 4,535 who registered their occupation as firefighters in the 1991 census. Pukkala et al. (2014) found a decreased risk of testicular cancer and increased risk of myeloma, adenocarcinoma of the lung and mesothelioma in older individuals in a study of 16,422 male firefighters.

There is certainly significantly more literature on cancer risk in firefighters than that covered here. However, in all studies of cancer risk reviewed here, circadian disruption due to shift work is mentioned as a possible causal factor. Firefighters are exposed to a range of carcinogens, but no study reviewed had quantified exposure to shift work and thus, its potential contribution to cancer risk cannot be determined.

> Accurate long-term records of an individual's role and associated work patterns would be needed to better understand the possible role of shift work in cancer risk.

Pain

Low back pain is also common in firefighters and is associated with sleep disturbances. Indeed, in Iranian firefighters, low back pain (assessed using the standardized Nordic musculoskeletal questionnaire) was significantly associated with severity of insomnia symptoms on the Insomnia Severity Index (Abbasi et al., 2020). Similarly, in a longitudinal study of Finnish firefighters sleep disturbances were a strong predictor of onset of and persistent radiating low back pain, a relationship that persisted when controlling for age, smoking, physical workload and psychosocial work demands (Lusa et al., 2015).

Markers of inflammation

Our searches identified a number of articles relating to sleep and markers of inflammation in firefighters. These studies reported elevated levels of inflammatory markers in firefighters, however given that both exercise and heat stress impact on these markers, it is difficult to determine whether the elevated levels of inflammatory markers are caused by fatigue or other aspects of firefighting activity. Additionally, the relationships and feedback loops between different inflammatory markers further complicate these observations. Nonetheless, it appears that the conditions experienced by firefighters result in inflammatory changes indicative of physiological stress.

For example, a study of volunteer and career Australian firefighters undertaking a simulated 3-day fireground deployment observed that the duration of the night-time sleep opportunity had differing effects on a range of inflammatory markers. Interleukin-6 (IL-6) increased across the simulated deployment independent of sleep duration suggesting that these changes were due to physical activity and not sleep duration (Wolkow et al., 2015b). Similarly, differences in IL-8 between groups were attributed to increased physical activity in those who received an 8hr sleep opportunity (Wolkow et al., 2015b). By contrast, sleep restriction resulted in elevated afternoon and evening cortisol indicative of a stress response (Wolkow et al., 2016c). Sleep duration also appears to mediate the relationship between morning IL-6 levels and evening cortisol. An 8hr sleep opportunity had seemingly protective effects in terms of the observed inflammatory response since elevated morning IL-6 levels in the 8hr sleep opportunity group were associated with a slight decrease in evening cortisol levels (Wolkow et al., 2015a). Consistent with these findings, Main et al. (2020) observed significant increases in IL-6 and IL-8 following a 12hr wildfire suppression shift in Australian firefighters. However, this study did not account for prior sleep history and it is not possible to

separate any potential effects of the long shift duration from the potential effects of other stressors such as heat exposure and physical exertion.

In a group of Korean firefighters, shift work was associated with increased levels of fibroblast growth factor 23 (FGF-23, an oncogene) and α-klotho (a tumour suppressor gene) when compared to firefighters who worked day shifts only (Min et al., 2020). While this study indicates that FGF-23 and α-klotho may be useful pre-clinical biomarkers of cancer risk in firefighters, the study did not account for other exposures, such as heat and smoke during the studied shifts, making it difficult to attribute this response to shift work alone. However, it is clear that night call outs induce a physiological strain in on-call firefighters with those who were called out during the night demonstrating increased cortisol awakening response compared to those who were off-call or on-call without a call out (Hall et al., 2019).

Changes in physiological markers of stress are also associated with changes in self-reported mood and fatigue in different groups of firefighters. Indeed, in the simulated fireground deployment study mentioned above, variations in IL-6 and IL-8 cytokines between the control and sleep restriction groups were also related to changes in self-reported mood, stress and sleepiness (Wolkow et al., 2016a, Wolkow et al., 2016b). Similarly, in fire service instructors leading a 4 week heat instruction course, the physical fatigue associated with repeated heat exposures altered their perception of fatigue in relation to their core body temperature leading to increased ratings of perceived exertion at the end of the course (Watt et al., 2016).

In a small group of Canadian paramedics (n=21; including dispatchers and ambulance attendants), the type of work (dispatch vs. ambulance attendance) and the type of shift (rotating day-night vs. day shift only) impacted on job strain and physiological markers of stress (Wong et al., 2012). This was a small pilot study designed to determine whether the study protocols were feasible in this occupational group and did not detect any significant statistical differences. Nonetheless, the observed trends consistently demonstrated increased physiological strain (i.e., altered cortisol and α-amylase profiles, reduced heart rate variability, greater endothelial dysfunction) in dispatchers compared to ambulance attendants, and in rotating shift workers compared to those who worked day shifts only (Wong et al., 2012). Similarly, in a study of French emergency medical dispatchers, stress as assessed by elevated salivary cortisol, was linked to the type of tasks undertaken during a 12hr day shift (Bedini et al., 2017). Dispatchers in this study worked from 7am-7pm but were responsible for a single type of task during their shift[19]. Due to the inherent stress associated with receiving and evaluating incoming emergency calls, salivary cortisol levels were highest on shifts where dispatchers were tasked with dealing with incoming calls and varied based on the severity of the emergency. Salivary cortisol levels also increased more in men than in women in response to stress (Bedini et al., 2017), a finding which is consistent with previous studies.

