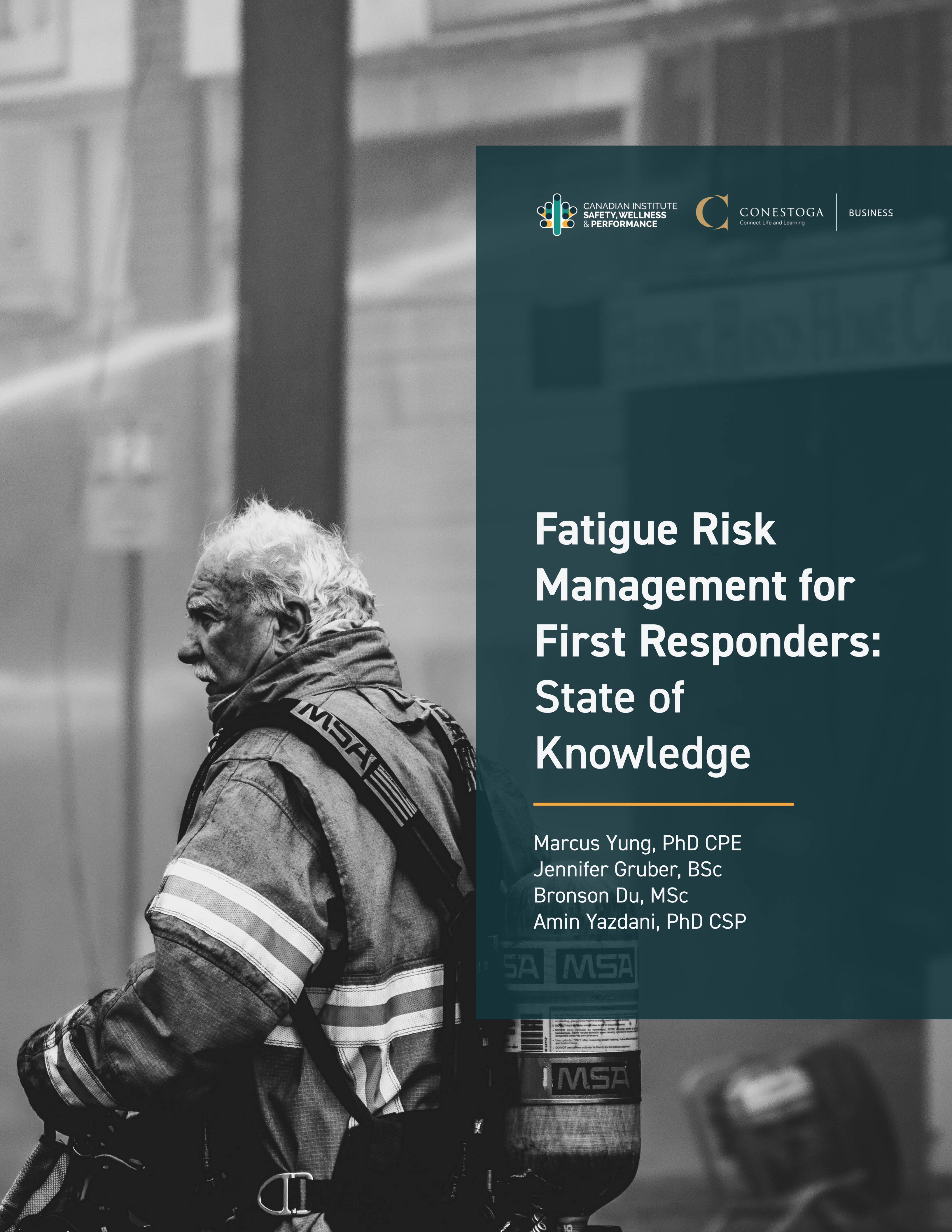

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Fatigue Risk Management for First Responders: State of Knowledge

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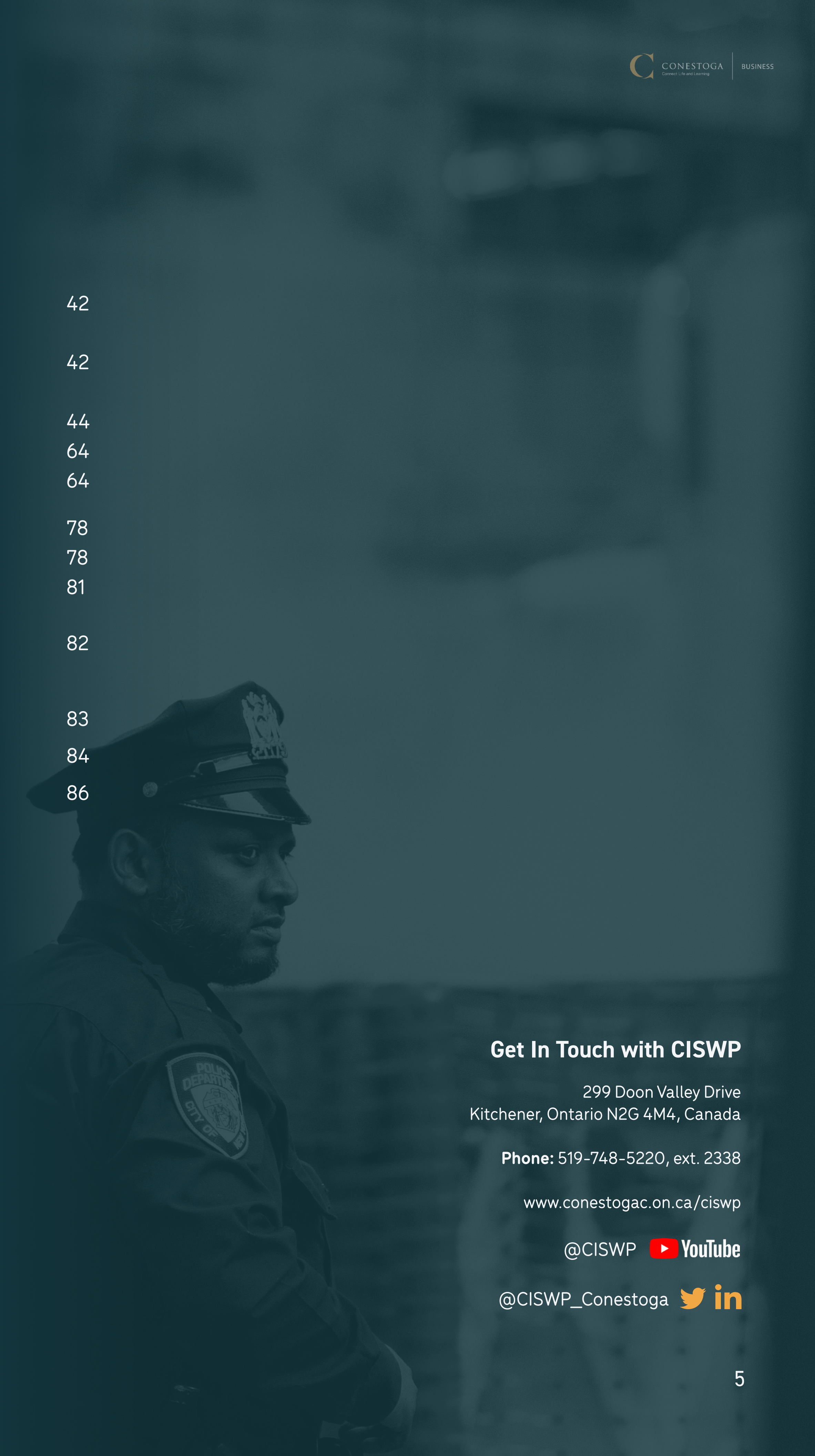

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Executive Summary

Objective for CSSP-2018-CP-2366

Our objective is to develop a consensus-based, evidence-informed national Standard on First Responder Workplace Fatigue Risk Management that will provide an approach to systematically prevent and manage workplace fatigue by addressing it in a strategic, coordinated approach, and as part of a broad organizational management framework.

How this milestone supports the objective for CSSP-2018-CP-2366

This milestone will contribute to the development of a Seeds Document that will be used to develop a national Standard, in accordance with CSA Groups' accredited standards development process. This report describes the "Research and Synthesis of Evidence" phase, specifically a scoping review of peer-reviewed literature to provide current state-of-the-art scientific knowledge in first responder workplace fatigue risk management. The objective of this scoping review was to broadly identify relevant research pertaining to fatigue risk management and synthesize the research to inform aspects of risk management model known as the RACE model (recognize hazards, assess risks, implement controls, and evaluate effectiveness of controls) that will be integrated into a broader management system framework using Plan-Do-Check-Act (PDCA).

Background

First responders are at high risk of suffering from decrements in neurocognitive and physical performance related to fatigue. Such performance decrements endanger not only the personal health and safety of these responders but also the health and safety of their fellow responders and the public they serve. Fatigue may also be a precursor to adverse longer-term outcomes, such as musculoskeletal disorders, cardiovascular disease, and mental health disorders. Appropriate management, policymaking, standards, guidance, and research activities can reduce the exposure to these fatigue-related risks and hazards before they pose significant problems during emergency response operations.

Methods

We conducted a scoping review to examine the extent, range, and nature of research activity, allowing us to identify gaps in the current literature. A scoping review consists of five stages: 1) identifying the pertinent research question(s), 2) searching the relevant studies, 3) selecting studies, 4) charting the data, 5) summarizing and reporting the results.

Due to the multifaceted nature of fatigue, we adopted an integrative approach focusing on cognitive fatigue (i.e., sleepiness, arousal, attention, cognitive overload/underload), physical fatigue (i.e., muscular fatigue, central/peripheral fatigue), perceptual fatigue (i.e., visual fatigue), emotional fatigue (i.e., compassion fatigue), and burnout. We were guided by the following questions:

1) In EMS, Firefighting, and Law Enforcement, how are hazards of fatigue identified?
2) In EMS, Firefighting, and Law Enforcement, how do organizations and personnel assess the risk of fatigue?
3) In EMS, Firefighting and Law Enforcement, what control actions or interventions are available to reduce fatigue?
4) In EMS, Firefighting and Law Enforcement, what are valid and reliable instruments for measuring or detecting fatigue among personnel?

General Findings

Our comprehensive literature search strategy resulted in a total of 403 relevant articles that met our inclusion criteria. We found that the focus on the type of fatigue differed between the three first responder occupations; the distribution of papers based on risk factor sub-categories and interventions also differed between occupations.

- 38.7% focused on firefighting, 33.3% on police, and 22.8% on EMS work, 5.2% of articles focused on a combination of the three occupations.
- Cognitive fatigue most represented in EMS research (45 articles) and Police research (88 articles).
- Physical fatigue most represented in firefighting research (116 articles).
- Personal/social/cultural (20 articles) and work organization (17 articles) fatigue risk factors were frequently cited in EMS research. Work organization (47 articles) and personal/social/cultural (36 articles) risk factors were common in police research. There was a consistent distribution of articles representing all four risk factor sub-categories in firefighting research.
- We identified potential fatigue-related outcomes into three outcome sub-categories. In both firefighting and police, physical health were most frequently identified. There was a consistent distribution of the number of articles among outcome sub-categories in EMS research.
- The primary type of intervention or risk control strategy in EMS research was engineered solutions (7 articles). In firefighting, 18 articles focused on PPE and 17 articles on engineered solutions. In police research, the most frequently cited intervention was training (12 articles).

Fatigue Measurement & Risk Assessment Tools

Tools ranged from self-reported instruments and surveys to objective measures. The Maslach Burnout Inventory was the primary tool of choice when measuring burnout; Schaufeli et al.'s (2001) study recommends using both the Maslach Burnout Inventory and the Malach-Pines Burnout Measure to balance both sensitivity and specificity. Surveys instruments were common to measure cognitive

fatigue, including the Pittsburgh Sleep Quality Index, Epworth Sleepiness Scale, and Chalder Fatigue Questionnaire; however, there is a lack of information on the sensitivity and specificity of these instruments. Objective measures of cognitive fatigue including heart rate, critical flicker fusion frequency, psychomotor vigilance task, oculomotor behaviour, polysomnography, and actigraphy have all been employed. These measures remain elusive in large-scale studies due to cost, practicality, and efficiency. Physical fatigue measures include heart rate as an index of physiological strain and metabolic rate, Borg's Rating of Perceived Exertion (RPE) as a psychophysical scale for physical strain, and observational risk assessment tools to assess musculoskeletal disorder risk. Further investigations are warranted to evaluate sensitivity and specificity of these tools.

Fatigue & Outcome Relationships in First Responder Occupations

We identified 22 papers that linked risk factors, fatigue type, and outcome. Cognitive fatigue was cited as the most acknowledged type of fatigue linked to health (injury, accident risk, musculoskeletal disorders, cardiovascular disease), wellness (depression, anxiety, dissatisfaction), and work performance. Increasing fatigue generally led to adverse outcomes, however 15 of the retained articles were cross-sectional studies, limiting our interpretation of causality.

Fatigue Management Interventions Identified in First Responder Occupations

We identified interventions and controls based on the Hierarchy of Controls (NIOSH, 2015). In all three occupations, training was the most common type of intervention to mitigate burnout. PPE and engineering controls were most common in combating physical fatigue. There was a stronger focus on administrative and training controls to reduce cognitive fatigue. No single intervention was supported by overwhelming evidence, but we found limited support for stretcher design, predictive capacity testing, self-contained breathing apparatus (SCBA) design (material and shape), and mindfulness-based resilience training. Articles indicate that changes to protective clothing, to reduce physical demands and fatigue, were not effective solutions in firefighting work.

Conclusion

The scoping review provides insight towards the extent, impact, and management of fatigue based on a broad range of fatigue types for first responder occupations. Categorizing by fatigue type might be useful in targeting appropriate controls and focus future research investigations. In all three occupations, burnout, cognitive fatigue, and physical fatigue were associated with adverse health and performance effects; these results highlight the importance of managing fatigue, of any type, to prevent longer term outcomes. Although a range of measurement tools have been identified in the peer-reviewed literature, future investigations are needed to identify tools specific to first responder occupations and information on the sensitivity and specificity of these instruments. No single interventions were supported by overwhelming evidence; high quality research, including randomized control trials, may help identify and inform effective risk mitigation strategies for first responders.

Historical Context

Fatigue did not appear in the scientific lexicon before the 1860s, with almost no records of medical or scientific studies on the subject matter (Rabinbach, 1992). Yet by the turn of the century, fatigue research had proliferated, with over a hundred scientific papers dedicated to muscle fatigue, exhaustion, and neurasthenia – or chronic fatigue syndrome (Evengård, 2007). The 1920s and 1930s saw a focus on the cognitive aspects of fatigue (e.g., attention) and later in the 1960s due to the emergence of cognitive psychology. The 1950s focused on fatigue issues of vigilance and monitoring (Hockey, 2013). As described in Yung (2016), historians postulate two concepts of the popularization of fatigue in occupation: the theorization of the laws of thermodynamics and the discovery of labour power during the Industrial Revolution.

Hermann von Helmholtz (1847) argued that forces of nature are forms of a single, universal energy, which cannot be added or destroyed; this principle of conservation of energy formed the first law of thermodynamics. Energy became the quintessential element. The 1850s saw the emergence of Rudolf Clausius' second law of thermodynamics, introducing concepts of entropy where the transfer of energy is accompanied by a decrease in total available energy. This revelation counterbalanced energy conservation, which implied that there was an inevitable dissipation of force and that entropy tends to a maximum. These laws have been applied to the human motor, which is capable of conserving and dissipating energy. Fatigue became the indicator of the body's inability for unlimited progress, and productivity was considered an instance of entropy (Rabinbach, 1992). Labour power was conceived as a result of the laws of thermodynamics, redefined from a measurement of the force of machines to the basis of all matter and motion. Work was redefined too, universalized in all mechanisms. The human body was therefore analogous to a machine, yielding work from muscles, nerves, and organs. Armed with the concepts stemming from the laws of thermodynamics and labour force, energy was perceived to be a limiting factor in production. Fatigue and energy emerged as a modern conceptual framework to describe both work and the human body; these concepts led to the ubiquitous energy-depletion based model, i.e., catastrophe theory (Hockey, 2013).

The pervasive ideology of the human motor and the resulting fatigue-energy paradigm has endured since the 19th century. Increased output, greater work performance, and more energetic workers were coupled with efforts to eliminate industrial risk, improve health and safety, and shorten the workday (Rabinbach, 1992). McIvor (1987) described the evolution of fatigue in Britain between 1890 and 1918, signifying the neglect of the human element, with minimal regard to the limitations of human physiology and psychology, in favour of production. Labour was widely

regarded as a pure commodity, a factor in the production process with relatively standardized capabilities (McIvor, 1987). In that era, most employers remained bound to traditional cost cutting techniques due to fear of compromising their competitive position; there was little evidence that improving worker health could reap benefits. However, this neglect resulted in ill health, disease, premature death, deprivation, exhaustion, and reduced productivity. Conceding that there may be greater potential for improvements in human efficiency, William Mather investigated the relationship between overstrain and impaired productivity. Most importantly, his studies concluded that decreasing working hours from 53 hours to 48 hours per week led to increased output, reduced costs, and reduced absenteeism. Later studies confirmed Mather's hypothesis that correlated reductions in excessive working hours with increased productivity. Meanwhile, in the United States, unions, women's advocates, and socialists pushed for expanded protective legislation against increased working hours (Dembe, 2009). In 1917, the landmark Bunting v. Oregon Supreme Court decision led to greater national attention towards ethical and medical issues associated with long working hours.