CARDIO-METABOLIC HEALTH

Firefighting activities are associated with cardiovascular responses indicative of cardiac strain and place firefighters at increased risk of cardiovascular disease which can be mediated through the adoption of healthy behaviours (Banes, 2014). However, adoption of these behaviours can be hindered by certain cultural factors inherent to firefighting work such as shift work, crew cohesion, and intrapersonal, interpersonal and organizational influences (Banes, 2014). For example, in a group of Nigerian public sector firefighters, the observed prevalence of hypertension was largely

[19] They were either responsible for dealing with incoming emergency calls (including evaluation of the situation and classification of the level of emergency), dispatch of emergency and/or medical personnel to the scene, or re-assessment of the different interventions and documentation of patient management.

attributed to poor health behaviours relating to modifiable risk factors such as weight, smoking and poor sleep (Douglas and Oraekesi, 2015). In studies which compared health status of firefighters and office based workers, firefighters were found to have a lower incidence of hypertension and metabolic syndrome than office workers but a higher incidence of cardiac events (Han et al., 2018, Strauss et al., 2016). The impact of shift length and in particular of consecutive 24hr shifts on the risk of cardiovascular strain in firefighters has not been studied. However, Choi et al. (2014) provide a useful framework for future research in this area.

Firefighting activity is associated with significant heat stress and fatigue build-up which also impact on cardiac measures. In a small study of full-time US firefighters, core body temperature, heat storage and heart rate increased across a live-fire exercise and remained elevated at the end of rest periods between exercises which is indicative of heat stress and increasing fatigue as well as insufficient recovery time between exercises (Mani et al., 2013). The time required for firefighters' heart rate to return to baseline levels also increased progressively across the exercises further supporting these observations of heat stress, fatigue build-up and insufficient recovery time. However, firefighters in this study were able to accurately perceive the heat strain and fatigue build-up which was reflected in their ratings of perceived exertion, thermal strain and respiratory distress which increased across the live-fire exercise (Mani et al., 2013). Similarly, in a small group of volunteer firefighters in Portugal, changes in heart rate variability and average heart rate mapped well to firefighter rankings of fatigue and stress levels of different types of firefighting activities (Pallauf et al., 2011). Increased average heart rate and decreased heart rate variability was observed when responding to car accidents ranked by firefighters as most stressful and fatiguing. A separate study of cardiac function following a 3hr firefighting exercise completed by male career and volunteer firefighters, documented increased heart rate (to maximal levels) and changes in cardiac performance indicative of cardiac fatigue (Fernhall et al., 2012). In particular, Fernhall et al. (2012) observed significant decreases in ventricular filling volume, left ventricular diastolic size and stroke volume which were linked to reduced plasma volume (a consequence of dehydration). They also observed changes to ventricular function that were independent of changes in ventricular filling volume, including changes in the contractile and relaxation properties of the myocardium (Fernhall et al., 2012).

Cognitive decline (from questions in the Profile of Mood States (POMS) questionnaire) was predicted by stress and sleep difficulties in last 3 months, but not by measure of arterial stiffness, in a cross-sectional study of Finnish firefighters (Lindholm et al., 2012).

Reinberg et al. (2017) investigated circadian disruption in systolic and diastolic blood pressure rhythms among males in the French fire service. They observed that the length of the circadian cycle (tau) in firefighters and dispatchers in their study differed from that of healthy day-active individuals and from administrative fire service staff (who only work day shifts). Instead of the 24hr periodicity typically seen in blood pressure rhythms, firefighters and dispatchers displayed a shorter 12hr period in their blood pressure rhythm. Additionally, in some individuals, tau of diastolic and systolic blood pressure differed from each other. While the change in tau of blood pressure occurred both in winter and in summer, it occurred more frequently during the summer. This change in tau also occurred independently of activity rhythms which maintained a 24hr period across both the winter and summer measures. The authors attributed these changes in periodicity to a desynchronization from external time cues resulting from shift work and cautioned that the impacts of these changes in blood pressure tau on health and wellbeing are not yet known.

HEALTH RISKS FOR FEMALE FIREFIGHTERS

Two studies have investigated reproductive health outcomes for female firefighters. The first, a study of hospital admission data in nearly 1,800 female Korean firefighters, found higher admission rates for adverse pregnancy, childbirth and puerperium outcomes compared to the general Korean population (Park et al., 2020). In a survey study of approximately 1,800 female US firefighters, rates of miscarriage and pre-term delivery were high (Jahnke et al., 2018). Both studies mention the possible role of shift work in these outcomes for female firefighters.

> We argue for further research on this issue and the need for policies to protect maternal and child health.

MENTAL HEALTH

BURNOUT

Burnout is a three-dimensional syndrome characterised by emotional exhaustion, depersonalisation (negative attitudes about clients or job) and low personal accomplishment, which persists even after a typical period of recovery from work. A study of 6,037 career firefighters found that nearly half reported high burnout on at least one dimension (Wolkow et al., 2019). Reporting sleep problems, including obstructive sleep apnoea and insomnia, increased the risk of burnout 2-3 fold. This relationship was partially mediated (i.e., explained) by the amount of sleep firefighters obtained when working overnight. Short sleep at work and when recovering from work was also directly related to burnout. The authors recommend screening firefighters for sleep disorders and having policies in place that encourage sleep during overnight shifts.

In contrast, a further study of 604 firefighters in Kazakhstan found relatively low levels of burnout with the highest scores in managers (Vinnikov et al., 2019). Fatigue, as measured on a 9-item Fatigue Severity Scale was not associated with burnout after adjusting for other factors.

> Firefighters should be screened and if needed, provided with treatment pathways for sleep disorders. Policies should address the sleep environment of firefighters when at work and firefighters should be encouraged to maximise sleep opportunities during night-time periods.

SUICIDAL BEHAVIOURS

Stanley et al. (2016), in a systematic review of suicidal thoughts and behaviours in emergency response personnel, noted a limited amount of research on this topic in firefighters. Current evidence suggests an increased risk of suicidality for firefighters compared to the general population and that sleep disturbances increase a firefighter's risk. The authors argue that because shift work increases the risk of insomnia, further explanation of the role of sleep disturbances in increasing suicide risk among emergency response personnel is needed. Additional research by the same group found an increased prevalence of suicidal thoughts and behaviours amongst volunteer firefighters compared to career firefighters (Stanley et al., 2015).

A study of 858 US firefighters found a relationship between the severity of insomnia and suicidal ideation, which was mediated by loneliness (Chu et al., 2017). Recommendations from this study include the need to address sleep disturbances and have peer support programs in place.

Expanding on the relationship between insomnia and suicidal ideation, Kim et al. (2018) found a relationship between Post-Traumatic Stress Disorder (PTSD) and suicidal behaviour which was partially explained by insomnia and alcohol use disorders. The authors hypothesise that after exposure to trauma, PTSD occurs, which leads to an increased use of alcohol and subsequent

insomnia. Previous research has shown that insomnia mediates both the relationship between PTSD and suicide ideation, and also alcohol use and suicide ideation. This supports further research on the effectiveness of interventions for insomnia.

Henderson et al. (2016) also point to a lack of research on suicide risk in firefighters and the prevalence and role of rumination and sleep disturbances as a stressor. This article describes considerations for mental health practitioners working with firefighters and an education program that addresses mental health stigma which includes information on sleep disorders.

> Sleep disturbances, particularly insomnia, appear to a risk factor for suicidal behaviour in firefighters. Screening and cognitive behavioural therapy for insomnia is needed. Volunteers may be at greater risk of suicidal behaviours.

Post-Traumatic Stress Disorders (PTSD)

A study of 1,215 career firefighters in Bangkok found that 6.4% met the criteria for PTSD and that 49.1% had poor sleep quality (Khumtong and Taneepanichskul, 2019). Those with PTSD had a 6.5 increased odds of poor sleep quality.

As well as PTSD resulting in sleep difficulties, there is also evidence from Psarros et al. (2018) that insomnia independently increases the odds (3 fold) of a firefighter experiencing PTSD. Interestingly, this study also noted that seasonally employed firefighters were much more likely to experience PTSD than permanently employed firefighters, suggesting that the training and experience associated with permanent employment was protective.

In line with the work of Kim et al. (2018) discussed above, Smith et al. (2018) investigated the relationships between PTSD, alcohol use and sleep disturbance in 639 urban career firefighters. They found greater PTSD severity to be associated with greater alcohol use severity, and greater sleep disturbance severity also to be associated with greater alcohol use severity. The association of PTSD and alcohol use was stronger when sleep was more disturbed.

Walker et al. (2016) propose a model of PTSD for first responders and military personnel in which occupational exposures (including sleep restriction) alter immune response leading to changes in mood and well-being that may reduce resilience and increase the risk of PTSD if an individual is exposed to a traumatic event. Like other studies discussed, they argue for screening for sleep disorders, providing education and, where needed also cognitive behavioural therapy as treatment, and the use of best practice rostering methods.

Another study investigated the relationship between resilience and PTSD, and the role of sleep, depression and anxiety in this relationship, for 125 full-time firefighter paramedics (Straud et al., 2018). Individuals with greater resilience experienced less depression, anxiety and sleep difficulties which in turn resulted in fewer symptoms of PTSD.

In one of the few studies focused on dispatchers, Shakespeare-Finch et al. (2015) investigated the relationships between self-efficacy, social support and mental health, particularly well-being and symptoms of PTSD. They considered a range of predictors, including whether the individuals worked shift work. Interestingly, working shifts was found to be protective for PTSD symptoms and was related to better well-being, which the authors argued was possibly related to the peer support found when working shifts and self-selection for shift work, respectively.

Sleep difficulties may contribute to PTSD either directly or mediate the effects of other factors such as alcohol use or resilience. PTSD may also in turn lead to difficulties with sleep. As with other aspects of mental health, the identification and treatment of sleep difficulties would be of benefit to firefighters.

Emergency communications personnel may have better mental health if they are able to choose shift work and if they have strong social networks on shifts.

Depression

Using data from 880 current and retired US firefighters (41.8% career, 27.8% volunteer and 28.4% mixed career/volunteer departments), Hom et al. (2016) investigated the relationships between insomnia and depressive symptoms. They found co-occurrence and high rates of both. The authors suggest that insomnia and depression are linked through emotional dysregulation, and that the relationship between insomnia and depression is bidirectional. The treatment of insomnia using cognitive behavioural therapy (CBT-I) is argued for, with some parts of therapy focused on emotion dysregulation, although the efficacy of such an approach does require further investigation.

Carey et al. (2011) also described levels of sleep loss, alcohol use and depressive symptoms in professional firefighters (n=112) and found high rates of sleep deprivation (59%), binge drinking (58%) and reduced mental well-being (21%), and small-medium correlations between these factors.

A study of excessive daytime sleepiness (EDS) in 458 male career firefighters found that those with EDS had twice the rates of depression compared to their less sleepy peers (Haddock et al., 2013). Supporting the bi-directional nature of the relationship, Lim et al. (2014) found clinically significant depressive symptoms increased the odds of reporting poor sleep quality 7-fold in 730 male Korean metropolitan firefighters.

A cross-sectional study of 118 Iranian firefighters found that nearly 60% reported poor quality sleep (Abbasi et al., 2018). In contrast to other studies, poorer sleep quality was not associated with depression or stress but was found to be associated with the presence of musculoskeletal disorders, shift work, and higher BMI.

In contrast to other literature, a study of 45 firefighters who participated in an objective study of sleep and cognitive functioning, found relatively low rates of depression (6.7% were classified as having major depression measured using clinical interview), anxiety symptoms and PTSD (4.4%) (Stout et al., 2020). It is not clear why the findings of this study differed from others, although the small sample size is of note.

The relationship between sleep disturbances and depressive symptoms in firefighters is likely to be bi-directional. These findings lend further support to the need to identify and treat sleep problems in firefighters.