The decision set the foundation for passing the Fair Labour Standards Act (FLSA) in 1938, which required most government contractors to adopt an 8-hour day and a 40-hour week. Due to a combination of protective legislation, changes in production methods, and societal trends, the average workweek decreased from 60-70 hours in the 19th century, to 50-60 hours from 1900 to 1930, and has remained at 40 hours since the Great Depression (Dembe, 2009).

However, long working hours continue to persist today. Although the mean hour per week has not dramatically changed, there are now a greater proportion of workers in both low-hour (less than 30 per week) and in high-hour (greater than 50 per week) work schedules. Cited in Dembe (2009), as of 2007, 18.1% of Americans worked more than 48 hours per week. In Japan, 5.77 million people worked 60 hours or more on a weekly basis in sectors other than agriculture and forestry (Kajimoto, 2007). It is not surprising that research in optimal permissible working hours is currently pertinent. For instance, Nagashima and colleagues (2007) investigated the number of working hours that can be recommended to protect workers from health effects and found that working less than 260 hours per month (i.e., 60 hours per week) resulted in a significantly lower prevalence of fatigue symptoms.

Prevention of fatigue is not limited to the reduction of working hours. Work has led to increased levels of physical and mental fatigue (Kajimoto, 2007; Saito, 1999). It is not surprising that fatigue is as relevant, and strategies for its reduction more complex, in the 21st century as it was in the early 20th century.

HISTORICAL CONTEXT OF FATIGUE

Fatigue: A Multidimensional Construct

Fatigue has been described as a multidimensional construct, affecting the overall state of the whole organism, and is associated with physical, psychological, socioeconomic, and environmental factors (Barker & Nussbaum, 2011; Saito, 1999). In the short term, fatigue at the workplace is linked to reduced performance, lowered productivity, deficits in work quality, and increased incidence of accidents and human errors. To support this, a recent systematic review demonstrated that fatigue was a frequent issue in the human factors and manufacturing quality relationship (Kolus et al., 2018); fatigue may explain up to 42% of variance in quality deficits (Yung et al., 2020). In the longer term, fatigue may lead to compromised immune function and adverse health outcomes, including myalgia, chronic fatigue syndrome, and burnout (Kajimoto, 2007). Speculatively, fatigue may also be a precursor to WMSDs – work-related musculoskeletal disorders (Iridiastadi & Nussbaum, 2006).

Fatigue has different institutionalized meanings across different scientific groups, and not surprisingly, there is no succinct and widely accepted definition. For years scientists have sought, but unsuccessfully, a single definition of fatigue (Aaronson et al., 1999). A single and possibly dogmatic definition, although convenient for scientific investigation, may instead confirm our own biases and misrepresent the reality of fatigue (Marino et al., 2011). Such is the case with the erroneous usage of the "lactic acid theory", a phenomenon that persists despite current flaws in our understanding of metabolic acidosis (Marino et al., 2011). Additionally, given the complex redundancy in most biological systems, a single mechanism unlikely explains fatigue under all conditions. Consequently, as Weir et al (2006) suggested, the search for a grand unifying theory of fatigue, based on reductionist approaches, may be futile. A single definition cannot describe the complex interaction of biological processes, behavioural manifestations, and psychosocial phenomena (Aaronson et al., 1999); and a single theory cannot explain all observations of performance decrement (Weir et al., 2006). It is perhaps the integration of different perspectives and disciplines that may lead to a greater understanding.

An integrative approach on fatigue has long been recognized. Ash (1914) stated: "Fatigue is a comprehensive term which in its widest application embraces all those immediate and temporary changes, whether of a functional or organic character, which take place within an organism or any of its constituent parts as a direct result of its own exertions, and which tend to interfere with or inhibit the organism's further activities."

Ultimately this integrative approach, as advocated by Marino and colleagues (2011), may result in a new conceptual landscape to better understand the aetiology and establish possible interventions to reduce, prevent, or minimize the effects of fatigue. Case in point, in terms of aetiology, Evengård (2007) suggested that biological and psychological data could be co-analyzed with social data and environmental factors of potential influence for the pathology.

A workshop hosted by Ontario's Centre of Research Expertise for the Prevention of Musculoskeletal Disorders (CRE-MSD) was convened in 2012 to critically evaluate occupational fatigue from different research disciplines and perspectives. In the workshop, the panel of experts discussed the concept of fatigue which was described as a balance between inhibitory and facilitatory effects, and possible adaptative and maladaptive behaviour of biological tissue. It was also stated that no single biomarker could determine whether the fatigue response will lead to an adaptive or maladaptive effect or a reversible or chronic effect; and fatigue may only be problematic when coupled with another risk factor. Despite the many considerations when defining fatigue and its effects, the panel agreed that fatigue over a working day might impact performance and quality at work. Fatigue over multiple days, accumulating over time, may be more indicative of longer-term health outcomes. A broad definition of fatigue was developed to include neuromuscular, emotional, and mental aspects, but remain under the framework of occupational work. CRE-MSD definition of workplace fatigue (Yung, 2016): Fatigue is a process that results in the impairment of wellbeing, capacity, and/or performance as a result of [work] activity.

We also considered the Canadian Centre for Occupational Health and Safety's definition: "Fatigue is the state of feeling very tired, weary or sleepy resulting from insufficient sleep, prolonged mental or physical work, or extended periods of stress or anxiety. Boring or repetitive tasks can intensify feelings of fatigue. Fatigue can be described as either acute or chronic."

Types of Fatigue

An integrative approach recognizes fatigue in its many forms. We broadly categorize fatigue as: (1) cognitive (includes mental, central, sleepiness), (2) physical (includes neuromuscular, peripheral, muscular, cardiovascular, exhaustion), (3) perceptual (includes visual or sensory), (4) emotional (includes compassion), and (5) burnout. These categorizations may be induced by physically or mentally demanding tasks and workplace psychosocial demands, may be related to sleep quality and duration, may be related to circadian disruptions, may be related to the individual's capacity, and related to stress arising from exposure to a traumatized individual. These categorizes have been described elsewhere: Grandjean, 1979; Saito, 1999; Barker & Nussbaum, 2011; Yung et al., 2020.

1. Cognitive fatigue involves decrements in human information processing capability due to mental workload. It is an executive failure leading to competency, productivity, and error avoidance (Techera et al., 2016). In this report, we include aspects of sleepiness, sleep quality/duration, arousal, attention, alertness, and both cognitive overload and underload theories of fatigue.

2. Physical fatigue is the inability to maintain physical performance and can be attributed to metabolic disturbances, failure of neuromuscular transmission, changes that affect the myosin-actin complex, etc. In this report, we include tiredness or exhaustion involving the cardiovascular system. Physical fatigue is associated with a reduction in strength capability, changes in motor control, and reduced proprioception (Vøllestad, 1997; Gates & Dingwell, 2008; Björklund et al., 2000).

3. Perceptual fatigue includes visual fatigue that may result in a decline in visual/perceptual performance and/or an increase in visual discomfort (Megaw, 1995). Visual fatigue is a consequence of prolonged visual activity rather than mental workload.

4. Emotional fatigue includes compassion fatigue, which is the emotional, physical, and cognitive stresses resulting from exposure to a traumatized individual rather than from the exposure to the trauma itself (Figley, 1995). Caregivers, or emergency and community service workers, are susceptible to developing compassion fatigue. It is characterized by exhaustion, anger and irritability, the lack of sympathy and empathy, reduced sense of enjoyment or satisfaction with work, increased absenteeism, and the impaired ability to make decisions (Cocker & Joss, 2016). Compassion fatigue is the emotional and physical erosion when helpers are unable to refuel and regenerate

5. Burnout is a psychological response to work stress and is defined by three dimensions: exhaustion, cynicism, and professional inefficiency (Maslach & Leiter, 2016). Burnout is cumulative stress from demands of daily life and results from prolonged high levels of stress; compassion fatigue is closely related and may be considered as a form of burnout.

TYPES OF FATIGUE

Prevalence & Impact of Fatigue

When considering lost productivity to U.S. employers, fatigue is associated with an excess cost of $101 billion per year. The majority of this cost is due to reduced performance at work rather than absenteeism (Ricci et al., 2007). Chronic fatigue syndrome (CFS), in particular, is associated with $9.1 billion in annual productivity losses in the United States (Evengård, 2007). Ricci and colleagues (2007) found a fatigue prevalence estimate of 37.9% in the U.S. workforce. In Sweden, fatigue has been a dominant symptom among individuals on sick leave or taking early retirement. The cost of sick leave and early retirement was more than $17US billion annually (Evengård, 2007). In Japan, an epidemiological study determined that 60% of working individuals experienced fatigue and more than 50% of these individuals suffered from chronic fatigue lasting at least 6 months (Kajimoto, 2007). In Canada, persistent work-related fatigue has been reported among 15% male and 20% female workers (Winwood et al., 2007).

Fatigue Among First Responder Occupations

We examined the prevalence and/or severity of fatigue among three first responder occupations: Emergency Medical Services, Firefighting, and Law Enforcement using data from our scoping review of literature. Fatigue is differentiated and described (if available) in 5 categories: cognitive/mental fatigue (e.g., sleepiness), physical/muscular fatigue, emotional/compassion fatigue, and perceptual (e.g., sensorimotor, visual, proprioception).

EMS/Paramedics

According to the National Occupational Classification (NOC) system, workers in "Paramedical occupations" (NOC Code: 3234) are individuals who administer pre-hospital emergency care to patients with injuries or medical illnesses. These patients are transported to hospitals of other medical facilities for medical care (NOC, 2016). The Occupational Information Network (O*NET) in the United States describes "Emergency Medical Technicians and Paramedics" (SOC Code: 29-2941.00) as individuals who assesses injuries, administer emergency medical care, extricate trapped individuals, and transport patients to medical facilities (www.onetonline.org). The NOC system further describes paramedics as those employed by private ambulance services, hospitals, fire departments, government departments and agencies, manufacturing firms, mining companies, and other private sector establishments (NOC, 2016).

Cognitive Fatigue: Bentley and Levine (2016) in a US national assessment of health and safety of nationally-certified EMS professionals (Longitudinal EMT Attributes and Demographic Study – LEADS program), found that sleeping problems was one of the most prevalent negative health outcomes reported over a 10-year period. Within this 10-year period, 20% to 27% of EMS professionals reported sleeping problems in the previous year. Measuring daytime sleepiness using the Epworth Sleepiness Scale (ESS), the authors found that 19.3% to 24.9% of respondents reported excessive daytime sleepiness (score > 10). A 2012 study on the prevalence of self-reported sleep complaints among US EMTs revealed that 36% of 1306 sampled participants reported substantial levels of daytime sleepiness; nearly 6% of participants scored >16 on the Epworth Sleepiness Scale (Pirrallo et al., 2012). In a commentary of fatigue and safety in EMS, Patterson et al., (2012) indicated that 10-55% of EMS professionals experienced severe mental and/or physical fatigue, which was higher than fatigue reported in the general US work population (38%). A survey of 60 Australian paramedics was conducted to investigate the impact of shift work on sleep and daytime sleepiness (Sofianopoulos et al., 2011); over two-thirds of 60 participants reported poor quality of sleep, based on the Pittsburgh Sleep Quality Index (PSQI) and one-third reported being excessively sleepy. Ten percent of participants were categorized as dangerously sleepy.

Physical Fatigue: Fifty-three of 60 Australian paramedic respondents reported that they experienced fatigue in the previous 6 months (88%), 50 of the 53 respondents indicated that fatigue affected their job performance in the previous 6 months (Paterson et al., 2014). Physical fatigue has been linked to particular paramedic tasks. For instance, manual carry of a stretcher has been associated with heavy dynamic work of the legs and static strength of the upper extremities, requiring muscular strength and endurance and cardio-respiratory capacity (Barnekow-Bergkvist et al., 2004). According to Kluth and Strasser (2006), carrying manual stretchers is a risk factor of muscular fatigue, static shoulder muscle strains were observed to be 45% of maximum force and static low back muscle strains were 30%. In that study, the holding time of these forces was approximately one minute. In another study, the mean hand grip force during manual stretcher carry corresponds to 70% of maximal handgrip force in women and 40% in men (Leyk et al., 2007). Leyk and colleagues (2007) observed changes in physical performance after stretcher carriage: a three- to fourfold reduction of manual fine-coordination (hand steadiness) and a 14% to 25% reduction in maximum handgrip strength compared to baseline. Recovery of strength persisted up to 72 hours after the carrying activity.

Another strenuous paramedic activity reported in the literature is cardiopulmonary resuscitation (CPR). According to the American Heart Association, CPR should be performed with a depth > 5cm and at a rate of >100 compressions per minute (Souchtchenko et al., 2013); CPR represents 65% of maximum achievable workload (Ock et al., 2011). Fatigue may occur as early as one minute into compressions, which impacts prolonged CPR quality (Souchtchenko et al., 2013). Although the number of compressions was maintained over a 5-minute period, there was a significant reduction in the percentage of "correct compressions" (defined as one with a depth of 4-5 cm) from 78.8% in the first minute to 28.0% in the fifth minute (Ock et al., 2011). Paramedic tasks have also led to awkward postures where 16 to 29% of a work shift are spent in a harmful posture, measured by OVAKO Working Posture Analysing System (Doormaal et al., 1995).

Burnout: The prevalence of paramedic burnout has been reported globally. In Germany, 20% to 40% of 1101 EMS workers showed

a high degree of burnout in one of the Maslach Burnout Inventory dimensions (emotional exhaustion, depersonalization, personal accomplishment) (Baier et al., 2018). In Spain, 136 of 201 (67%) medical transport professionals (148 were EMT workers) had one or more dimensions of burnout. In South Africa, the prevalence of burnout was 30% among Johannesburg-based paramedics (Stassen et al., 2013). In a study on psychological well-being of ambulance personnel in the Netherlands, there was an 8.6% risk of burnout, which was higher compared to burnout cases in the general working population (5.25%) (van der Ploeg & Kleber, 2003). In India, EMS personnel had significantly higher levels of emotional exhaustion (20%) compared to a non-emergency comparative group (4.3%). Depersonalization levels were also statistically higher among EMS personnel (9.3%) compared to the comparative group (1.4%). There were no differences between groups based on personal achievement (Khashaba et al., 2014). A US study indicated that urban and rural paramedics with less than 9 years of experience were less likely to report burnout (Chng et al., 2001). A study on Canadian paramedics revealed that 74% of 87 paramedics reported at least one symptom of high burnout based on established cut-offs in the three MBI dimensions (Kukowski et al., 2016). Based on individual dimensions of burnout, 49%, 67%, and 21% of paramedics reported high levels of emotional exhaustion, depersonalization, and personal accomplishment, respectively.

Firefighters

Firefighters (NOC code: 4312) are referred to as workers who carry out firefighting and fire prevention activities, and assist in other emergencies (NOC, 2016). Firefighters are described in the US as "Municipal Firefighters" (SOC code: 33-2011.01) who control and extinguish municipal fires, protect life and property and conduct rescue efforts (www.onetonline.org). These workers may be employed by governments (municipal, provincial, or federal), and by private industrial organizations that have internal firefighting services (NOC, 2016).

Cognitive Fatigue: Firefighters may suffer from sleep disorders that exacerbate workplace fatigue. In a prospective cohort study on the impact of a sleep health program, 179 of 431 firefighters (42%) who completed a sleep disorder screening questionnaire tested positive for one or more sleep disorders (Sullivan et al., 2017). In another US study (Barger et al., 2015), 37.2% of 6933 firefighters screened positive for at least one sleep disorder, where obstructive sleep apnea was most prevalent (28.9%), followed by shift work disorder (9.1% of 5771 firefighters who reported working night shifts). It was reported that over 80% of firefighters who screened positive for a sleep disorder were undiagnosed or untreated (Barger et al., 2015). Similarly, in a study of South Korean firefighters, 320 or 657 (48.7%) had poor sleep quality, which was shown to be higher than the reported prevalence of sleep disorders in the general South Korean adult population (10 – 30%) (Lim et al., 2014). The prevalence of poor sleep quality appears to be higher in Iran. A study on Iranian firefighters indicate that 69.6% of 427 participants were categorized as poor sleepers (PSQI score > 5) (Mehrdad et al., 2013). This statistic was similar to another study from Iran that found 59.3% (70 firefighters) had poor quality of sleep (Abbasi et al., 2018).

The incidence of sleep disorders may be due to length of work shifts, work shift schedules, and other workplace conditions. For instance, Choi and colleagues (2016) indicated that firefighters often work a standard 10 to 11, 24-hr shifts per month; however, many firefighters work additional 24-hr shifts voluntarily and non-voluntarily beyond the standard schedule. Excessive 24-hour shifts have also been reported in Australian firefighters due to a combination of volunteer activities, regular paid employment, and second jobs (Dawson et al., 2015; Barger et al., 2015). Choi et al., (2016) observed among 330 US firefighters that 85.8% (n=283) reported 12 to 21, 24-hr shifts in the previous month. Within this range, 23.3% of 330 firefighters (n=77) reported 14, 24-hr shifts. Barger and colleagues (2015), in a sample of 66 fire departments (6933 participating US firefighters), found that nearly all fire departments (97.0%) employed extended duration work shifts greater than 24 hours; 19.7% of departments scheduled their firefighters to shifts greater than 48 hours. The mean work hours of the 6933 firefighters was approximately 64hrs per week. Billings and Focht (2016) compared shift schedules (24on/47off,

48on/96off, Kelly schedule: 24on/24off/24on/24off/24on/96off) and their effect on sleep quality. Of the sampled 109 firefighters, 80 (73%) reported poor sleep quality. When examining the prevalence and severity of excessive daytime sleepiness (EDS), Haddock et al., (2013) calculated unadjusted rates of EDS of 13.7% and 14.0% for on- and off-duty, respectively. Those who worked a 48-hour schedule, shared sleeping areas with other firefighters, or had a second job were more likely to score high on excessive daytime sleepiness (>10 on the Epworth Sleepiness Scale) (Haddock et al., 2013).