Stress

Young et al. (2014) conducted focus groups with 22 UK full-time fire service personnel to determine the types of stressors they experience and the strategies individuals use to cope with these stressors. Physical stressors included physical fatigue from the tasks being conducted and the equipment worn, heat stress and the need to rapidly adapt in response to an event. Other stressors included the risk of injury to self or others, driving demands, dealing with fatalities and cognitive stressors, which included decision making under pressure, responding when fatigued, controlling frustration when fatigued, and keeping emotions at an appropriate level. Most of the coping strategies firefighters used were problem-focussed, such as utilising their experience; being aware of the potential for cognitive changes and gathering information and communicating in response; and eating well and remaining hydrated. Emotion-focussed coping strategies were less well used but included accepting the situation they were in and trusting their colleagues and equipment; relaxation strategies; and avoidance and distraction. Strategies that were mixed included social support, humour, seeking support from more experienced colleagues, and talking about a problem sooner rather than later.

A study of 40 Brazilian military firefighters found ratings of fatigue, tension, depression and an overall rating of stress to be higher on work days compared to non-work days and for these scores to increase with increasing age (de Oliveira et al., 2012).

Alcohol misuse

Secondary analysis of data from a study of 652 professional US firefighters found an association between alcohol misuse and sleep disturbance (Smith et al., 2019b) with greater alcohol use related to more disturbed sleep after controlling for other factors. Distress tolerance (the extent to which a person reports being able to withstand distressing emotional states) moderated the relationship between alcohol misuse and sleep disturbance.

Multiple mental health issues

A systematic review of mental health in first responders focussed on sleep disorders and disturbances, and noted that sleep disorders are often associated with symptoms of anxiety and depression but if left untreated can increase the risk for mental health and substance abuse disorders (Jones, 2017). A further study (Varker et al., 2018) created an evidence map of the literature investigating mental health in Australian emergency services personnel and found a reasonable body of literature, with those studies that addressed sleep and fatigue reviewed elsewhere in this document (that is, Dawson et al., 2015, Paterson et al., 2016). Among 303 Brazilian firefighters, psychological distress and psychosomatic symptoms were associated with sleep disturbances (de Barros et al., 2013), with over half of the sample reporting disturbed sleep. Suicidal ideation and high rates of alcohol use also showed links to reports of disturbed sleep, but these relationships did not reach statistical significance.

A recent review of the psychological health of emergency dispatch centre personnel (Golding et al., 2017) highlights that there are a number stressors related to the occupation, and in particular that the nature of calls can lead to vicarious trauma, which can manifest through disturbed sleep and unwanted flashbacks. The review also included a qualitative study of white British ambulance dispatch personnel documenting a number of stressors associated with dispatch roles, most of which related to the emotive content of the work and a lack of support and value for the role from other teams within the system, in particular from paramedics (Coxon et al., 2016). While the study did not directly assess shift work or fatigue, some comments from participants touched on factors that are likely to impact on fatigue. In particular, participants reported difficulties unwinding after

their shift which is likely to impact on their fatigue and recovery. Other participants indicated that while they were provided with regular breaks during their shift, the nature of their work and exposure to rapidly changing situations meant that they avoided taking breaks away from their desks whenever possible, so as not to return to a different situation from the one they had left (Coxon et al., 2016).

A study describing mental health symptoms in 220 career and volunteer first responders (67.4% firefighters, 12% of total sample were volunteers) found that 14% reported moderate-severe and severe depressive symptoms, 28% reported moderate-severe and severe anxiety symptoms, 26% reported symptoms of PTSD, 31% reported harmful/hazardous alcohol use, 93% reported significant sleep disturbances, and 34% were identified as high risk for suicide (Jones et al., 2018). An individual's shift structure was classified as either >48 hrs or 12/24 hrs, with shifts longer than 48 hrs associated with an increased likelihood of scoring positive on scales for mental health problems after controlling for other risk factors. Being female also increased the risk of mental health problems. In contrast to other research, no differences in mental health outcomes were found between volunteer and career firefighters, but this finding may have been influenced by the relatively small number of volunteers in the sample.

A large survey study of 4,441 Canadian Public Safety Personnel (including firefighters and dispatch personnel) investigated the associations between stressors and mental health outcomes (Carleton et al., 2020). Stressors were defined as exposure to traumatic events, as well as occupational and organisational factors. The occupational stress of shift work, over-time and fatigue were all associated with a range of mental health outcomes (PTSD, anxiety, depressive symptoms and panic) even after controlling for exposure to traumatic events, suggesting that improving mental health in this population should also focus on the non-traumatic workplace stressors, which may play an even larger role in mental health than exposure to traumatic events.

Bartlett et al. (2018) investigated the mental health of firefighters who also identified as military veterans. Using data from 910 career firefighters, they found that military veterans had higher rates of sleep disturbance, depression and PTSD symptoms, but the size of the difference compared to the non-veteran groups was small.

In a large study of Canadian Public Service Personnel (n=5,813; including communications officials and firefighters), Angehrn et al. (2020) reported high rates of clinically significant insomnia symptoms and short sleep, compared to the general Canadian population. Almost half of the personnel screened positive for one mental health disorder based on self-reported measures, with communications officials one of the most likely groups to screen positive. Across all groups, insomnia symptoms were associated with a 3.4-7.0 times greater likelihood of a mental disorder and poor sleep quality was also correlated with a range of mental health issues. Stress associated with shift work was correlated with shorter and poorer quality sleep. The study authors argue for workplace policy and initiatives that are focused on sleep management to improve the sleep and mental health of this population.

Another factor investigated in relation to the mental health of firefighters is chronotype, which refers to individual differences in the preferred timing of sleep and waking activity. In a study of 515 Korean firefighters, evening type firefighters (individuals who prefer to go to bed later and get up later) were more likely to report depression, alcohol use, PTSD, stress and sleep disturbance (Yun et al., 2015). After controlling for a range of factors, evening chronotype was the most significant risk factor for poor sleep quality.