Firefighting activities are risk factors for cognitive fatigue. In a study interviewing UK fire and rescue personnel, 22 respondents cited physical fatigue (67% of all responses), risk of injury (13%), and cognitive stressors (12%) as important types of stressors prior and during an emergency incident (Young et al., 2014). The most significant cognitive stressors were fears of incorrect decision when wearing self-contained breathing apparatus (SCBA), controlling frustration when fatigued at an SCBA incident, the ability to provide required response when sleep deprived on a night shift, and keeping emotions and arousal at self-perceived appropriate levels (Young et al., 2014). Roja et al., (2009) asserted that mental load during firefighting is related to "psycho-emotional" load rather than processes like decision-making and solution finding. After an emergency incident, firefighters may experience subtle decreases in reaction time, sustained attention, and other changes in cognitive performance (Hostler et al., 2016; Greenlee et al., 2014). Reduced sleep quality has also been attributed to anticipating alarms and calls (Jahnke et al., 2012; Carey et al., 2018).

Physical Fatigue: Studies have investigated the relationship between physical capacity and injury risk or performance using both well-controlled treadmill protocols (e.g., Baek et al., 2018; Horn et al., 2015; Gendron et al., 2015; Lindberg et al., 2014), simulated protocols (e.g., Marcel-Millet et al., 2018; Kesler et al., 2018; Walker et al., 2017; Siddall et al., 2016; Ensari et al., 2017; von Heimburg et al., 2013), and protocols within a live-fire burn building (e.g., Yeargin et al., 2016; Horn et al., 2015; Eglin & Tipton, 2005; Clark et al., 1998). Physical responses (i.e., fatigue) has been measured as an intermediary between mismatches of capacity and demand, and outcome. For instance, Angelini et al. (2018) examined the risk of slips, trips, and falls after the three assessment protocols and found that fatigue increased the risk of trips and falls (increase of 86% major contact errors and 56% minor contact errors committed by the trailing foot); decrement in performance was amplified when carrying a load (e.g., hose). Changes in gait performance, where firefighters walked more cautiously and with less confidence after firefighting activities (i.e., decrease in step length, decrease in stride length), was observed by Park et al., (2018). Park and colleagues (2018), Kesler et al., (2018), and Colburn et al., (2017) all asserted that firefighters adopted more conservative gait and compensation strategies to maintain balance following strenuous activity. The impact of fatigue on hand-eye coordination and the risk of slips, trips, and falls have been corroborated by interviews of firefighters in Australia (Dawson et al., 2015). The effect of fatigue on gait and postural balance may be more pronounced among less-trained, less-experienced personnel, including retained (on-call) firefighters (Pau et al., 2014). Load carriage, including SCBAs, further impairs gait performance, as well as long work shifts (Sobeih et al., 2006).

Overexertion due to strenuous physical work has also been linked to adverse health outcomes, such as fatal cardiac events (odds ratio of 11.6) (Sen et al., 2016). Overexertion accounts for 33% of injuries claimed by firefighters, where 83% of injuries due to overexertion were strains and sprains; lifting was the cause of 49% of overexertion-related injuries (Walton et al., 2003). Overexertion-related injuries, after controlling for age and year, were 89% more costly than any other causes of injury, averaging a total cost of $319 per firefighter per year (Walton et al., 2003). These statistics have been corroborated by Fiodorenko-Dumas et al., (2018), who found that 64% of 61 firefighters reported an increase of frequency of back pain after starting work in the firefighting service, and the most common risk factor was overexertion (40%) followed by static postures (36%). A study of 6997 cases of work-related injuries in Australian firefighting (Taylor et al., 2015) suggest that three of the top five causal mechanisms of injury involved muscular stress (74 injuries per 1000 FTE each year, 62.1% of the 74 injuries occur during material handling activities) and two of the top five were related to slips, trips, and falls (40 cases per 1000 FTE each year).

Physical demands (e.g., heart rate, heart rate variability, % VO2 max) have been recorded over 8-, 12-, and 24-hour work shifts (Kaikkonen et al., 2017); both mean and peak physiological loads indicate the possibility of excessive fatigue in firefighting activities. Fatigue and cardiocirculatory strain may be hastened by working in heat (Smith, 2011; Angerer et al., 2008); firefighters reported that exhausting fires while wearing a SCBA was the most physically demanding stressor that result in excessive fatigue (Young et al., 2014). Kaikkonen et al., (2017) found that fire and rescue service activities, compared to ambulance and emergency service activities, were associated with higher stress and lower recovery. According to Dolezal et al., (2014), US firefighters complete fire suppression activities at levels greater than 80% of their maximum heart rate. In a study of German firefighters, under conditions simulating real-life emergencies, including fire suppression and person rescue, heart rate exceeded the maximum heart rate obtained from exercise stress tests (Angerer et al., 2008). The thermal and physical strain may be more pronounced among volunteer firefighters, who experienced higher increases in tympanic temperature and pulse rate than career professional firefighters who may be better adapted to thermal, physical, and psychological strains of firefighting (Ljubicic et al., 2014). In a 1993 study of Canadian firefighters, when compared to the general Canadian population, firefighters were significantly heavier than the 50th percentile of Canadian males of similar age, had significantly lower cardiovascular endurance, but had higher flexibility and higher muscular endurance (Horowitz & Montgomery, 1993).

Burnout: In a study of 109 South Korean firefighters, the mean scores between 1 (never) to 5 (every day) of emotional exhaustion, cynicism, and burnout was 2.30 (SD = 1.04), 1.76 (SD = 0.96), and 2.06 (SD = 0.95), respectively (Jo et al., 2018). Study authors indicate that the low mean burnout scores of their sample were comparable to previous studies of Korean firefighters. Similarly, a study of 220 French firefighters also revealed low scores of burnout using a scale of 1 to 6, with dimensions of cognitive weariness (M = 1.48, SD = 0.78) and emotional exhaustion (M = 1.70, SD = 0.85) (Vaulerin et al., 2016). Low burnout scores based on the three dimensions from the Maslach Burnout Inventory were also observed among a sample of firefighters in Kazakhstan (Vinnikov et al., 2019). A study on 286 US firefighters assessed job burnout on a 1- (not at all) to 5- (very much) point Likert scale (Sattler et al., 2014). Participants reported minimal burnout (mean score of 2.43, SD = 1.18, when asked "Sometimes I feel burned out on the job"). Smith and colleagues (2018) reported a mean score of 1.65 (SD = 0.64) on a 5-pt Likert scale (10 items from Malach-Pines burnout scale) of 208 career US firefighters.

Police Officers

This standard will be focused on "Police officers (except commissioned)" (NOC code: 4311), who protect the public, detect and prevent crime and perform other activities directed at maintaining law and order (NOC, 2016). According to US database O*NET, these workers are categorized as "Police Detectives" (SOC code: 33-3021.01), "Police Patrol Officers" (SOC code: 33-3051.01), and "Police and Sheriff's Patrol Officers" (SOC code: 33-3051.00). Police officers are workers who conduct investigations to prevent crimes or solve criminal cases, whereas Police Patrol Officers are workers who are assigned to an area to enforce laws and ordinances, regulate traffic, control crowds, prevent crime, and arrest violators (www.onetonline.org). According to O*NET, Police and Sheriff's Patrol Officers are those who are responsible for maintaining order and protecting life and property by enforcing local, tribal, State, or Federal laws or ordinances; these workers perform a combination of duties, including patrolling a specific area, directing traffic, issuing traffic summonses, investigating accidents, apprehending and arresting suspects, and serving legal processes of court (www.onetonline.org). The NOC system indicates that police officers are employed by municipal and federal governments and some provincial and regional governments (NOC, 2016).

Cognitive Fatigue: An Italian study of 1280 police officers suggest that 9 to 10% of their cohort experienced excessive sleepiness, based on the Epworth Sleepiness Scale (Garbarino et al., 2002). A significant risk factor of sleepiness and tiredness among police officers is work shift and length of shift. In a study of 308 US police officers from the large Buffalo Cardio-Metabolic Occupational Police Stress Study (BCOPS), there was a significant association between shift work and feeling of tiredness after stratifying by sex. The prevalence of tiredness was more than two times higher in male officers who work the afternoon shift (PR = 2.17, 95%CI: 1.33-3.56, p = 0.0020) compared to male officers working the day shift; this relationship was found to remain significant after adjusting for covariates (PR = 1.89, 95%CI: 1.12-3.23, p = 0.0196). Male officers working the afternoon shift had a higher prevalence of tiredness compared to male officers working night shifts (adjusted PR = 1.59, 95%CI: 1.05-2.37, p = 0.0266). There were no significant trends among female officers (Violanti et al., 2018). Elgmark and colleagues (2017) assessed the predictive power of the job-demand-control-support model in Swedish police and found that job demands accounted for the most variance related to fatigue (r2 = 22%), however shift work did not significantly affect predictive power. The effect of the pattern or arrangement of shifts on fatigue have also been examined. A 2-year longitudinal study on 42 police officers from the Netherlands found that 41% of recorded workdays were extended shifts of more than 9 hours (Lammers-van der Holst et al., 2016).

The quality and duration of sleep has been investigated in law enforcement. In a US study, 43% of 379 police officers reported less than 7 hours of sleep while 11% reported less than 6 hours (Everding et al. 2016). In Australia, the mean PSQI score of 6.83 (SD = 3.58) indicated that a substantial number of the 206 police officers reported poor sleep quality; 69% of officers scored above the PSQI threshold score of five. These statistics were similar to a study of 796 Taiwanese police officers where the mean global PSQI score was 6.09 (SD = 3.09), and 52.3% exceeded the PSQI threshold value, indicating poor sleep quality (Chang et al., 2015). The BCOPS cohort study revealed that the prevalence of poor sleep quality among 464 US officers was 53.9%; when stratified by shifts, the prevalence was 43.9% among officers who predominantly worked day shift, 59.8% for afternoon shift, and 69.1% for night shift (Fekedulegn et al., 2016). After adjusting for covariates, the prevalence of poor sleep quality was 72% higher among officers who worked night shift compared to day shift, and 49% higher when comparing afternoon to day shift. A US study of 106 officers indicated a lower prevalence of poor sleep quality, 36% were poor sleepers (PSQI score > 5) and 30% reported sleep durations of less than 6 hours (Yoo & Franke, 2013). Thirteen percent of 105 US police officers as part of the SHIELDS program reported insomnia (Gershon et al., 2002). In Canada, 61 RCMP officers from 11 detachments enrolled into a Calgary Police Service Fatigue Training Program, reported an average of 6.3 hours of sleep per night during the work week; 14% suffered from sleep apnea, 45% suffered from insomnia, and only 21% were satisfied with their sleep (James et al., 2018). A large cohort study of 4957 police officers over a two-year period indicated that 40.4% of police officers reported symptoms consistent with at least one sleep disorder, but many have not been diagnosed in the past or were not taking regular treatment (Rajaratnam et al., 2011). A systematic review on the sleep quality of police officers calculated a pooled prevalence of poor sleepers as

51.1%; the pooled mean score of the PSQI was 5.64 (Taylor et al., 2019).

Physical Fatigue: Sprains and strains represent 30% of all nonfatal injuries among law enforcement officers in the US; the most common nonfatal injury events between 2003 and 2011 were related to bodily reactions and exertions (15%), including overexertion from running and repetitive motion injuries (Tiesman et al., 2018). These injuries may be attributed to physically demanding tasks in police work. An Australian study created a job task inventory of the most physically demanding police officer tasks. Eleven tasks represented the most physically demanding and frequently occurring requirements, where seven of the eleven were rated "moderate" or "higher" for physical demand. The task requiring muscular strength included "wrestling, restraining, and handcuffing someone resisting arrest while in full gear", while "standing for long periods" and "running long distances to support dog squad in full gear" were perceived to require muscular endurance and aerobic power (Silk et al., 2018). DiVencenzo and colleagues (2014) found that PPE increased VO2 and increased overall bodily discomfort due to the added weight of the gear but did not significant affect respiratory exchange ratio and rating of perceive exertion. In a study investigating the effect of environmental pollutants on physical fatigue in a cohort of officers in Iran, high exposure to ozone was related to higher levels of physical fatigue (Jazani et al., 2015). A similar study in Italy examined the effects of pollutants on respiratory and cardiovascular function, finding that outdoor air pollutants reduced officers' gross mechanical efficiency, reducing endurance time at maximal effort (Volpino et al., 2004). A study using BCOPS data found that increasing fatigue was associated with higher prevalence of injury. That study assessed the levels of chronic fatigue (i.e., the level of tiredness or energy, irrespective of sufficient sleep) and general feelings of tiredness and lack of energy (i.e., feelings of exhaustion, lethargy, weariness, etc.). Study results indicate that 46% of officers had above average chronic fatigue scores and nearly 40% reported "feeling drained" (Fekedulegn et al., 2017).

Compassion Fatigue: Few studies have examined compassion fatigue among law enforcement officers. It has been hypothesized that traumatic work events may be related to a high risk of compassion fatigue but may affect men and women differently (Violanti & Gehrke, 2004). Turgoose et al., (2017) assessed the levels of compassion fatigue of officers who work with victims of rape and sexual assault; of 142 UK police officers, 84% compassion fatigue scores were ranked as being low, 16% were average, and none rated as high.

Burnout: Police officers may be prone to burnout, which is characterized by emotional exhaustion, depersonalization, and low personal accomplishment. De la Fuente Solana (2013) measured burnout in 747 Spanish police officers and found that 32.2% demonstrated a high level of burnout, 12.5% a medium level, and 55.4% a low level of burnout. In a Swedish study of 856 officers, 30% of female and 26% of male officers had high levels of emotional exhaustion while 52% of females and 60% of males had high levels of depersonalization (Backteman-Erlanson et al., 2013). One hundred and five police officers in the US completed a self-administered survey to assess the relationship between perceived work stress and stress-related outcomes (Gershon et al., 2002). The authors indicated that 40% of participants felt "burned out" from the job, 31% were on "automatic pilot most of the time", and 13% stated that they "were at the end of their rope." Another US study of 486 civilian employees and 2078 officers from 12 agencies found that the mean burnout scores between groups were comparable (3.79 civilians vs 3.76 officers). Approximately 28% of civilian employees felt burned out from their work 2 to 3 times per week or daily, whereas 20% of officers felt burned out from their work 2 to 3 times per week or daily (McCarty & Skogan, 2013). Agency size appeared to have a significant effect on burnout; officers serving populations less than 250,000 had higher levels of burnout. Female officers also reported significantly higher levels of burnout than their male counterparts (McCarty & Skogan, 2013). Unlike other countries in the world, a study from Italy reported low burnout manifestations based on the MBI scale and concluded that the 88 police officers in their study may not be at risk for developing burnout (Setti & Argentero, 2013). A Canadian study of 410 participants (69% of which were police officers) found that psychological demand was consistently associated with burnout (Marchand & Durand, 2011); burnout tends to manifest from organizational factors rather than from critical incidents (Brady, 2017). However, the effect of psychological demands on men and women and resulting levels of burnout may be different (Tehrani, 2016).

Objective

First responders are at high risk of suffering from decrements in neurocognitive and physical performance related to fatigue. Such performance decrements endanger not only the personal health and safety of these responders but also the health and safety of their fellow responders and the public they serve. Fatigue may also be a precursor to adverse longer-term outcomes, such as musculoskeletal disorders, cardiovascular disease, and mental health disorders. Appropriate management, policymaking, standards, guidance, and research activities can reduce the exposure to these fatigue-related risks and hazards before they pose significant problems during emergency response operations.

Emergency response providers are called into service on very short notice and at all hours of the day. As a result, they may be: deployed without sufficient sleep and rest to ensure optimal alertness and performance levels; called into service during the circadian trough of alertness and the circadian peak of sleepiness in humans; and required to perform safety-critical tasks that may be physically or mentally demanding within minutes of waking up, when the effects of sleep inertia are most potent. Once deployed, responders may participate in continuous operations requiring extended work shifts and sustained wakefulness during all hours of the day and all circadian phases of the human body. For these reasons, first responders constitute an occupational group that is particularly vulnerable to the effects of fatigue. Managing responder fatigue and mitigating its associated health and safety risks are therefore essential to protect first responder and public health and safety.

In Lerman et al., (2012), fatigue risk management was defined as a science-based, data driven process that is subject to continuous improvement, and designed to improve outcomes. When incorporated into a management system, elements are linked into a formal structure. These elements are: (1) safety management policy, (2) risk management, (3) reporting, (4) incident investigation, (5) training and education, and (6) internal and external auditing (Lerman et al., 2012); these elements can be integrated within a broader plan-do-check-act framework. One fundamental aspect of fatigue risk management, that can be integrated into PDCA, is to deal with fatigue hazards based on risk assessment RACE model – recognizing hazards, assessing risks, implementing controls to mitigate risk, and evaluating the effectiveness of controls.