FATIGUE INTERVENTIONS

FATIGUE INTERVENTIONS USED IN FIREFIGHTERS

Our search for interventions that have been used in firefighters to manage fatigue yielded six studies. Of these, two include findings that are of particular relevance to the New Zealand Fire and Emergency context.

The first of these is a study by Dawson et al. (2015), which used qualitative methodology (interviews and thematic analysis) to explore informal fatigue management strategies used by rural volunteer Australian firefighters in wildfire suppression deployments. This approach was taken based on the fact that despite extended hours and sleep restriction being common experiences among rural volunteers in wildfire suppression deployments, the self-reported incidence of fatigue-related accidents and injuries was "anecdotally low". As noted earlier in the section on physical and cognitive performance, the interviews highlighted that fatigue was commonly experienced by firefighters while working in this setting. However, in relation to fatigue-related risk assessment, firefighters often conflated physical and mental fatigue, and did not distinguish between fatigue and sleepiness (consequently, the terms were used interchangeably). Firefighters' calculations of fatigue-related risk were based on the likelihood of a fatigue-related error occurring and usually did not take into account the consequences of the error.

There was a disconnect between firefighters' actions on the fireground and their perceptions of fatigue mitigations; that is, the interviews highlighted that firefighters rarely attributed their strategies to being fatigue-risk mitigations or safety behaviours. There was also a limited understanding of the formal fatigue management policy and little recall of formal fatigue management strategies being communicated. In relation to informal strategies and the aims of the study, some interviewees found it difficult to identify any informal strategies until provided with examples. At an individual level, fatigue awareness and changing behaviours as a result of this was the most frequently identified strategy used by firefighters. Firefighters considered fatigue awareness a shared responsibility, and that identifying fatigue in others was an important part of their role. However, fatigue reporting was considered 'taboo' at an organisational level and firefighters were more likely to suggest a strategy for a colleague (e.g., taking a break) than explicitly comment on or report fatigue. Firefighters often employed cross-checking, re-checking and the use of mnemonic devices to reduce the likelihood of fatigue-related error. Additional informal strategies included increasing the frequency of communication with team members and napping, although it was noted that the environment made napping challenging. At a team level, monitoring of task performance was used to identify fatigue in others. Additional informal strategies included maintaining adequate food and hydration, and task rotation. At the organisational level, management understanding of firefighters' external commitments meant that 'good' decisions could be made when allocating tasks and working time. It should also be highlighted that there was some cynicism about formal training in fatigue management, and it was felt that the fireground experience was the most valuable experience in relation to developing fatigue management strategies, over formal training.

The second relevant study is an evaluation of a sleep health program among 1,189 firefighters working in US fire stations (Sullivan et al., 2017). Fire stations were paired by workload, station type and employee profile, and then one station from each pair was randomly assigned to a sleep health intervention, which was comprised of: a mandatory 30-minute education session, voluntary screening for sleep disorders (obstructive sleep apnoea, insomnia, restless legs and shift work disorder), and referral to a sleep clinic for those who screened positive for a sleep disorder. The

education intervention included information on firefighter mortality, fatigue-related health hazards, the physiological importance of sleep, strategies to improve sleep hygiene, and tips on how to strategically use caffeine and naps to promote alertness. Ninety percent of eligible firefighters participated in the education intervention. It was demonstrated that 77% of those who attended the education session volunteered to be screened for a sleep disorder, which might be indicative of intervention acceptability. Over the 12-month assessment period, firefighters in the control group averaged nearly double the number of 24hr pay periods coded as disability than firefighters in the intervention group. There were no significant differences between the control and intervention groups in the number of sick days taken, and the number of motor vehicle accidents. The number of injury reports was marginally higher among the control group than intervention group, and firefighters who attended the education session were 24% less likely to file at least one official injury report during the study than those who did not attend, regardless of randomisation. Interestingly, surveys of firefighters in the intervention group did not find any difference pre- and post-intervention in self-reported sleep duration, attentional failures while driving or while stopped in traffic, or self-reported general health.

A randomised, cross-over trial of 21 firefighters with poor sleep quality (based on scores from the Pittsburgh Sleep Quality Index) has demonstrated that 10mg of zolpidem taken daily for 14 days significantly improved global sleep quality, compared with placebo (Mehrdad et al., 2015). In a pilot study of 41 participants, including police and firefighters, it has been shown that ~25% of participants experienced a significant improvement in sleep quality after brain music neurofeedback (DuRousseau et al., 2011). This neurofeedback training converts a person's EEG activity into music notes to create two 'musical maps' – one for activating and one for relaxing brain activity. Alongside improvements in sleep quality, statistically significant improvements were also observed in 33-35% of participants for insomnia severity, 25-40% of participants for mood and 13-25% of participants for daytime function (negative aspects)[20]. However, the results are not reported in a way that clearly showed how clinically meaningful these changes are.

Two studies have investigated the impact of glutamine supplementation[21] in small samples of non-firefighters in a randomised, double-blinded cross-over trial involving a 2-day simulated wildfire suppression protocol (Nava et al., 2019, Moore et al., 2019). In one study, glutamine supplementation led to increased levels of heat shock protein 70 which were linked to decreased ratings of perceived exertion and decreased ratings of fatigue on the Samn-Perelli fatigue scale (Nava et al., 2019). In a separate study, glutamine supplementation led to a significantly higher number of repetitions of shoulder press and arm curls on day 2 compared to day 1, and decreased fatigue on the Samn-Perelli scale at the beginning of day 2. Alongside these findings, there was upregulation of total antioxidant capacity and heat shock response with glutamine supplementation. This upregulation may act to enhance recovery after initial exposure to physical exercise and heat stress, and further improve tolerance against repeated exposure.