There are a few studies that have developed and/or investigated the effectiveness of a fatigue risk management program. Barger and colleagues (2017) conducted a station-level randomized trial of a fatigue risk management program for urban firefighters, with a focus on policies to improve the quality and duration of sleep. The authors found that firefighters assigned to the fatigue risk management group reported significantly improved sleep quality and 49% reported increased sleep at the fire station. In the law enforcement literature, there has been a focus on fatigue management training, including one developed for the Royal Canadian Mounted Police (RCMP). The fatigue-management training program was found to improve sleep satisfaction, reduce symptoms of insomnia, and reduced incidence of headaches (James et al., 2018). Studies have also focused on law enforcement policies and practices to minimize police officer fatigue, including shift scheduling and work hours (Vila et al., 2002). Recently, Dr. Daniel Patterson, his colleagues, and in partnership with the National Association of State EMS Officials (NASEMSO) have been developing a fatigue risk management guideline for EMS operations in the US. Currently, an evidence-based guideline for EMS has been developed, is now being evaluated, and there is a prospective goal of developing a biomathematical model for EMS shift scheduling. Resources can be accessed at: https://nasemso.org/projects/fatigue-in-ems/. These existing initiatives underscore the need for a Canadian standard to promulgate these ideas into workplace practices and policies and are valuable resources to spearhead the development of a Canadian standard for first responder organizations.

The main objective of this project is to develop an evidence-informed National Standard on First Responder Workplace Fatigue Risk Management (the "Standard") which will be used across Canada to improve first responder health and wellness and will support the collection of consistent, national data that will inform the development of a robust and comprehensive Canadian Paramedic Information System. A goal of the project will be that first responder organizations incorporating the national Standard into their existing management systems will experience reduced worker injuries and improved health and wellness as a result of having a Workplace Fatigue Risk Management System in place. In addition, the Standard will enable further paramedic research in the area of health and wellness as well as organizational performance and productivity by contributing a common national dataset to the proposed Canadian Paramedic Information System. Canada will be the first country to have such a Standard. The project also proposes to elevate the final Standard for consideration as an international ISO standard, thus promoting Canada's leadership in the international first responder community.

The scope of this project includes: 1) conducting research related to first responder workplace fatigue risk management (including working with partners and workplaces); 2) developing a consensus-based, evidence-informed national Standard; 3) developing supporting Standard implementation tools; 4) pilot testing the standard in an organization in British Columbia; and 5) supporting the internationalization of the Standard to showcase Canada as a leader in first responder health and wellness and build capacity within international community.

This report describes the "Research and Synthesis of Evidence" phase (Figure 1), gathering evidence from three sources: 1) a scoping review of peer-reviewed literature to provide the current state-of-the-art scientific knowledge in first responder workplace fatigue risk management, 2) an environmental scan of good practices based on grey literature (e.g., reports, policy documents, best practice guidelines available on the web and elsewhere), and 3) interviews of key informants (front-line staff or management) from exemplary organizations. The scoping review will mainly inform the RACE model while the environmental scan and key informant interviews will mainly inform other aspects of the PDCA model. Collectively, the data will be synthesized, and a needs assessment will be performed to identify the issues, gaps and needs of key stakeholders.

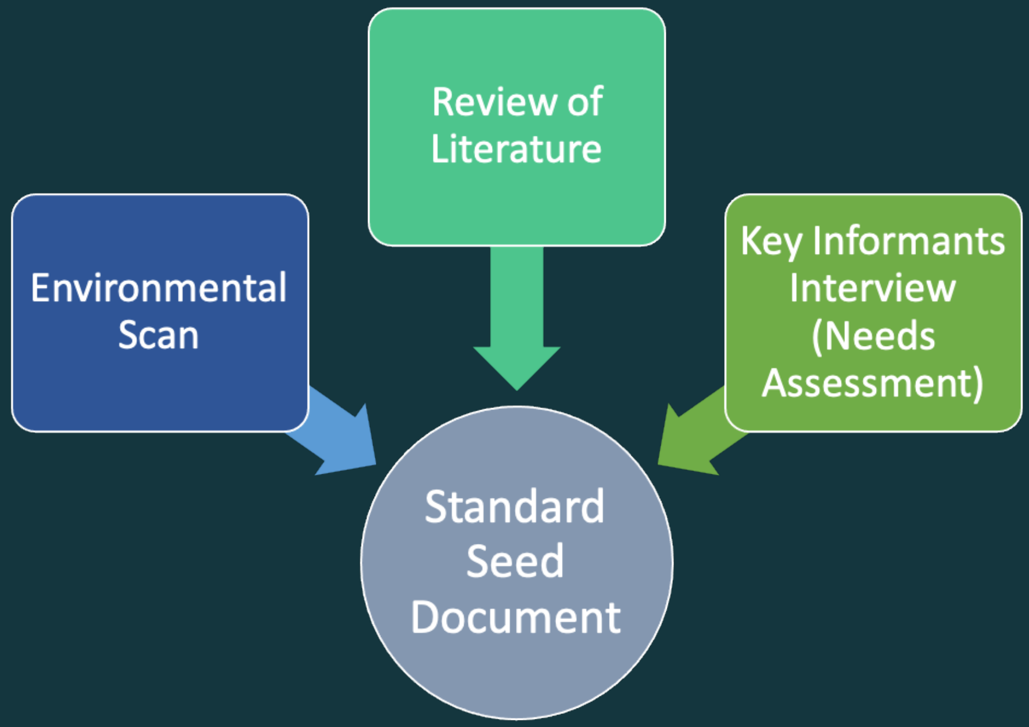


Figure 1. Three sources of information for the development of a seed document to create a workplace fatigue risk management standard.

Methods

Our objective was to broadly identify relevant research pertaining to fatigue risk management and synthesize the research to inform aspects of the risk assessment RACE model (recognize hazards, assess risks, implement controls, and evaluate effectiveness of controls). We conducted a scoping review to examine the extent, range, and nature of research activity, allowing us to identify gaps in the current literature. A scoping review does not assess the effectiveness of an intervention nor the quality of the literature but remains a transparent and systematic approach to gather information (Arksey & O'Malley, 2005; Levac et al., 2010). Scoping reviews follow a methodology that is equivalent to qualitative analysis of literature to itemize and summarize existing findings on a topic, and to facilitate an in-depth understanding of how findings relate to each other and to the research question (Poth & Ross, 2009). Arksey and O'Malley (2005) identified four reasons to conduct a scoping review:

1) examine the extent, range, and nature of research activity,

2) determine the value of undertaking a full systematic review,

3) summarize and disseminate research findings,

4) identify gaps in the existing research literature.

For this scoping review, our objectives are satisfied by reasons (1) and (4). A scoping review consists of five stages: 1) identifying the pertinent research question(s), 2) searching the relevant studies, 3) selecting studies, 4) charting the data, 5) summarizing and reporting the results.

Stage 1: Identify the Research Questions

The following research questions guided this scoping review:

1. In EMS, Firefighting, and Law Enforcement, what are the potential health, wellbeing, and performance outcomes of fatigue?
2. In EMS, Firefighting, and Law Enforcement, how do organizations and personnel identify hazards of fatigue and assess the risk of an adverse outcome?
3. In EMS, Firefighting and Law Enforcement, what control actions or interventions are available to reduce fatigue?
4. In EMS, Firefighting and Law Enforcement, what are valid and reliable instruments for measuring or detecting fatigue among personnel?

These questions were developed to address aspects of the RACE model and was intentionally structured broadly to capture a wide range of research and ideas.

Stage 2: Search for Relevant Studies

We conducted a systematic search of using three large databases: PubMed, Scopus, and Embase. After consulting with a research librarian, we developed a list of relevant search terms within three core concepts and their synonyms (person/subject, task/discipline/subject area, fatigue/health outcome/effect). We used the Boolean operator "OR" between search terms within each concept, and Boolean operator "AND" across concepts. The systematic search focused on articles from 1990 to May 2, 2019. We pre-determined a list of 10 relevant articles to cross-reference with the search results.

Stage 3: Select Relevant Studies

Papers obtained from our systematic search went through two screening processes. In the first screening process, included were: a) papers that were written in English and b) papers published in peer-reviewed journals. Any duplicates of articles were removed. We created a screening tool to assist in selecting articles for inclusion on the basis of its title and abstract. In the first screen, we retained articles that involved a first responder occupation. Here, paramedic includes EMT, EMS Personnel, EMT Personnel, Ambulance Worker, Ambulance Driver, and Paramedic Trainees. Firefighter includes Fireman, Ladderman, and Firefighter Trainees. Police officer includes Policeman, Officer, Cop, Constable, Law Enforcement, and Police Trainees. We also retained articles that involved aspects of the RACE model for fatigue. Articles on single events (e.g., plane crashes, natural disasters, terrorist attacks), those that did not focus on civilian first responders (e.g., wildland firefighters, military police, border police or patrol, correction officers, intelligence officers), those that involved air ambulances, or did not focus on worker fatigue (e.g., material fatigue) were all excluded from review.

Titles and abstracts were screened by two reviewers: MY and JG. The first 60 titles and abstracts were screened by both reviewers independently and then evaluated for inter-rater agreement. Cohen's unweighted kappa was calculated to determine the level of agreement between the two reviewers; the strength of agreement was "Very Good" ($k = 0.859$, $z = 6.67$, $p < 0.05$). With this level of agreement, each reviewer independently screened the remaining articles. After both reviewers completed the first screen, any discrepant results were discussed until consensus was reached. Any article where consensus was not reached was included for full-text review. All papers for the data gathering and extraction process was retained within a publicly available online tool (Rayyan, Ouzzani et al., 2016).

Stage 4: Chart the Data

The retained articles underwent a full-text review where key data was extracted into a second screening tool using Microsoft Excel. In this second screening tool, high-level information was retained (e.g., authors, year of publication, journal, type of study, world region or country of study sample, and categorization of first responder occupation). We also retained detailed information, including the objective of the study, the sample size, sample characteristics (age, work experience in years, sex), and the type of fatigue (using our categorizations in "Fatigue: A Multidimensional Construct" section, we indicate here the details of experimental protocols or methods, or the prevalence of fatigue). The type of fatigue was determined by evaluating three criteria: 1) the type of fatigue described by the study authors, 2) the measurement tools (if available), and 3) the task or risk factors that may be attributed to the fatigue response. We also retained information pertaining to hazard and risk factors (categorized broadly into work organization, physical environment, personal/social/cultural, task), fatigue measurement and risk assessment tools, fatigue outcomes or symptoms (categorized broadly into performance/productivity, physical health, wellness), outcome measurement tools, interventions and risk mitigation strategies based on the hierarchy of controls (categorized broadly into training, PPE, administrative, engineering), any recommendation for the process of fatigue risk management, and additional notes. Each category is defined in Table 1. Articles that did not meet our inclusion criteria were removed. Two reviewers (MY and JG) extracted data from the full-text review. The first 20 articles were extracted by both reviewers to ensure quality of the retained data. Both reviewers consulted with one another, throughout the entire second screening process, if there were any uncertainties with interpreting articles.

Stage 5: Collate, Summarize, and Report Results

We describe our findings in four sections. First, we provide a cursory overview of the number of articles in each category and sub-category. Due to the significant number of articles for full-text review, a cursory analysis provides the scope of available research and scientific evidence devoted to the three first responder occupations, and opportunities for further investigation. Second, we describe from the literature the fatigue measurement and risk assessment tools that have been used to detect or document fatigue. Third, we observationally interpret the potential relationship between risk factors, fatigue, and outcome (performance/productivity, health, wellness) based on studies that have measured these aspects. Lastly, we discuss the interventions that have been studied to reduce or mitigate the levels of fatigue in first responder occupations.

SCOPING REVIEW

Table 1. Categories and definitions of second screen to extract from full-text reviews.

Category	Sub-Category	Definition or Example
Title		
Authors		
Publication Year		
Journal		
Type of Study		From Aguayo et al., 2017: Describe study design (experimental. quasi-experimental, survey, observational, commentary, review), measurement strategy (cross-sectional, prospective cohort, case-control, longitudinal, parallel, cross-over), and sampling method (randomized, non-randomized, matched)
Sample Size		
Occupation		Paramedic, Firefighter, Police Officer
Age		Mean years of sample
Experience		Mean years of sample
Sex		% or sample size of male and female participants
Region/Country		Of the sample population but not of the authors
Type of Fatigue		See above.
Risk Factors	Work Organization	Scheduling, work arrangement, management style, organizational behavior, safety climate/culture, programs, work hours, job demands etc.
	Physical Environment	Tools, equipment, PPE, workstation layout, physical hazards (noise, sound, light), etc.
	Personal/Social/Cultural	Personal capacity, demographics, anthropometrics, interactions with people outside of workplace, work/life balance, societal roles
	Task	Repetition, force, duration, posture, vibration.
Risk Tool		Describe the tool (instrument, survey, questionnaire) used to measure fatigue or assess risk.
Fatigue Effect/ Outcome	Performance/ Productivity	Quality - metrics: # defects, % defects, frequency of quality deficiencies, human error rate); productivity - concept that measures the ratio of outputs to inputs (Munnell, 1990).
	Health	Musculoskeletal, acute injuries (trips, slips, accidents, falls), adverse outcomes (chronic diseases, cardiovascular disease, illnesses, cancer, immune deficiencies, etc.)
	Wellness	Depression, emotional, job satisfaction, stress, spiritual, enrichment, attitude toward work, conflict, burdens, financial, intellectual, social
Outcome Tool		Describe how the outcome of interest was measured (instrument, survey, questionnaire).
Interventions	Training	Capacity tests, performance training, training to perform tasks (e.g., lifting, movement, etc.), prevention programs.
	PPE	Wearable to prevent fatigue (like a garment). Includes insoles, type of shoes, eyewear (visual strain). Not PPE or wearable for the job to reduce exposure to other work exposures.
	Administrative	Workplace organizational efforts (work scheduling, rest breaks, restricted work hours per day or week, fatigue risk management).
	Engineering	Specific to mitigate or reduce fatigue, could be a new intervention device or study that evaluates the effectiveness of different types of engineering controls.
	Not Sure/Elim. or Sub.	Not specific to a category. Could be a mix of interventions. Could be elimination or substitution methods.
Recommendation		Any recommendation provided by authors on fatigue risk management (policies, process, procedures, PDCA, organizational management, incident reporting, etc.)
Notes		Provide any details or notes from the paper that does not fit into any of the preceding categories, include ideas generated from the paper that could be of interest in the standard.

Results: Overview

Our search resulted in a total of 3671 papers and removed 1197 duplicates, leaving 2474 papers eligible for title and abstract review (first screen). A total of 507 papers remained after the first screen and were eligible for full text review (second screen). We further excluded 104 papers, leaving 403 papers for full text data extraction (Figure 2).

We performed a cursory analysis of each occupational group, to identify the number of articles by fatigue type, the general categorizations of risk factors, outcomes, and the type of interventions based on the hierarchy of controls. The number of articles in each sub-category does not summate to the category's total number of articles, as studies are accounted for in each individual sub-category.

EMS Personnel/Paramedics

Cognitive fatigue was most represented in EMS research, with 45 articles devoted to this topic, followed by physical fatigue and burnout (30 and 27 articles, respectively) (Figure 4a). Risk factors were mainly of the personal/social/cultural and work organization sub-categories (20 and 17 articles, respectively), while tasks (9 articles) and physical environment (7 articles) both represent half that number (Figure 4b). There was a consistent number of articles within outcome sub-categories from a total of 15 articles (Figure 4c). Interventions were categorized by engineering (7 articles), followed by administrative (5), and training and PPE (4 each) (Figure 4d).

Firefighters

A total of 156 articles were reviewed in firefighting research (Figure 5). The majority focused on physical fatigue (116 articles) followed by cognitive fatigue (42 articles) (Figure 5a). There was a consistent distribution of articles devoted to each of the four risk factor sub-categories (Figure 5b). Physical outcomes were a primary focus (31 articles), while performance and wellness were represented with 4 and 5 articles, respectively (Figure 5c). Fifty-five articles focused on interventions, 18 of which were PPE and 17 were engineered solutions (Figure 5d).

Police Officers

A total of 134 articles focusing on police officers were reviewed. Eighty-eight articles were categorized as cognitive fatigue, 34 as burnout, 23 as physical fatigue, 4 as emotional, and 2 were perceptual fatigue (Figure 6a). Work organization risk factors represented 47 of the 85 articles, personal/social and cultural risk factors represented 36 articles (Figure 6b). A total of 43 articles had data on fatigue outcomes (Figure 6c); physical outcomes were the focus of 32 articles. Lastly, there were 25 articles on fatigue interventions or risk mitigation strategies (Figure 6d). Twelve articles represent interventions that were categorized as training, followed by administrative controls (6 articles), and engineering controls (3 articles).