An evaluation of a health and safety risk management intervention in the fire service has the potential to be useful in relation to fatigue management (Poplin et al., 2018). The authors utilised a 3-phase process including hazard identification, risk assessment and implementation of mitigations over a 3-year period, followed by a 1-year observation period. Unfortunately, shift work and fatigue and relevant mitigations were not assessed as part of the intervention, although the approach maps

[20] The proportion of the participants experiencing improvement differed depending on whether they worked in operations support or were first responders.

[21] Glutamine is the most abundant amino acid in the body and plays a role in the prevention and treatment of physiological stress (including heat stress) and illness.

somewhat to that used in safety management systems for workplace risks, including fatigue risk management systems. The authors focussed on hazards and injuries related to physical exercise, patient transport and fireground activities. There was a reduction of 13% for all reported injuries, and a 21% reduction in mean workers' compensation costs after the program was implemented.

FATIGUE INTERVENTIONS USED IN ON-CALL WORKERS

Following initial screening, there were 10 articles identified in the searches related to interventions used in on-call workers. Four of these articles did not evaluate an intervention and were excluded from the review. One of the excluded articles includes a protocol for a study that will evaluate the effectiveness of individual online mindfulness training and an organisational stress reduction toolkit among emergency call centre workers (Meischke et al., 2018). Although no findings have been published to date, these findings may be of interest once they are published. Of the remaining six articles, two of are particular relevance to the New Zealand Fire and Emergency context.

The first relevant study evaluated the effectiveness of a 'sit less, move more' intervention in Australian emergency services call centre personnel (Chau et al., 2016). Qualitative findings from this study have been published to date from 22 participants in the intervention group. The intervention consisted of three components: emails, timer lights and posters. Weekly emails were sent to participants in the intervention group about prolonged sitting and health, reminders to stand up more at work and a brief video. Timer lights with the message 'try standing up' were mounted at two ends of the call centre and set to an electronic timer that illuminated the message for 30 minutes on and 60 minutes off (8 x 30-minute periods per 12-hour shift). Posters were also displayed on notice boards. Control group participants received the intervention material after the evaluation was completed. At baseline, and at 5- and 10-week follow-up, participants completed an online survey that captured their perceptions and experiences of the intervention. Overall, participants liked the programme and appreciated the initiative from their managers, but acknowledged that their sit-stand habits were entrenched and work took precedence. Perceptions about standing varied. Some participants found that it was difficult working standing up, particularly during night shifts, while others found standing to be less tiring and helpful for dealing with stressful calls. Managers noticed that staff tended to stand during periods of high call volume and sit during quieter periods. Social motivation (such as having a buddy to remind them to stand and a champion that called out when the timer light for standing was on) helped them incorporate more standing into their work shift. The authors note that quantitative findings will be published elsewhere.

The second relevant study is a systematic review of the literature in relation to proactive countermeasures that can be used on waking to reduce sleep inertia, conducted by Hilditch et al. (2016). The literature was reviewed in relation to caffeine, light, sound, temperature, self-awakening and common countermeasures. Caffeine administered both before a nap and after a nap can reduce sleep inertia (indicated by improved alertness and performance, compared to control) but there was a delay before the positive effects of caffeine were seen in all studies of at least 15 minutes. This means that caffeine is not able to reduce sleep inertia during the often critical period immediately upon waking. It was also noted that most studies administered caffeine prior to a nap but this might not be possible in unpredictable work environments. The effect of caffeine on nap sleep architecture, habitual caffeine use and caffeine sensitivity were not well studied and are worthy of further exploration. Studies examining the impact of light have produced conflicting findings. Overall, studies suggest that bright light exposure or dawn light simulation on waking from a nap may improve subjective alertness, effectively reducing the time it takes to feel fully alert. It was noted that dawn light simulation may not be possible in unpredictable work environments and the effects of bright light on the circadian timekeeping system must also be taken into account when

implementing exposure to bright light in the workplace. Much less research has been conducted on sound, temperature and self-awakening. It has been found that continuous white or pink noise did not reduce sleep inertia. However, music that the participant prefers (played at 60dB for 20 minutes following waking) improved subjective alertness after a nap compared to a no-music control. It is not known how long this effect is sustained for, but research suggests the effects of noise on performance are short lived. Temperature has been evaluated in a rapidly alternating 75 min sleep / 150 min wake protocol, which has shown that a reduction in the distal-proximal skin temperature gradient was associated with a reduction in subjective sleepiness. Studies of self-awakening have produced inconsistent findings but there is some evidence to support the use of self-awakening to reduce sleep inertia. The challenge is that there is a low success rate (18-42%) in study protocols, suggesting that most participants tend to oversleep. Common countermeasures such as cold air or playing the radio have not been well studied in relation to sleep inertia. An overall concern of the literature to date is that improvements in subjective alertness are seen, without improvements in objective performance. This may lead to a false sense of improvement for many workers, without being cognisant of the remaining risks.