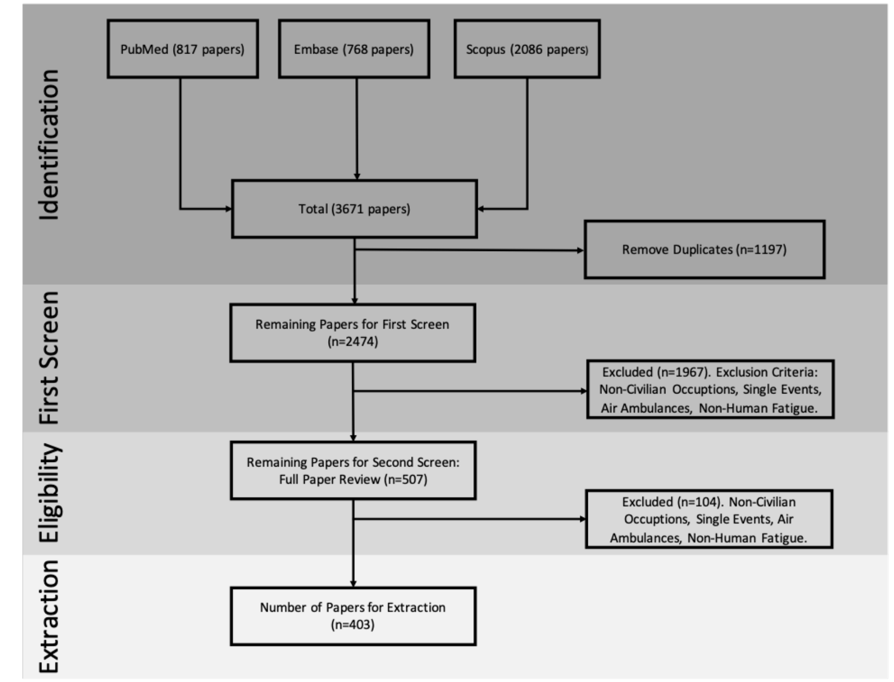


Figure 2. Flow diagram of systematic process of gathering, screening, and extracting data. Of the 403 extracted articles (Figure 3), a large proportion focused on fatigue among firefighters (38.7%) followed by police (33.3%), and EMS personnel/paramedics (22.8%). Studies also described fatigue not specific to a single first responder occupation but may involve more than one or all occupations (5.2%).

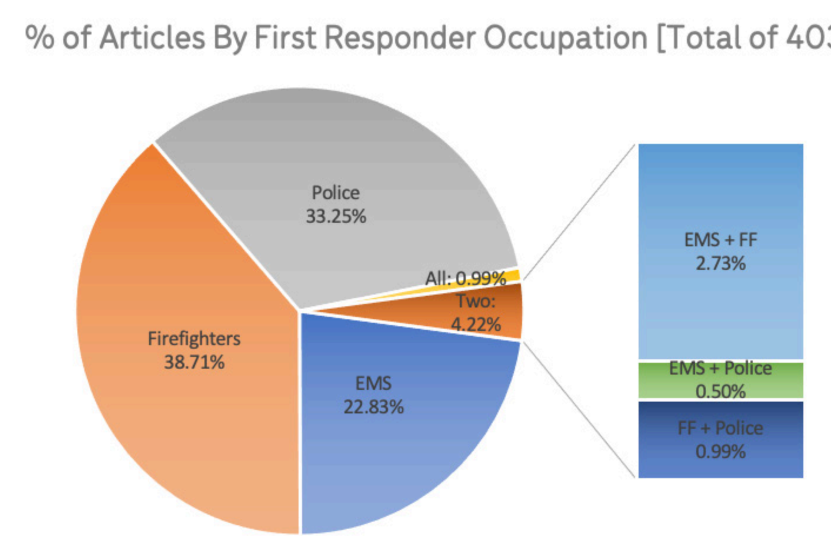


Figure 3. Percent (%) of Articles by First Responder Occupation from a Total of 403 Articles

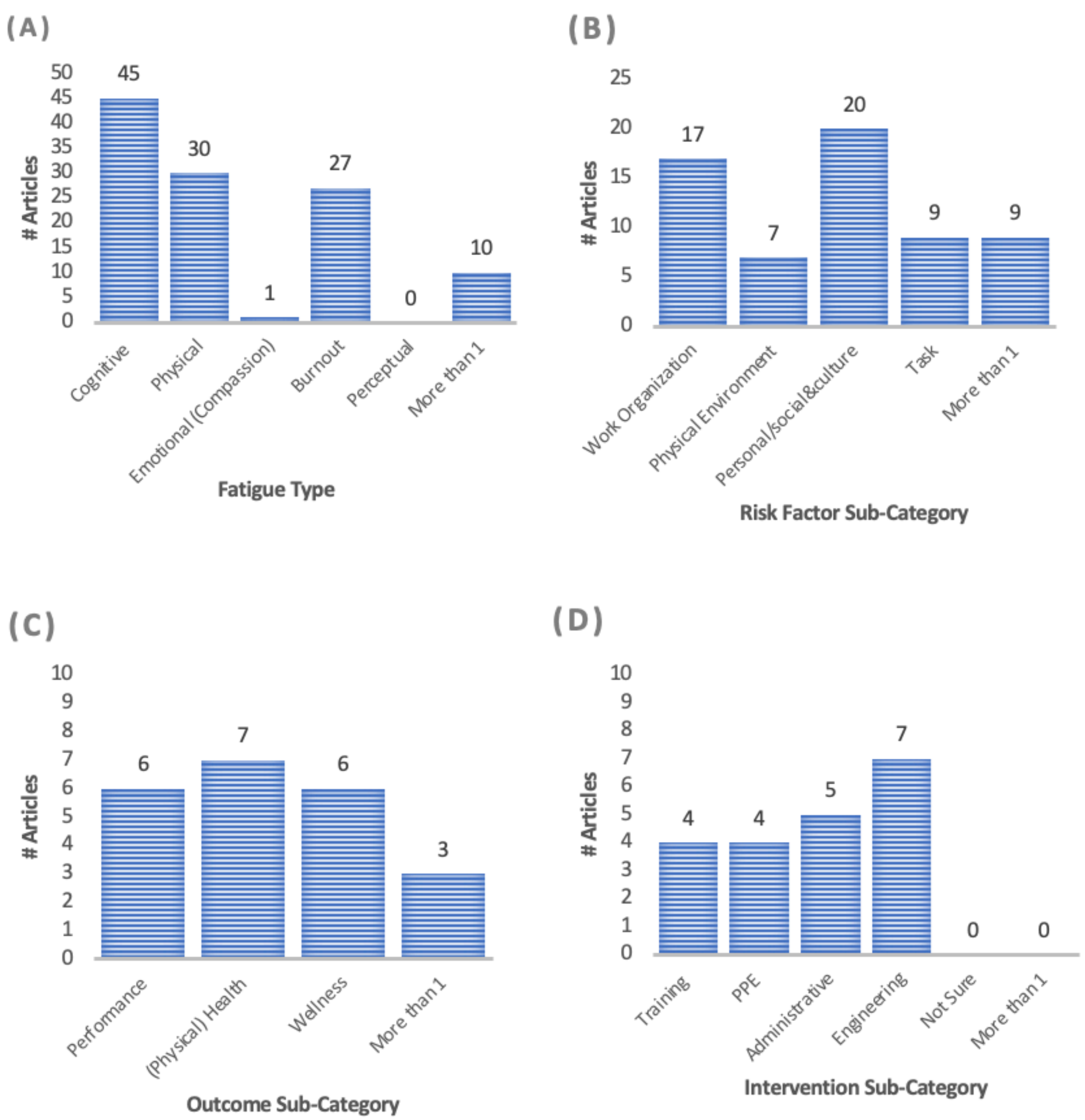


Figure 4. Number of articles for EMS personnel/paramedics by (A) Fatigue type, (B) Risk factor sub-category, (C) Outcome sub-category, and (D) Intervention sub-category. Articles counts are shown as distributions into categories are not mutually independent.

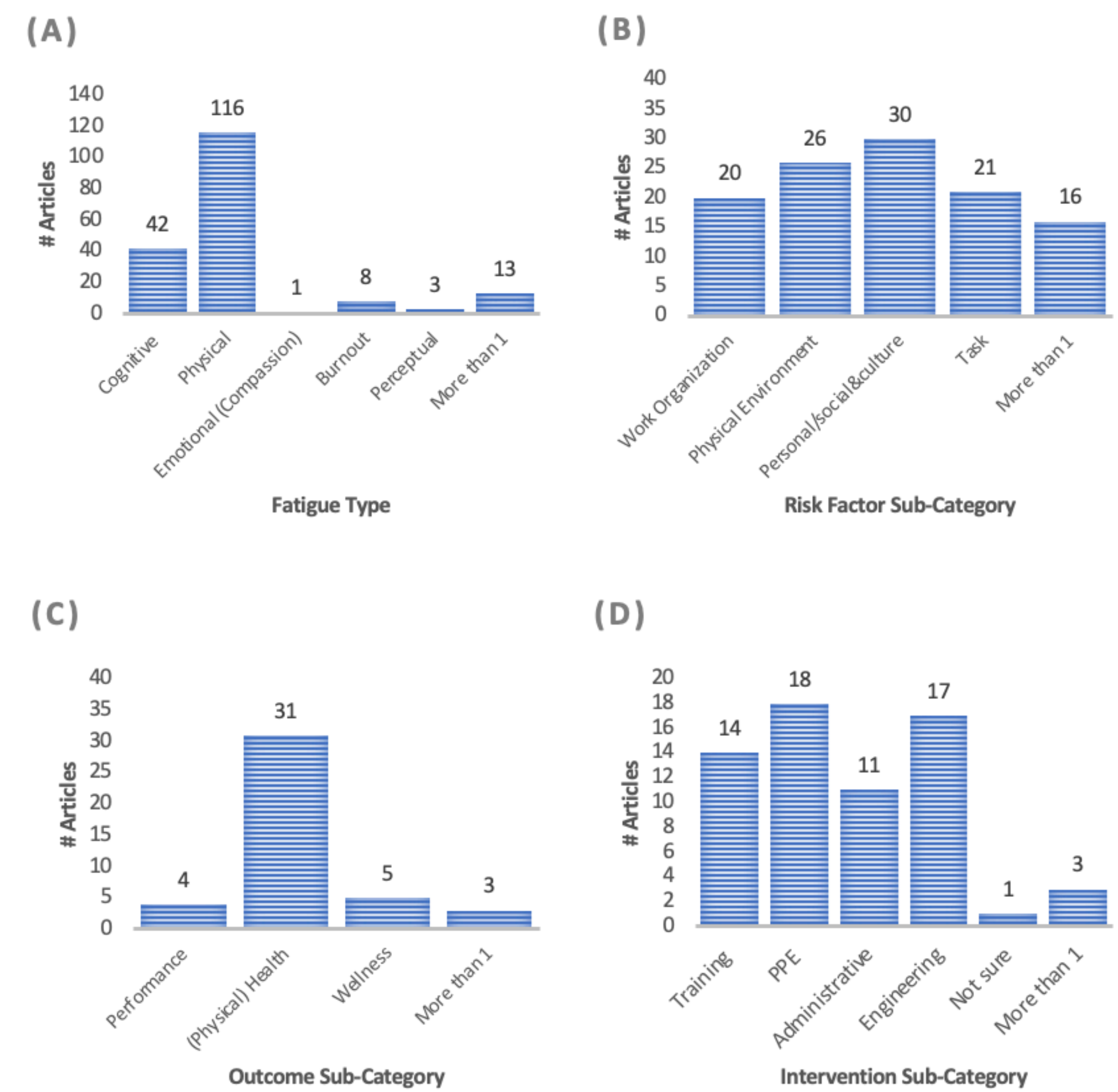


Figure 5. Number of articles for firefighters by (A) Fatigue type, (B) Risk factor sub-category, (C) Outcome sub-category, and (D) Intervention sub-category. Articles counts are shown as distributions into categories are not mutually independent.

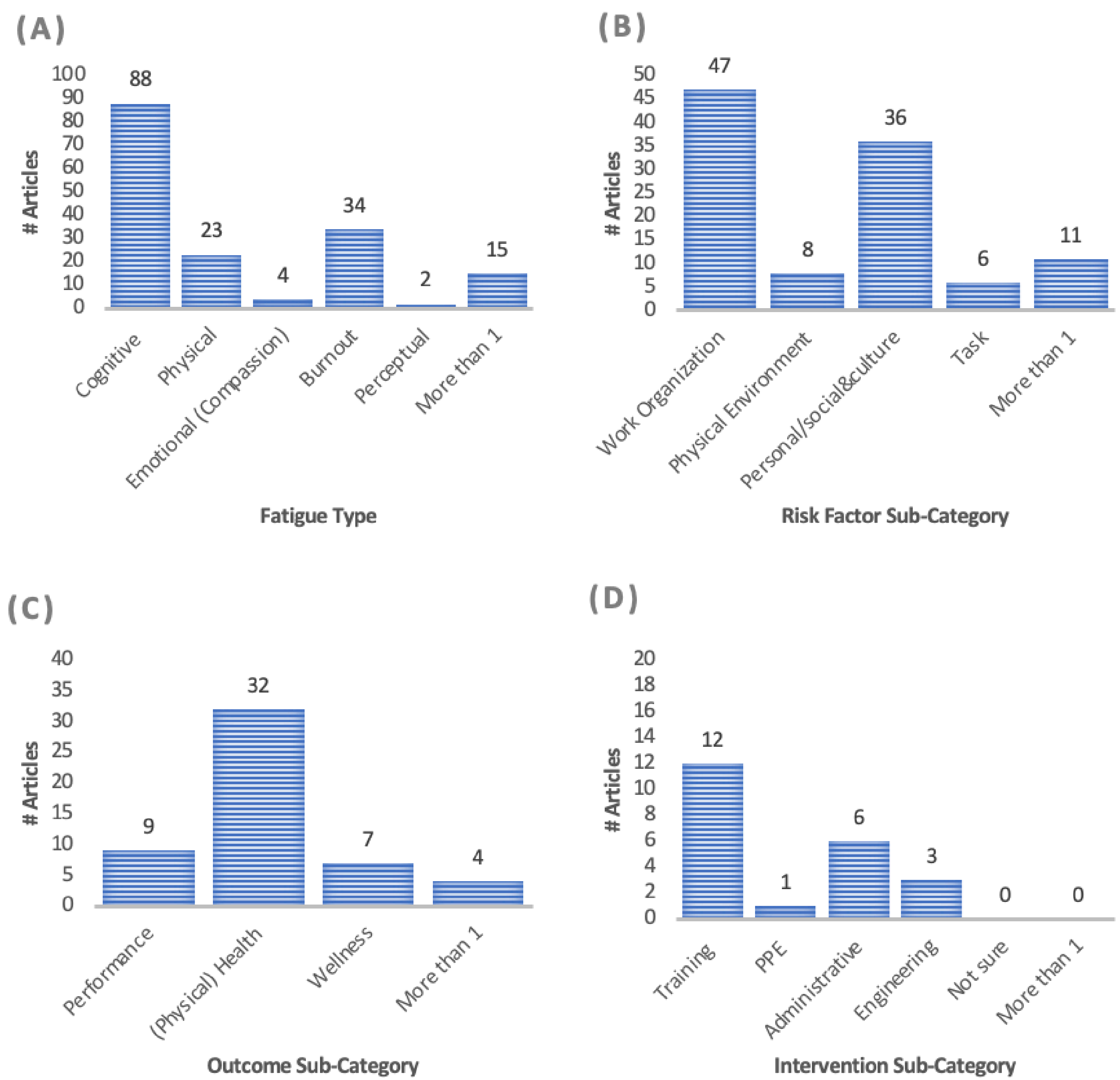


Figure 6. Number of articles for police officers by (A) Fatigue type, (B) Risk factor sub-category, (C) Outcome sub-category, and (D) Intervention sub-category. Articles counts are shown as distributions into categories are not mutually independent.

Results: Fatigue Measurement and Risk Assessment Tools

EMS Personnel/Paramedics

A total of 47 unique papers involved a measurement of fatigue or an assessment of risk for EMS personnel/paramedics (Table 2). Forty-two papers measured a single type of fatigue and 5 papers measured more than one type of fatigue. Five other papers were categorized as EMS and firefighters. Treating single and multiple fatigue papers as individual studies, 19 studies were measures of burnout, 14 studies involved a measure of cognitive fatigue, 17 studies of physical fatigue, and 2 studies measured emotional fatigue. Thirty-one of the 52 studies utilized multiple measures or risk assessment tools, the remaining studies used a single measure. Burnout was primarily measured using validated questionnaires (e.g., Maslach Burnout Inventory, Work-Related Strain Inventory, etc.). Maslach Burnout Inventory (MBI) was utilized in 14 studies. Heart rate measures (heart rate variability and blood pressure) and non-specific questionnaires were frequently used in cognitive fatigue studies. Kinematics and observational task analysis tools were common in physical fatigue studies while the Professional Quality of Life Scale (ProQOL) was the only measure in the studies involving compassion fatigue.

Firefighters

Seventy-four unique papers focused on firefighter fatigue (Table 3). Eight papers involved multiple types of fatigue and the remaining 66 papers involved a single type of fatigue. Five papers were focused on both firefighters and EMS, and one paper focused on firefighters and police. Individual studies, considering both single and multiple fatigue papers, were distributed as follows: burnout (7 studies), cognitive (19 studies), physical (53 studies), and emotional fatigue (3 studies). Twelve studies utilized a single measure in its experimental protocol. There were a few similarities with EMS. Burnout was measured by validated scales and questionnaires, the most frequently used were Malach-Pines Burnout Measure and the Maslach Burnout Inventory. Similar to EMS, heart rate measures were most common followed by the Pittsburgh Sleep Quality Index (PSQI). Heart rate measures were also common in physical fatigue studies as well as perceived exertion (e.g., Borg's RPE scale). ProQOL and the Compassion Fatigue Short Scale were utilized in studies investigating emotional fatigue.

Police Officers

Papers on police fatigue studies totaled to 75 papers (Table 4). Sixty-five studies reported a single type of fatigue, 9 studies reported 2 types of fatigue, and 1 study reported all 3 types of fatigue. One study focused on police and firefighters. There were 86 studies from both single and multiple fatigue papers, 24 focused on burnout, 44 on cognitive, 15 on physical, 2 on emotional, and 1 on perceptual. A single measure of fatigue was found in 22 studies. MBI was utilized in 10 studies to measure police burnout. Non-specific questionnaires and PSQI were used in 13 and 10 studies, respectively. Physical fatigue was primarily measured using non-specific questionnaires (5 studies), perceived exertion (4 studies), and heart rate measures (4 studies). ProQOL and non-specific questionnaire were used in emotional fatigue studies, while the perceptual fatigue study measured sound/noise levels of the physical work environment.

Table 2. Fatigue Measurement & Risk Assessment Tools in EMS Research.

Type of Fatigue	Measurement Tool	# of Studies
Burnout	Maslach Burnout Inventory	14
	Work-Related Strain Inventory	2
	Human Services Survey - Emotional Exhaustion Scale	1
	Copenhagen Burnout Inventory	1
	Oldenburgh Burnout Inventory	1
	Stressor Assessment Questionnaire	1
	Job Stress Survey	1
	Symptoms of Stress Inventory	1
	Other Questionnaires (Non-Specific)	1
Cognitive	Heart Rate, Heart Rate Variability, Blood Pressure	4
	Other Questionnaires (Non-Specific)	4
	Observations & Interviews	2
	Pittsburgh Sleep Quality Index	3
	Epworth Sleepiness Scale	3
	Chalder Fatigue Questionnaire	2
	Occupational Fatigue Exhaustion Recovery Scale	2
	Personal Recordings of Sleep Times	2
	Oral Temperature	2
	Visual Analog Scale for Drowsiness, Fatigue, Attention	2
	Grip Strength	2
	Berlin Questionnaire	1
	Beck Depression Inventory	1
	Demand-Induced Strain Questionnaire	1
	NASA Task Load Index	1
	Sleep Fatigue and Alertness Behavior Survey	1
Physical	Kinematics or Task Analysis (Observation, RULA, PDD)	9
	Heart Rate	6
	Kinetics or Forces/Weights	5
	Interviews or Questionnaires	5
	Perceived Exertion (Borg's RPE) or Perceived Force	5
	Fine Motor Coordination Tests	3
	Respiratory Measures (Rate, Gas Composition)	2
	Blood Sampling (lactate)	2
	Electromyography	1
	Task Performance (Completion Time)	1
Emotional	Professional Quality of Life Scale	2

Table 3. Fatigue Measurement & Risk Assessment Tools in Firefighting Research

Type of Fatigue	Measurement Tool	# of Studies
Burnout	Malach-Pines Burnout Measure	2
	Maslach Burnout Inventory	2
	Symptoms of Stress Inventory	1
	Shirom Melamed Burnout Measure	1
Cognitive	Heart Rate, Heart Rate Variability, Blood Pressure	7
	Pittsburgh Sleep Quality Index	5
	Other Questionnaires (Non-Specific)	5
	Body Temperature (Core, Skin)	3
	Perceived Psychological Demand/ Sleepiness (VAS)	2
	Beck Depression Inventory	2
	Stroop Colour-Word Test	1
	NASA Task Load Index	1
	Polysomnography	1
	Samn-Perelli Fatigue Checklist	1
	Psychomotor Vigilance Test	1
	Simple Reaction Time Test, Choice Reaction Time Test	1
	Critical Flicker Fusion Frequency	1
	Grip Strength	1
	Eye-Hand Skill Test	1
	Single-Letter Cancellation Test	1
	Salivary Samples (Melatonin)	1
	Karolinska Sleepiness Scale	1
	Work Sleep Survey	1
	Stanford Sleepiness Scale	1
	Health and Safety Executive Stress Questionnaire	1
Physical	Heart Rate, Heart Rate Variability, Blood Pressure	28
	Perceived Exertion (Borg's RPE) or Perceived Force	21
	Respiratory Measures (Rate, Gas Composition)	19
	Body Temperature (Core, Skin, Gastrointestinal)	16
	Kinematics (Postural Sway, Gait) or Task Analysis (Observation, RULA, PDD)	10
	Blood Sampling (lactate)	8
	Kinetics or Forces/Weights	7
	Questionnaires	6
	Fluid Loss (Sweat Rate)	3
	Physiological Strain Index or Perceptual Strain Index	3
	Task Performance (Completion Time)	2
	Muscle (EMG or MYO)	2
Emotional	Professional Quality of Life Scale	2
	Compassion Fatigue Short Scale	1

Table 4. Fatigue Measurement & Risk Assessment Tools in Police Research.

Type of Fatigue	Measurement Tool	# of Studies
Burnout	Maslach Burnout Inventory	10
	Other Questionnaires (Non-Specific)	8
	Oldenburgh Burnout Inventory	4
	Professional Quality of Life Scale	3
	Maastricht Vital Exhaustion Questionnaire	2
	Perceived Stress Scale	2
	Shirom Melamed Burnout Inventory	2
	Bergen Burnout Inventory	1
	Staff Burnout Scale	1
Cognitive	Other Questionnaires (Non-Specific)	13
	Pittsburgh Sleep Quality Index	10
	Sleep Logs and Wrist Actigraphs	6
	Polysomnography	3
	Epworth Sleepiness Scale	3
	Cortisol Awakening Response	2
	Task Performance	2
	Psychomotor Vigilance Test	2
	Standard Shiftwork Index	1
	Heart Rate, Heart Rate Variability, Blood Pressure	1
	Karolinska Sleep Questionnaire	1
	Critical Flicker Fusion Frequency	1
	Multidimensional Fatigue Inventory	1
	Motor Praxis Task (Psychomotor speed and visual tracking)	1
	Visual Object Learning Task (Working memory and visual object learning)	1
	NBACK test (Attention and working memory)	1
	Digital Symbol Substitution Task (Attention, complex scanning, visual tracking)	1
Physical	Other Questionnaires (Non-Specific)	5
	Perceived Exertion (Borg's RPE) or Perceived Force	4
	Heart Rate, Heart Rate Variability, Blood Pressure	4
	Task Performance (Completion Time, Completion)	2
	Body Temperature (Core, Skin, Gastrointestinal)	2
	Respiratory Measures (Rate, Gas Composition)	2
	Kinematics (Postural Sway, Gait)	2
	Blood Sampling (Lactate)	1
	Situational Awareness	1
Emotional	Professional Quality of Life Scale	1
	Other Questionnaires (Non-Specific)	1
Perceptual	Sound Level Meter	1

Results: Fatigue & Outcome Relationships in First Responder Occupations

Articles providing both a fatigue effect (i.e., quantified from fatigue measurement or risk assessment) and an outcome response (i.e., measure of performance, health, or wellbeing) were extracted from the 403 set of papers. We documented the risk factor sub-category, the type of fatigue, the resulting fatigue effect, the outcome sub-category, and the resulting outcome effect. We excluded literature reviews or systematic reviews from analysis (n = 6). Retained were observational (prospective cohort [n = 2] or cross-sectional [n = 15]), quasi-experimental (n = 4), and a qualitative interview study (n = 1).

EMS Personnel/Paramedics

We retained four articles with available fatigue effect and outcome effect data (Sterud et al., 2007; Sofianopoulos et al., 2011; Ock et al., 2011; Patterson et al., 2012). Risk factors represent non-specific EMS work, work organization, and task factors (Figure 7). Sofianopoulos et al., (2011) measured the impact of cognitive fatigue on depression/anxiety and work performance, finding that over two-thirds of paramedics suffered poor quality sleep (n = 41) and a mean PSQI global score was 7.98 (SD = 3.86). Of the same sample, 88% of paramedics believed that fatigue affected their work performance. Additionally, 10% of paramedics reported moderate depression and 1.7% reported severe depression. Patterson et al. (2012) examined the relationship between sleep quality, fatigue, and self reported safety outcomes in a sample of 511 EMS workers in the US. Full-time workers, individuals who worked 6-15 shifts monthly, personnel who worked 24-hour shifts, and those who reported poor general health were often classified as "fatigued". The odds ratio for injuries and error/adverse events were 3.8 and 3.2 respectively for EMS personnel who reported 6-15 shifts per month; the authors also observed higher odds, 4.0 and 2.9 respectively, for EMS personnel who reported more than 16 shifts per month (Patterson et al., 2012). Surprisingly, longer shift length than did correspond to higher odds of adverse safety outcomes. Sterud et al., (2007) measured burnout, finding mean scores of 2.0 (SD = 0.6). 1.7 (SD = 0.6). and 1.3 (SD = 0.04), for emotional exhaustion, depersonalization, and low personal accomplishment, respectively. Almost 11% of paramedics within this study reported drinking to cope, and a mean score of 2.5 (SD = 1.1) and 1.0 (SD = 1.9) for alcohol consumption and alcohol problems, respectively (on a scale of 0 – 8). However, the relationship between burnout and alcohol use was not significant, nor were there strong relationships between dimensions of burnout, general job stressors, and alcohol-related problems (r2 = 3.6%) and alcohol consumption (r2 = 1.5%). The Ock et al., (2011) study examined the effect of chest compressions over a 5-minute period on physical fatigue and resulting performance and quality of chest compressions. There was an increase in rating of perceived exertion, each minute, over the 5-minute period (T1-T5 = 5.8), an increase in heart rate (T1-T5 = 15.8 bpm), and an increase in VO2 max (T1-T5 = 1.57 mL/kg/min). The number of compressions (mean rate) over the 5-minute period was maintained but there was a significant reduction in the percentage of correct compressions, defined as one with depth of 4 to 5 cm (T1-T5 = -50.8%). The authors found strong correlations between number of correct compressions and muscle strength at each increasing minute.

Firefighters

We identified 6 studies with fatigue and outcome effects (Ives et al., 2016; Paterson et al., 2016; Park et al., 2011; Colburn et al., 2017; Smith et al., 2018; Lusa et al., 2006). Ives et al., (2016) measured the effect of exercise-induced heat stress (wearing turnout coat, trousers, thermal hood, helmet, gloves and boots, and SCBA) during three, 20-minute bouts of treadmill walking. Resulting core temperature, brachial artery diameter, blood flow, and vascular conductance, mean arterial pressure, and biomarkers of vascular endothelial health. The authors found that brachial diameter increased after exercise-induced heat stress (mean pre-trial: 4.40mm [SD = 0.12], post-trial: 4.62mm [SD = 0.09]). Brachial artery blood flow significantly increased (mean pre-trial: 122 ml/min [SD = 15], post-trial: 548 ml/min [SD = 38]). Vascular endothelial function was significantly reduced after exercise-induced heat stress (pre-trial: 0.13 [SD = 0.02], post-trial: 0.06 [SD = 0.01]), which is related to reduced vascular reserve and increased coronary risk. Park et al., (2011) evaluated the potential link between wearing PPE and gait (i.e., risk of tripping). While performing simulated firefighting activities in a burn tower, there was an increase in proportion of participants committing gait errors (stepping outside of a boundary area, contacting an obstacle, or causing an obstacle to tip over) from baseline to post-activity (Baseline-Post = 48%). The mean number of errors increased from pre-activity to post-activity while wearing PPE ((Pre-Post = 0.6). In our final example, Smith et al., (2018) the relationships between work stress, burnout, and safe work practices. On a 5-point Likert scale, the work stress mean score was 1.73 (SD = 0.79) and was positively associated with burnout (5-point mean score: 1.65 [SD = 0.64]). Burnout negatively influenced three safety behaviour outcomes (all using 5-point Likert scales): safe work practices (mean = 4.39 [SD = 0.55]), wearing PPE (mean = 4.78 [SD = 0.41]), and reporting and communication (mean = 4.41 [SD = 0.60]). Relationships for all 6 studies are linked in Figure 8.

Police Officers

There were 12 studies retained from the police officer literature (Figure 9). Risk factor sub-categories include work organization, personal capacity, and physical environment. These factors are associated with cognitive fatigue, physical fatigue, and burnout, leading to increased accident risk, coronary/CVD risk, psychosomatic symptoms, musculoskeletal disorders, and changes in job satisfaction and attitude towards work. As an example, Garbarino et al., (2001) measured the level of sleepiness of shift workers and non-shift workers, finding significantly higher levels of pathological sleepiness (> 10 ESS score) among shift workers (10%) than non-shift workers (9%). Shift workers had a high probability of sleep-related accidents (Odds Ratio = 2.24). Yadav and colleagues (2016) measured the effect of chronotype, sleep quality, daytime sleepiness, and fatigue on heart rate and blood pressure, risk factors for CVD. Twenty-seven of 85 participants suffered poor sleep quality (>5 on PSQI global scale), 9 participants suffered high daytime sleepiness, and 24 participants experienced high levels of fatigue. Although there were no changes in blood pressure, there were changes in amplitude of heart rate. Meena et al., (2018) identified risk factors associated with 149 participants who reported a high burden of health complaints; the majority of problems were linked to the metabolic and cardiovascular system (36.2% of participants with health complaints), musculoskeletal (31.5%), vision (29.5%), and respiratory system (25.5%). Of the 149 participants, 36.3% suffered a high risk of obstructive sleep apnea, 32.2% had high levels of mental stress, and 86.5% had abdominal obesity. Our final example involved the relationship between burnout and health and wellness (Martinussen et al., 2007). In their sample of police officers, job demands, and job resources were risk factors of burnout (scores on 7-point scale of exhaustion [mean = 1.38, SD = 1.14], cynicism [mean = 1.50, SD = 1.33], and efficacy [mean = 4.72, SD = 0.97]). Burnout predicted health and work outcomes, predicting 29% of the variance of psychosomatic health complaints and 15% of variance of life satisfaction. The authors identified emotional exhaustion as highly correlated with health complaints.

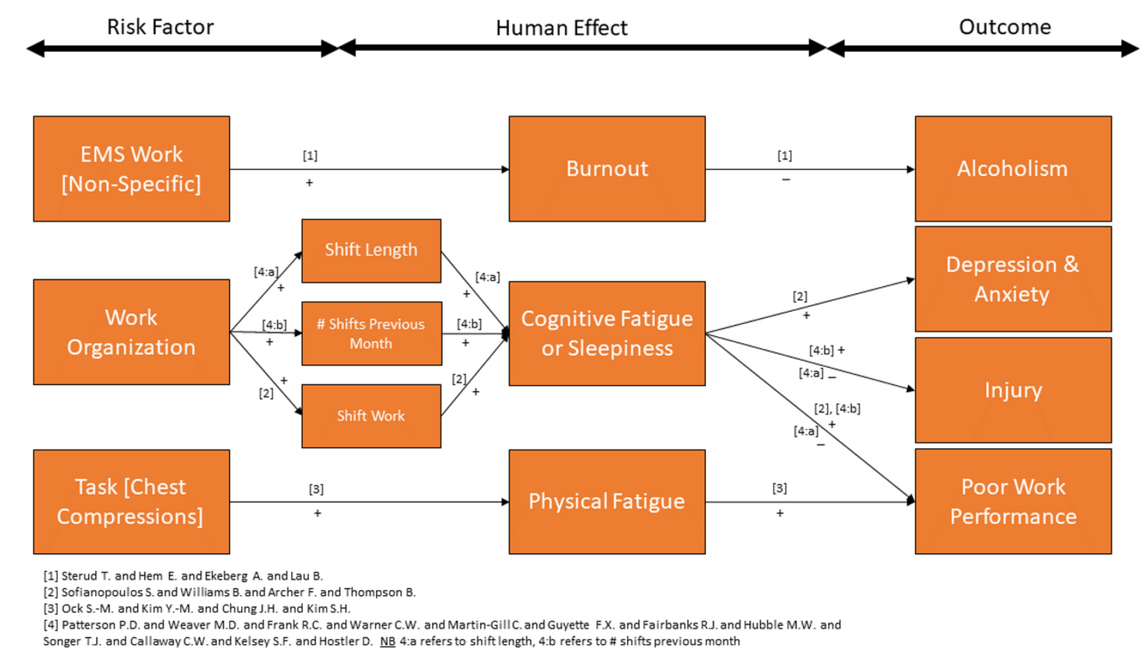


Figure 7. Concept maps of risk factors, fatigue, and outcomes for EMS personnel/paramedics.