The remaining studies have evaluated the impact of changing work schedules among healthcare professionals, particularly in relation to implementation of the European Working Time Directive and Accreditation Council for Graduate Medical Education duty hour standards in the United States (Auger et al., 2012, Brown et al., 2010, Kocolas et al., 2017, Song et al., 2019). However, the work patterns are unique to healthcare professionals in Europe and the United States, and the findings are not necessarily applicable to Fire and Emergency New Zealand. Two of the studies evaluated the impact of call schedules compared with a standard shift schedule (Auger et al., 2012, Kocolas et al., 2017). Call schedules included a 30-hour continuous shift every fourth shift. Shift schedules included 12-hour rotating shifts. These studies showed that doctors worked fewer hours with a standard shift schedule than when working long on-call shifts, and there were fewer work hours that were preceded by little to no sleep when working a shift schedule compared to an on-call schedule (Auger et al., 2012). The amount of sleep obtained around a 30-hour call shift varied significantly from 6-8 hours' sleep pre-call, little to no sleep while on-call and 12-14 hours' sleep post-call (Kocolas et al., 2017). However, the doctors rated work/life balance, job satisfaction and motivation as worse on the rotating shift schedule (Auger et al., 2012). A thematic analysis of junior doctors' perceptions of performance and well-being following implementation of the Working Time Directive in Europe found that working long stretches of night shifts (i.e., 7 nights in a row) or day shifts (i.e., 12 days in a row) was associated with increased fatigue, decreased alertness and concentration, increased errors, reduced work speed and impaired information processing and reduced motivation (Brown et al., 2010). Lastly, Song et al. (2019) evaluated the effect of physical activity on fatigue states in the last week. Total and physical fatigue was highest among those who seldom did exercise, compared to those who sometimes and always did exercise. Those who exercised for 30-60 mins each day had the lowest total and physical fatigue scores, compared to those who exercised for 1-30 mins, or more than 60 mins. There was no difference observed in mental fatigue for exercise frequency or duration.

AREAS FOR FUTURE RESEARCH

The existing literature is very heavily focused towards career firefighters, and where individuals with other fire service roles are included as participants in studies there is often no differentiation of outcomes by role. The limited research in relation to volunteer firefighters has generally been conducted in the context of wildfire suppression deployments, rather than urban volunteer settings. Understanding the fatigue-related risks for Fire and Emergency New Zealand (FENZ) personnel, other than career firefighters, is therefore suggested as an important area for future investigation. For example, volunteer firefighters, emergency communications/dispatch personnel and those in management positions. Considering the health risks identified for female firefighters identified in this review, an additional area of research may be gender differences in risks for volunteer firefighters and potentially, emergency communications personnel. Given the relatively low number of female career firefighters, it would likely be difficult to examine gender differences in this group.

It is recommended that, in relation to career firefighters, future research focusses on what can be done to reduce fatigue-related risks for this group, rather than solely an exploration (e.g., survey) of well-understood risks. That said, many of the studies have investigated the risks associated with shift work in firefighter and emergency communications personnel but have not evaluated the risks associated with specific aspects of work patterns (e.g., shift length, shift timing, number of consecutive shifts, sleep opportunities, unpredictable work hours, change to work hours etc.) There may be value in identifying specific aspects of work patterns for all FENZ personnel that carry the greatest fatigue-related risks, as potential opportunities for intervention.

As noted throughout the review, firefighters appear to be at greater risk of sleep disorders and difficulties compared to other populations. However, much of this research in US based, where shift patterns often differ from those employed in New Zealand (i.e., 24hr or 48hr shifts). To be able to manage the health and safety needs of FENZ staff, it would be advantageous to understand the prevalence of sleep disorders and sleep problems in this population. Related areas for investigation could include the impact of sleep problems on health and safety outcomes and the effectiveness of screening and treatment.

As noted in the section on interventions, firefighters often employ “informal” fatigue management strategies and are perhaps reluctant to accept fatigue management education as useful. Research exploring both formal and informal fatigue management strategies presently utilised in FENZ and the acceptance (or not) of these would contribute to future fatigue policy and process revisions and formal fatigue management training within the organisation.

Also noted in this review is that factors that mitigate sleep inertia are not well understood. In addition, sleep inertia was perceived to dissipate more quickly in response to urgent calls. The physiological and psychological effects in response to alarms is considered one of the greatest health and safety risks for US firefighters. Future research could potentially investigate how alarms could be delivered to reduce these adverse effects and explore strategies for mitigating the effects of sleep inertia on waking.

ISSUES RELEVANT FOR THE REVIEW OF THE FATIGUE MANAGEMENT POLICY

The following points include our feedback on relevant issues for the review of the fatigue management policy.

- In our interviews with Fire and Emergency New Zealand (FENZ) personnel, it was noted that the existing policy is not necessarily well understood or systematically applied within the wider FENZ workforce. Communication and visible endorsement of the policy to all relevant areas of an organisation is vital in ensuring the policy can assist in the effective management of fatigue. We recommend that communication about fatigue occurs on a regular and on-going basis through multiple channels. Communication needs to come from the top of the organisation but also be appropriately targeted to the needs of different groups within FENZ. For example, communication strategies need to take into account that the risks for career firefighters are different from the risks for volunteers, and the issues relevant to emergency communications personnel are different from workers in other parts of the organisation.
- The policy states that it applies to all urban personnel, both career and volunteer while a separate document applies to rural volunteers (National Rural Fire Authority Work Rest Guidelines). However, the content of the policy is very much centred on career firefighters with no recommendations directed specifically to volunteers, other shift workers within the organisation, and workers for which fatigue-related risk is elevated but are not typically considered shift workers (e.g., day workers with long hours and/or on-call work) . The fatigue risks associated with volunteer firefighters and other shift workers are likely to be very different to those of career firefighters and need to be managed quite differently. As noted in Paterson et al. (2016), fatigue is reported as a significant health and safety risk for volunteer firefighters both while firefighting and in their employment.
- Shift work is not currently defined in the policy. We recommend the following definition: 'shift work is any type of work that requires a worker to be to be awake when they would normally be asleep, if they could choose their own sleep schedule'. Any type of work that requires a worker to shift their preferred sleep/wake schedule is shift work, and shift work includes early starts, late finishes and night work.
- In places the documentation is clearly out of date. For example, there are references to the Department of Labour. It was also last reviewed in 2012.
- A fatigue management policy is normally signed by an accountable executive of the organisation. This confirms organisational commitment to the policy and clearly identifies who has overall responsibility for fatigue management within the organisation. Clear lines of accountability for fatigue should also be identified. On the other hand, the policy does point to the need for shared responsibility for fatigue by identifying individual and supervisor/manager responsibilities, although the need for shared responsibility could be stated more explicitly. It is important to highlight that shared responsibility is crucial for effective fatigue management, because fatigue-related risks arise from both work- and non-work-related activities.
- The purpose of the policy is outlined, but the actual safety objectives of the policy are not as easily identified. That is, what is the policy wanting to achieve from a health and safety perspective? For example, is the objective of the policy to increase fatigue awareness, reduce fatigue-related incidents, improve workforce health and well-being, or something else? And in relation to this, what are the targets or indicators that would be used to determine if the policy is effective? Examples from other industries and organisations

include a reduction in fatigue-related events or a reduction in adverse health and well-being outcomes for the workforce.