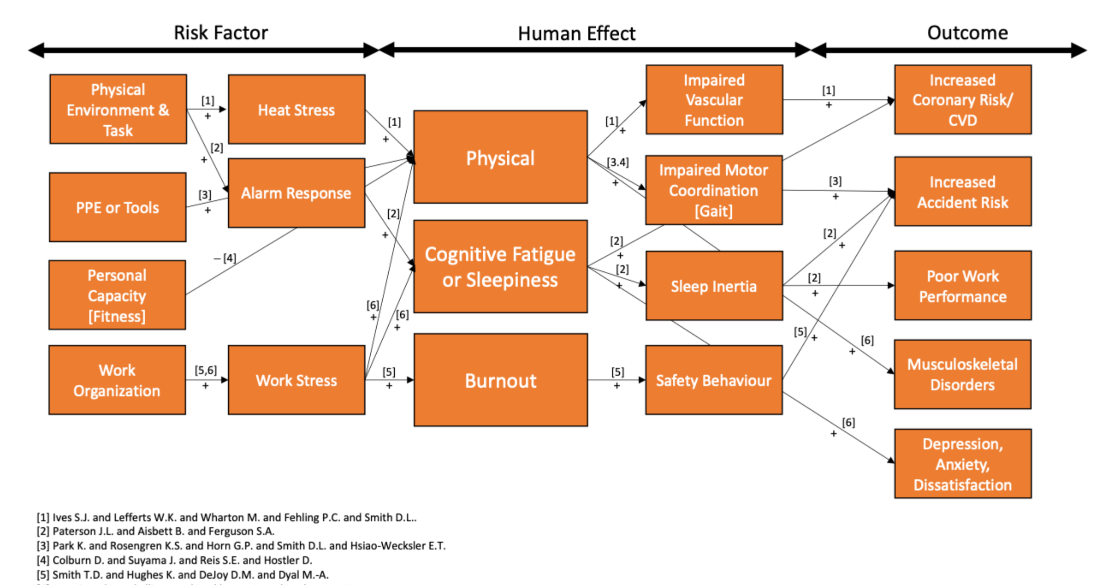
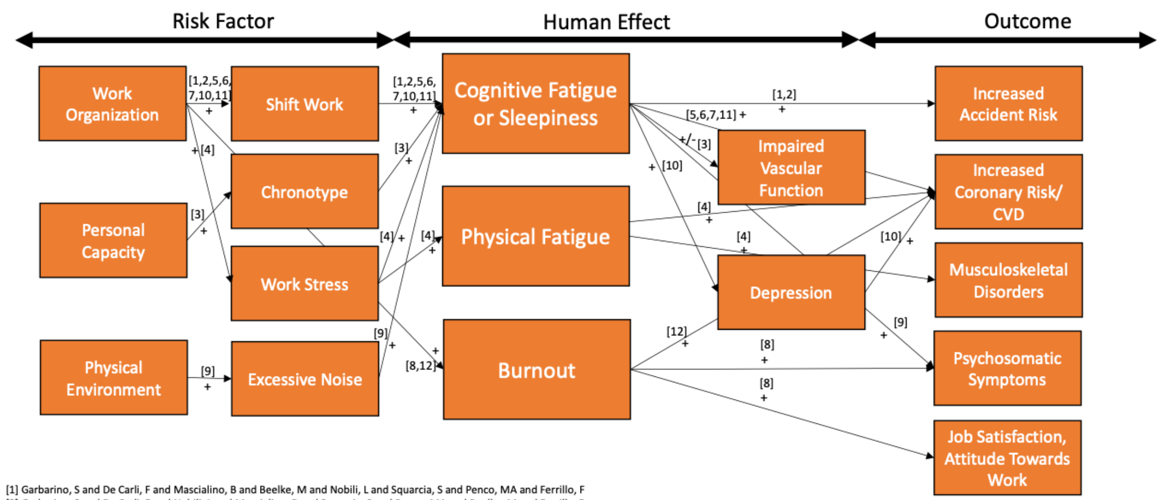


Figure 8. Concept maps of risk factors, fatigue, and outcomes for firefighters



[1] Garbarino, S and De Carli, F and Mascialino, B and Beelke, M and Nobili, L and Squarcia, S and Penco, MA and Ferrillo, F
[2] Garbarino, S and De Carli, F and Nobili, L and Mascialino, B and Squarcia, S and Penco, MA and Beelke, M and Ferrilla, F
[3] Yadav, Arjita and Rani, Sangeeta and Singh, Sudhi
[4] Meena J.K. and Kumar R. and Meena G.S.
[5] Charles L.E. and Gu J.K. and Tinney-Zara C.A. and Fekedulegn D. and Ma C.C. and Baughman P. and Hartley T.A. and Andrew M.E. and Violanti J.M. and Burchfiel C.M
[6] Gu J.K. and Charles L.E. and Burchfiel C.M. and Fekedulegn D. and Sarkisian K. and Andrew M.E. and Ma C. and Violanti J.M.
[7] Charles L.E. and Gu J.K. and Andrew M.E. and Violanti J.M. and Fekedulegn D. and Burchfiel C.M.
[8] Martinussen, M. and Richardsen, A.M. and Burke, R.J.
[9] Venkatappa K.G. and Vinutha Shankar M.S.
[10] Violanti J.M. and Charles L.E. and Gu J.K. and Burchfiel C.M. and Andrew M.E. and Nedra Joseph P. and Dorn J.M.
[11] McCanlies E.C. and Slaven J.E. and Smith L.M. and Andrew M.E. and Charles L.E. and Burchfiel C.M. and Violanti J.M.
[12] Ramey S.L. and Perkhounkova Y. and Downing N.R. and Culp K.R.

Figure 9. Concept maps of risk factors, fatigue, and outcomes for police officers.

Results: Fatigue Management Interventions Identified in First Responder Literature

We categorized interventions and risk controls using broad categories of hazard controls – the Hierarchy of Hazard Control (HOC) (NIOSH, 2015). To categorize fatigue-specific interventions and controls, we further operationalized the scope of the HOC categorizes (see Table 1). We also categorized studies focused on capacity tests, prevention programs, and exercise training as training controls. Systematic or literature reviews and commentaries were excluded from this analysis, but we retained all other experimental designs. To assess the effectiveness of an intervention, we considered the reported statistical significance and the direction of the fatigue response (increasing or decreasing).

Recommended Interventions for EMS Personnel/Paramedics

EMS fatigue management interventions focused on mitigating cognitive and physical fatigue; cognitive fatigue interventions ranged from PPE, training, administrative, and engineering while physical interventions were categorized as PPE, training, and engineering (Table 5). All interventions demonstrated a positive fatigue mitigating effect except for melatonin supplementation, critical incidence debriefing, and physical exercise training program. The melatonin supplementation demonstrated improved sleep quality by 12% and fewer interim awakenings during day sleep but did not improve night shift performance nor was statistically significant (James et al., 1998). The physical exercise training program involved resistance and cardio-respiratory training; the authors did not observe an improvement in performance in either strength or endurance tests and work-simulated tasks, and there were no differences between the intervention and control groups (Aasa et al., 2008). However, the authors argued that training at least three times per week will lead to performance benefits. Engineering controls were frequently the focus for physical fatigue studies; these articles were mainly devoted to stretcher design (5 papers) and automated CPR devices (2 papers). In general, powered stretchers, compared to manual stretchers, reduced biomechanical and psychosocial demands (e.g., Lad et al., 2018; Sommerich et al., 2012; Kluth & Strasser, 2006). Similarly, automated CPR devices minimized the effects of fatigue while improving the proportion of effective compressions (e.g., Szarpak et al, 2017).

Table 5. EMS Fatigue Management Interventions

Type of Fatigue	Type of Intervention	Intervention	Effective? Yes/ Maybe	No	Effect
Cognitive	PPE	• Melatonin Supplement		✓	• Improved sleep quality by 12%, fewer interim awakenings during day sleep. Not statistically significant. Did not improve night shift performance.
	Training	• Cognitive Training	✓		• Initial support of online cognitive training for resilience, including sleep problems.
	Administrative	• Critical Incidence Debriefing		✓	• Need of critical incidence recovery identified by 75% of participants. Need further investigation.
		• Work Scheduling (Shifts)	✓		• The switch from the Kelly schedule to the 48/96 schedule, led to favorable improvements in sleep, including an increase of hours slept, a small but statistically significant reduction in daytime sleepiness, and an increase in feelings of refreshment. Improved scores for secondary objectives of interest, such as feelings of burnout, time for personal schedules and perceptions of satisfaction with the work schedule.
	Engineering	• Real-Time Fatigue Assessment Platform	✓		• Text messages to track self-reported fatigue and sleep symptoms found to be useful and can reduce fatigue for shift workers. Impact greatest for 12h shift workers.
Physical	PPE	• Chemical-Impermeable PPE	✓		• Did not impose additional thermal burden compared to short pants and cotton shift during high-intensity work. Core temperature increased within 5 minutes of activity.
		• Adhesive ACD-CPR Glove	✓		• Improved chest decompression in adolescent/child/infant manikin and no increase in fatigue based on HR and RR over 5 minutes.
	Training	• 30:2 compression ventilation CPR ratio	✓		• Similar quality to 15:2 CPR ratio. No differences in fatigue between 30:2 and 15:2 ratios, except peak heart rate (5 bpm higher in lay persons at 30:2 ratio).
		• Physical Exercise Training Program		✓	• Resistance and cardio-respiratory training did not have more favorable outcomes than control group. However, training had more favorable outcomes when performed 3 times than <2 times per week. Training program effective in reducing blood lactate concentration during carrying loaded stretcher on stairs.]
	Engineering	• Powered Stretchers	✓		• Powered stretchers with load assist reduced biomechanical and psychophysical demands. Peak L4/L5 compression and shear forces reduced by 13-62% and 58-93%, respectively. Peak shoulder flexor moment reduced by 16-95%. Power stretchers perceived to be less demanding but required long task time.
		• Automated CPR Device	✓		• Automated CPR device resulted in higher % of effective compressions than manual CPR (100 vs. 43). Number of effective compressions decreased over time with ARM by 0.05%/min and by 0.86%/min with manual. ARM significantly reached required depth of 5 cm compared with manual (97% vs 63%).
		• Stretcher Design	✓		• Cot 1 (one-handle Stryker M-1). Cot 2 (two-handle Ferno Washington Mondial). Cot 2 led to lower muscle activity (forearm flexors, back muscles). Cot 1 led to lower biceps and shoulder muscle activity.
		• Lifting aids (shoulder straps)	✓		• Shoulder straps decreased heart rate variability, salivary cortisol concentration, body strain. Carrying time of stretcher longer with shoulder straps.
		• Stretcher Design	✓		• Three designs: Stryker, Ferno, Stollenwerk. All led to comparable body strain. Stollenwerk more favorable based on whole-body strain. Stryker and Stollenwerk more favorable based on subjective ratings. Stryker easier to handle but Stollenwerk (lightest) received best marks.
		• Automation-based out-of-hospital cardiac arrest resuscitation	✓		• Change in %mHR, energy expenditure, salivary alpha-amylase, Borg and NASA-TLX scores from resting state detected significant differences across simulations.

Table 5. EMS Fatigue Management Interventions

		Automation-based approach and equipment for OHCA resuscitation led to lower workload scores of EMS providers.
• Bed to Staircase Transfer Devices	✓	• Objective and subjective measures support the use of the Drew People Mover and the Transfer Sling. Compared to the under-axilla transfer, the Transfer Sling and the Drew People Mover reduced the recruitment of selected back muscles and potentially improve spinal posture.
• Lateral Transfer Device	✓	• Compared to the standard bedsheet transfer, both the bridge board and the single-rod interventions assisted one or both FFPs. The dual rod intervention did not work well. The bridgeboard's effect was focused on the FFP located on the stretcher-side of the transfer. The single rod significantly reduced the Erector Spinae recruitment for both FFPs. Combining the single rod with a bridgeboard reduced the increased Latissimus Dorsi activity found with the single rod by itself. FFPs in both roles rated the single rod conditions as the easiest exertion.
• Stair Descent Devices	✓	• First intervention: foot strap that attached to the backboard to prevent the patient from sliding toward the leader. Second intervention: hand truck-type device that allowed the backboard to be rolled down the stairs changing the carrying task into a push and pull task. Third intervention: ‘‘tank treads’’ that allow a stretcher to be rolled down the stairs by bridging the steps. Fourth intervention: change in the handle configuration of the stair chair. Only the extended handle on the stair chair failed to reduce back muscle recruitment. The foot strap is easily implemented with materials most EMS crews have on hand and will add little time to the patient preparation. Preventing the patient from sliding down the board, in addition to helping out the FFP in the leader role will likely make the transfer less uncomfortable for the patient. The DCS and potentially the backboard wheeler, in transforming the carrying task to a push pull task, will likely be the most beneficial approaches to preventing back injuries associated with the transport of patients.

*Exclusions: Systematic/Scoping/Literature Review: EMS Cognitive PPE (1), EMS Cognitive Training (1), EMS Cognitive Administrative (4)

Recommended Interventions for Firefighters

Fifty-seven articles focused on controls for burnout, cognitive fatigue, and physical fatigue in firefighting work (Table 6). Training interventions were identified to reduce burnout (2 papers). Eight papers were focused on engineering, administrative, training, and PPE controls to reduce cognitive fatigue. The remaining 47 articles identified controls for physical fatigue. Two studies on cognitive fatigue investigated the effect of work scheduling/shifts (Caputo et al., 2015; Kazemi et al., 2018). Caputo and colleagues (2015) assessed the impact of switching from the Kelly schedule (9-day rotation – work 3, 24-hour shifts, 24 hours off after the first shift, 96 hours off after the third shift) to a 48/96 work schedule (work 48 consecutive hours followed by 96 hours off). The switch from the Kelly schedule to 48/96 schedule led to improvements in sleep (sleep duration), and a small but statistically significant reduction in daytime sleepiness. Kazemi et al., (2018) compared a slow shift rotation (7N7D7O) to a fast shift rotation (4N4D4O) and found better physiological adaption with the former.

Physical fatigue interventions include PPE (e.g., work wear, aspirin supplementation, cooling), training (e.g., predictive capacity testing), administrative (e.g., rest breaks), and engineering (e.g., SCBA design, stretcher design). SCBA design was heavily studied, with 7 articles devoted to this intervention. SCBA studies ranged from its material and shape to the design of its breathing valve. One study (Kesler et al., 2018a) found that heavier, extended SCBAs (> 30 minutes of air supply) modified gait, leading to increased time spent with both feet in contact with the ground, which is representative of more conservative gait and compensation strategies to maintain balance. Kesler et al., (2018b), however, observed minimal impacts of SCBA size on cardiorespiratory strain, perceived stress, and work output, with no interactions between cylinder size and duration of firefighting activity. Therefore, the authors indicate that fatigue and physiological stress resulting from prolonged activity, which is made possible with an extended duration SCBA, is a more significant risk factor than the added weight and bulk of the SCBA. Kesler et al., (2018b) found that SCBA design had an impact on peak core temperature, with lower-profile SCBAs attributed to less muscular work. Griefahn et al., (2003) investigated the effect of both size (i.e., weight) and shape (i.e., weight distribution) of SCBA devices. The authors found that a rucksack-designed SCBA made of light carbon fiber composite material led to a significant reduction in physiological strain compared to a device with a conventional cylindric shape made of steel and a cylindric shape SCBA made of light carbon fiber. Therefore, the authors conclude that the design and weight distribution of the SCBA was more important than the absolute weight of the SCBA. A study on hose nozzle design (Kluth et al, 2004) compared a standard nozzle with a pistol nozzle and an ergonomic nozzle with a rectangular-shaped valve handle (Quadrafog 150 – designed with a pistol handle allowing for a power grip) during three firefighting tests (straight stream for 60 seconds, wide fog moving nozzle left to right for 60 seconds, and alternating operations switching between horizonal straight stream and wide fog). The pistol and ergonomic nozzles led to lower overall strain compared to the standard nozzle, particularly during the straight stream test. Overall, the pistol nozzle exhibited a balanced strain profile between tests, and less than 30% of standardized EMG activity during the most physically demanding task – the alternating test. Interestingly, the ergonomically designed nozzle led to high hand abduction activity to counter high water pressure forces.

Table 6. Firefighter Fatigue Management Interventions

Type of Fatigue	Type of Intervention	Intervention	Effective? Yes/ Maybe	No	Effect
Burnout	Training	• Stress management workshop for supervisors		✓	• Workshop for supervisors on how to provide support to subordinates who was returning to work after experiencing critical incident. Significantly positive intervention effect on colleagues' social support, a marginally significant intervention effect on chronic demands and on vigor dimension of engagement, but no significant effect on burnout.
		• Mindfulness-Based Resilience Training	✓		• Increased mindfulness through mindfulness-based resilience training (MBRT) was related to increased resilience (b=0.41, SE=0.11,p< .01), which in turn was related to decreased burnout (b=−0.25, SE=0.12,p= .03).
Cognitive	PPE	• Zolpidem	✓		• Findings confirm therapeutic effect of zolpidem in treating uncomplicated, poor sleep quality of FF in the short term. Zolpidem significantly improved all components of PSQI (subjective sleep quality, sleep latency, sleep duration, habitual sleep efficiency, sleep disturbances and daytime dysfunction). Slightly reduced "time of going to bed" but had no significant effect on "time of waking up".
		• Napping	✓		• Over half of participants identified that napping was a useful critical fatigue-countermeasure.
	Training	• Music-Based Neuro-Training	✓		• Uses individualized music compositions derived from one's own brain wave patterns to improve sleep duration and quality, A ''musical map'' is created to correlate brain activity ratios associated with two primary functional resting states—active and relaxed. There were statistically significant improvements in 4 behavioral measures: sleep quality (94%), insomnia (89%), mood (74%), and daytime function (82%). For the sleep quality assessment, 25% of the first responders (five of 20) and 16.7% of the crossover controls (one of six) experienced a significant positive change after BM. Volunteers classified as operations support showed the largest gains in sleep quality and mood scales, whereas the first responder group showed the largest gains in insomnia and daytime function scores. Effect sizes ranged between 3.5 and 7.0 for sleep quality, 31.1 to 40.9 for insomnia, 3.1 to 5.9 for mood, and 8.5 to 10.8 for daytime function negatives over the experimental and crossover control groups. For the sleep quality assessment, the effect sizes are as follows: ops support=7.0, first responder=5.7, and control=3.5.
	Administrative	• Incident Rehabilitation		✓	• Incident rehabilitation is planned rest and recovery where FF provided time to rest, rehydrate, and cool down, restoring FF performance. No discernible effects of incident rehabilitation on perception of exertion, thermal sensation, respiratory distress, and feeling state. Effect of activity on cognitive function not differentially influenced by more aggressive rehabilitation protocol.
		• Work Scheduling (Shifts)	✓		• The switch from the Kelly schedule to the 48/96 schedule, led to favorable improvements in sleep, including an increase of hours slept, a small but statistically significant reduction in daytime sleepiness, and an increase in feelings of refreshment. Improved scores for secondary objectives of interest, such as feelings of burnout, time for personal schedules and perceptions of satisfaction with the work schedule.
		• Work Scheduling (Shifts)	✓		• Adaptation better in 7N7D7O than 4N4D4O shift pattern. Overall melatonin changes: 17.3 +/- 7.90 (7-night shift); 9.77 +/-5.70 (4-night shift) p<0.0001.