- A fatigue management policy should also declare management commitment to effective fatigue reporting. To effectively manage fatigue within an organisation, there must be a culture in which individuals are comfortable raising fatigue as a concern. In the interviews we conducted, there were concerns raised that this was not always the case. Changing the culture around fatigue takes time and requires significant organisational effort and commitment, including effective fatigue policy, clear and regular communication about fatigue, support for fatigue management initiatives from management, and taking fatigue reports and issues seriously. There also needs to be mechanisms in place through which individuals can report potential and actual fatigue hazards, and processes for ensuring fatigue is adequately investigated as a potential causal factor in any safety related incidents or accidents. An example of a fatigue reporting form can be found in the recently published National Code of Practice for Managing Nurses' Fatigue and Shift Work in District Health Board Hospitals, developed as part of the Safer Nursing 24/7 project (Appendix C; https://www.safernursing24-7.co.nz/code-of-practice/).
- The policy should also reflect management commitment to adequately resourcing fatigue management processes and a commitment to assess and improve fatigue management processes.
- An important health and safety consideration is ensuring members of the workforce are able to get home after work safely, especially if the work they have just undertaken has resulted in fatigue. The present policy refers to other driving related policies (FL1-1-3 Guide to Driving Hours and FL1-1-3a NZFS Driving Hours Variation), but it is not clear whether the risk associated with a fatigued individual driving home after work is addressed in these documents. Consideration should be given as to where information on managing this risk should be provided and what the options are available to individuals (e.g., sleeping at work prior to driving, the use of taxis, etc).
- The definition of fatigue is drawn from Queensland workplace health and safety documentation, and although it does have significant strengths in that it refers to both physical and mental changes in functioning and the role of extended periods of wakefulness and an insufficient amount or quality of sleep in causing fatigue, it does not refer to the contribution of the circadian time keeping system (i.e., the effects of time of day) or workload on fatigue levels. Although no definition of fatigue is perfect, the definition provided by the International Civil Aviation Organisation does cover these factors "A physiological state of reduced mental or physical performance capability resulting from sleep loss, extended wakefulness, circadian phase, and/or workload (mental and/or physical activity) that can impair a person's alertness and ability to perform operational duties."
- FENZ has identified 10 top critical risks for the organisation, and fatigue is identified as one of the critical health and safety risks. However, the review of the literature presented above strongly suggests that fatigue and fatigue-related outcomes, such as poor sleep, are contributors to the other health and safety risks identified. Fatigue should therefore not be treated in isolation when considering other health and safety risks.
- From the literature reviewed, a consistent theme was the need for the identification and treatment of sleep disorders and problems with sleep. Firefighters are at greater risk of sleep disturbances and disorders and these have clear links to other aspects of health, particularly mental health outcomes. It is recommended that the policy includes the organisation's position on supporting screening and treatment for sleep problems in its workforce.

- Another important aspect identified in the literature was the need for rostering practices to consider the opportunity for sleep, which differs depending on the time of day, rather than on the duration of a work period. That is, the combined effects of building pressure for sleep during wakefulness and the circadian timekeeping system mean that we have windows when the brain's drive for sleep is elevated. We are effectively programmed to sleep at night. Consequently, a 10-hour break from 9pm-7am provides a much better sleep opportunity (longer and more consolidated sleep) than a 10-hour break from 9am-7pm.
- The review of the literature identified that napping is a fatigue mitigation strategy used by firefighters in some situations, such as wildfire suppression deployments. It is important that if napping is to be promoted as a fatigue mitigation strategy, commitment to providing sleep-conducive environments and guidance for safe workplace napping is provided in policy and procedure documents. Guidance for safe workplace napping would include the following.
    - A fatigue report should be submitted when a worker needs to nap at work.
    - Workplace napping is not a tool for enabling extended shifts on a regular basis.
    - The shift supervisor should be advised where and when a worker plans to nap, and when the worker returns to work.
    - Napping should only occur during a break when it has been cleared with the shift supervisor to ensure that the worker's absence does not increase fatigue risk for others on the shift.
    - No more than 40 minutes should be spent trying to sleep during a nap and time should be allowed to recover from the effects of sleep inertia.
    - Napping procedures should be covered in shift work and fatigue training.
    - Suitable facilities should be provided for napping.
- The review of the literature also identified that fatigue education is a useful tool to reduce the health and safety risks associated with fatigue, and education is briefly mentioned in the fatigue policy. However, in our interviews with FENZ personnel, it was noted that a consistent approach to education and communication about fatigue was not in place. There is value in systematically providing education, training and regular communication about fatigue-related risks and appropriate mitigation strategies, using robust techniques that are acceptable to FENZ personnel. It is vital that education and training on shift work and fatigue is delivered to individuals at all levels within an organisation. It is important to consider who will deliver the training and that they have an appropriate background and understanding of fatigue science, the mode of delivery, content, training frequency, and how refresher training will be delivered. We recommend that the content of training includes responsibilities under the Health and Safety at Work Act (2015) in relation to managing fatigue and a worker's role in managing fatigue at FENZ, the basic science of shift work and fatigue, risks associated with shift work and fatigue, personal strategies for managing shift work and fatigue, and specific fatigue management initiatives at FENZ, including fatigue reporting.

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