Table 6. Firefighter Fatigue Management Interventions

				Sleepiness changes: 4.62 +/-2.54 (7-night shift), 4.14 +/-2.2, P = 0.442. Adaptation better in 7N7D70 than 4N4D4O shift pattern.
	Engineering	• Mental Health App	✓	• FFs were largely willing to utilize mental health apps but had clear preferences. Younger FFs were less likely to try a mental health app compared to physical health app, suggesting barriers such as stigma might remain. Focus on "fitness" and "well-being" was favoured over more stigmatizing ill-health concepts. Clear preference for behavioural therapeutic approaches (direct/active approaches to psychological therapy). 94% rated sleep/exercise/lifestyle as important features for a MH app.
		• Reduce Firehouse Environment Stimuli	✓	• Changes include: Reducing the number of audible alarms, diminishing the light levels, and regulating the temperature in the bunkroom between 63 and 67 degrees F. Post measures revealed the average lux level dropped from 0.75 lux to 0.19 lux (P<0.05); noise remained the same, 76 to 69 average decibels. Elevated blood pressure reduced from 86% to 15% (P<0.05). Routinely activating unnecessary fire alarms should be discouraged.
Physical	PPE	• Safety Ambient Monitor	✓	• Safety Ambient Monitor (SAM) measures air temperature under the suit as an indicator of overall workload. Does not affect or limit FF in their work.
		• Aspirin	✓	• Daily low-dose (81 mg) aspirin for 2 weeks is associated with lower peripheral arterial stiffness and wave reflection before and after exertional heat stress in firefighters. In contrast, a single high dose (325 mg) of aspirin chewed immediately after exertional heat stress had no significant effect on peripheral arterial stiffness. However, low-dose and single high-dose aspirin were not associated with significant effects on endothelial function and 90 minutes after exertional heat stress in healthy firefighters.
		• Cooling	✓	• Both cooling systems directly provided a cooler thermal sensation than the control condition. For the cool pad system, this effect disappeared after about 15 min exercise. The water perfused system, which continuously reduced the mean skin temperature, had a larger effect on thermal sensation and maintained its effect throughout the trial. However, none of the systems provided a higher thermal comfort or lower thermal strain regarding heart rate and core temperature.
		• Aspirin	✓	• Daily low-dose aspirin therapy prior to exertional heat stress partially inhibits platelet activation; a single dose of aspirin following exertional heat stress reduces platelet activation within 30 minutes. The doses and conditions tested in this investigation did not alter heart rate, temperature, or perceptual indices during exertional heat stress or recovery. No subject reported adverse effects from 2 weeks of aspirin therapy leading up to exertional heat stress. Aspirin therapy within the context of emergency incident rehabilitation might be limited to firefighters considered to be at greater risk for cardiovascular disease, such as those individuals who are older, have higher body fat, or have lower cardiorespiratory fitness.
		• Wearable Physiological Monitor	✓	• A functional garment acquires physiological-, activity-, and environment-related parameters. Sensors for physiological monitoring (HR, BR, body temperature, SpO2, and dehydration) and a pair of boots with sensors for activity detection and monitoring of environmental variables. The ProeTEX prototype was demonstrated to be reliable, since it produced negligible errors when used for up to 1 h in normal environmental temperature (20◦C and 35◦C) and up to 30 min in a harsher environment (45◦C).
		• Caffeine	✓	• The changes in VE with caffeine led to significant increases in total air consumption during the three work bouts. Work time in fire suppression and rescue situations is limited by air supply in the SCBA. Caffeine was also found to reduce RPE on the

Table 6. Firefighter Fatigue Management Interventions

				10-point Borg scale during three 10 min work bouts; caffeine might have altered the participants' sensation of force and pain.
	• Protective Clothing		✓	• Small variations in thermal properties of protective clothing have little or no effect on heat exchange and do not affect the resulting thermal strain. The most determinant factor for the resulting heat stress under the given conditions is the metabolic heat production. Hence a reduction in work rate has a larger effect on the final heat stress than small variations in heat transfer properties of the protective clothing.
	• Cooling	✓		• Body cooling application after live-fire exercise decreases HR and tympanic temperature (TT), no effect of cooling tactics on decision-making capacity. The cooling methods engaged in this study were beneficial at mitigating the physiological strain in firefighters during the recovery period.
	• Cooling	✓		• Exercise-induced heat stress trial (wearing structural FF clothing including turnout coat, trousers, thermal hood, helmet, gloves and boots, and SCBA) had a modest but significant increase in core temperature (EIHS 1.0 +/- 0.1 deg C). Core temp in no-EIHS (cooling shift, SCBA, vest weighted to match weight of FF clothing) trial did not change. EIHS may lead to impaired vascular function and is related to reduced vascular reserve and/or increased coronary risk (acute cardiac events). Strategies to mitigate EIHS (through cooling vests, etc.) may be beneficial in preventing acute cardiac events.
	• Cooling		✓	• Head cooling was ineffective in attenuating all outcome measures compared with control group. May be due to device's limited ability to maintain its original temperature and by the size and type of surface area. Forearm cool reduced physiological strain index scores after rehabilitation but did not lower HR or thermal sensation. Forearm cooling effective did not attenuate rise in GI temperature during ensuing drills.
	• Caffeine or Menthol		✓	• Acute administration of caffeine or menthol presented no ergogenic effect on perceived exertion, cognition, or mood, at least under current test conditions of a high heat strain and a dynamic exercise protocol. Neither caffeine nor menthol provided any positive effect on mood (e.g., alertness, calmness). There was no positive effect on perception of fatigue status.
	• Base Layer Material		✓	• Base layer had no impact on physiological or perceptual responses during exercise and recovery periods of an alternating work/recovery protocol of moderate intensity. Some clothing sensations (sticking to skin, coolness/hotness, and humidity sensation) were found to be slightly more favorable when wearing WOOL (wool blend) than COT (cotton). The results of this study suggest that there is no clear-cut advantage to anyone base layer over the others investigated in this project
	• Base Layer Material		✓	• Different fiber blends (A: 100% aramid, B: FR viscose/aramid blended outerwear, FR viscose/merino wool blended underwear). Time to exhaustion (endurance performance) did not differ between workwear A and B (46.2+/-7.2 vs. 45.9+/-7.4 min, p=0.782, effect size=0.089). The mean surface temperature of the outerwear of workwear B was higher during the submaximal and exhaustion/cool down period. The underwear of workwear B will have a beneficial effect on the moisture management but at an expense of a slightly higher temperature of the chest at exhaustion and cool down. Thermal comfort did not differ between workwear A and B.
	• Rehydration Fluid		✓	• Performance during a second bout of treadmill exercise is not altered by the choice of rehydration fluid (water, sport drink, or IV fluid) when full rehydration is provided.

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	• PPE Material (Aluminized vs non-aluminized jacket)		✓	• Frequently fatigued body parts were the ‘waist’, ‘shoulder’, and ‘arm’. It has been reported that the waist and low back are the most discomforted and fatigued body regions due to exposure to workload with PPE. Also found that the ‘hand’, ‘waist’, and ‘ankle and foot’ were frequently injured body parts. The causes of such muscle fatigue and injuries were falls, slips, and trips. Aluminized PPE is related to reduced wearer mobility as well as more aggravated heat strain, which is attributable to the worse ventilation and poorer flexibility of the aluminized jacket.
Training	• Functional Exercise Training	✓		• Functional workouts consisted of strength, cardiovascular and flexibility training that integrated movement found in emergency response. The PFF-Fit program included a nutrition intervention. The 2012 recruits experienced a 30% reduction in claims frequency compared with the control classes and a reduction of US$1224 in average cost per claim. If the intervention class experienced the same claims rate as controls (0.71), they would have filed 22.72 claims over the study period at a mean cost per claim of US$1737, for a total cost of US$39 465. The actual costs accrued by the 2012 class were US$6679, which results in an estimated savings of US$32 786. Similarly, the mean claims costs per recruit were US$208 for the intervention group, compared with US$1241 for the controls, a difference of US$1033. For 32 total recruits, this yields a decrease of US$33 056 in claims costs, comparing interventions with controls. The estimated savings in claims costs is, therefore, approximately US$33 000.
	• Predictive Capacity Tests	✓		• Rowing 500 m (s), maximal hand grip strength, (kg) endurance bench press (n), running 3000 m (s and s·kg-1), barbell shoulder press (n), standing broad jump (m), submaximal treadmill walking (% HRmax) and handgrip endurance are valid physical tests for prediction of physical work capacity for firefighters. Models excluding anthropometric data are valid for prediction of physical work capacity for firefighting work tasks
	• Functional Exercise Training		✓	• The primary objective of the FIT program was to elicit maximal improvements in physical fitness over the course of 12 weeks. The MOV coach also attempted to elicit maximum improvements in physical fitness but did so while emphasizing (through instruction and feedback) the importance of how exercises were performed. Both FIT and MOV subjects exhibited significant improvements in physical fitness but it could not be concluded that either intervention consistently impacted peak low-back loading responses to simulated job demands. Study suggest that short-term improvements in physical fitness alone are unlikely to translate into reduced low-back loading on the job without directed efforts to ‘transfer’ these improvements
	• Predictive Capacity Tests	✓		• Neuromuscular control and stability are significantly related to functional movement patterns (i.e., FMS™ score outcomes). Even though estimated 1RM-Squatmax was not significantly related to the Total FMS™ score after accounting for obesity-level and core muscular endurance, these results suggest that bilateral lower extremity strength still holds significant value in the prediction of injury risk among firefighter recruits. These health and fitness variables may be of primary interest when designing intervention programs targeted at improving functional movement patterns, and subsequently, decreasing the risk of future musculoskeletal injury among this population cohort.
	• Predictive Capacity Tests		✓	• PIP (progressive incline protocol) seems to be disadvantageous for the accurate determination of VO2max, especially in PPE condition. The drawbacks of this protocol may include a longer performance time to complete a test and greater muscle fatigue due to continuous uphill walking while carrying additional weight

Table 6. Firefighter Fatigue Management Interventions

			(e.g., PPE and SCBA), which, nonetheless, provides insufficient workload to reach VO2max.
	• Predictive Capacity Tests	✓	• Strong correlations between direct (laboratory) and indirect (field) aerobic capacity tests and firefighting tasks. Indirect (field) tests may serve equally well as more advanced (direct) aerobic capacity tests for prediction of firefighters' work performance. None of the included simulated work tasks were necessarily discriminative based on gender. Aerobic capacity is important for performance on commonly occurring, and physically demanding, firefighting work tasks.
	• Compression ventilation CPR ratio	✓	• Experienced rescuer performing ECC (external chest compression) on a standard manikin can deliver a similar force for 2 minutes at C/V ratios of 30:2 and 15:2 but deliver a lower compression force when performing ECC at a 30:2 ratio for 5 minutes. The C/V ratio 50:5 was used here in to simulate more continuous chest compressions and resulted in a reduced compression force in 2 minutes. The ratios 50:5 and 30:2 are more fatiguing than 15:2 when performing ECC for 5 minutes. Although there is a significant decline in performance over time for all 3 compression ratios, it was most pronounced for 30:2 ratio; the quality of chest compressions did not suggest a significant decline in percent proper compressions after 5 minutes.
	• Predictive Capacity Tests	✓	• A completion time of greater than 485 s would be unacceptable. This score was nearly 1 min slower than the average of 433 s presented by the 153 representative incumbents. These 3-predictor test items (i.e., hose drag/high rise pack, arm endurance, arm lift) were combined in a regression equation and collectively accounted for nearly 50% of the variance associated with performance of the evolution. This 3-predictor test battery offered a standardized set of muscular strength and endurance tests that could be administered safely and at a reasonable cost to large groups. A 3-predictor test score of 485 or lower for 'successful' performance on the Fire Suppression Evolution, derived as it was from incumbent ratings, suggests that 83% of incumbent firefighters would pass the performance expectation. Moreover, use of the 3-predictor test battery would correctly identify 'successful' performers of the Fire Suppression Evolution in 89% of the cases and would correctly identify 72% of the 'unsuccessful' performers.
	• Pacing Strategy	✓	• Pacing strategy selected by participants (fast-start: first lap significantly faster than all others; even-distribution: all laps similar). All participants who were able to complete the assessment chose a fast-start strategy and significantly improved their performance after a single practice trial. Familiarization and pacing strategy responsible for the improvement. Greatest gains in performance observed in subtask components that required additional external load carriage. Preferred fast start strategy during tasks 1 and 4 allowed opportunity for recover during third (static) task and increased rest before task 5.
	• Predictive Capacity Tests	✓	• Trondheim test vs. NLIA treadmill test to measure fitness. Trondheim test distinguishes aerobically fit and less fit firefighters and applicants, and does not depend on FF's experience; it can be used as an alternative to the NLIA treadmill test. Female applicants may benefit more on the NLIA treadmill test. Trondheim test cannot substitute strength tests required by NLIA. Trondheim test include tasks that require skill and agility but were not physically demanding (17% of total performance time). Slower and less fit participants spent more time on these tasks as they might fatigue easier and earlier, slowing their performance on skill and agility tasks. Applicants should complete the whole test within 19 minutes to fulfill requirements of NLIA treadmill test.

Table 6. Firefighter Fatigue Management Interventions

Administrative	• Incident Rehabilitation	✓		• Documented a significant drop in SBP during rehabilitation, and the magnitude of that drop was greater than what is normally associated with post-exercise hypotension (PEH). Modifications to current rehabilitation protocols, including adding active cooling and a nutrition intervention, did not provide significant improvements when rehabilitation was conducted in a cool, dry room with an ample supply of water.
	• Rest Breaks	✓		• During a single bout of simulated FF activities, subjects reached near max HR, with HR increasing with subsequent bouts. Subjects had lower peak HR with recovery than without break. Rest period reduced the rate of accumulation of heat stress during work, but 5-minute break did not provide significant reduction in total overall core body temp. Increased physiological strain after 2nd bout and cumulative fatigue may explain decreased work output (decrease of 10.4% in stairs, 22.4% in hose advance, 26.8% in search, 18.3% in overhaul).
	• Pre-warming		✓	• Active pre-warming increases GI temperature, mean skin temperature and HR, reduces speed during the last part of a simulated firefighting activity and reduces self-reported quality of performance. After the pre-warming period, the simulated firefighting activity was completed approximately 3 min slower in WARM than in CON. Although this difference was not statistically significant, it can be of great practical relevance, especially when human lives depend on an efficient emergency response.
	• Proactive H&S Management System		✓	• Physical Exercise (PE) controls, Patient transport (PT) controls, and Fireground (FG) controls. PE controls: Improve station exercise equipment and facilities, Increase role of Peer Fitness Trainers, Update and revise exercise standard operating procedure (SOP). PT controls: Test patient transfer devices, Establish chest compression rotation procedure during CPR, Create PT module for probationary firefighters. FG controls: Improve rehab protocols & adherence, Visual reminders for health and safety. In the intervention FD, a non-statistically significant decline of 8.1% (95% CI: -20.5, 6.3; p= 0.25) in the median monthly injury rate after the intervention began. Non-statistically significant declines in PE (−2.9%, 95% CI -25.4, 26.4) and FG (−9.1%, 95% CI: -57.8, 95.8) injuries, and a non-significant increase in PT injuries (21.4%, 95% CI: -22.1, 89.4). There was a non-statistically significant decline in the PE injury rate, while all injury rate as well as FG and PT rates increased over the same time frame. There was no statistically significant difference comparing the changes between the two fire departments (control and intervention).
	• Rest Breaks		✓	• Firefighters did not recover with respect to CBT and HR despite rest periods in between bouts. An additional 9 to 11 minutes after Sc1 and about 17 minutes after Sc2 should be provided to ensure sufficient recovery. Taking short breaks during scenarios of live-fire training may help firefighters avoid prolonged CBT elevation over the hyperthermia limit for longer durations and aid recovery.
Engineering	• SCBA (Material & Shape)	✓		• Use of heavier, extended duration SCBA, increased double support time. Prototype low-profile SCBA did not modify gait compared to traditional single-cylinder SCBA of similar mass. Smallest and lightest SCBA resulted in shortest double support time. No differences between larger SCBA cylinders.
	• SCBA (Material & Shape)	✓		• Minimal impacts of SCBA size on cardiorespiratory strain, perceived stress, and work output. No interactions between cylinder size and duration of FF activity. Fatigue and physiological stress induced during extended duration FF (made possible by additional air supply) is a more significant risk than added weight and bulk of the larger SCBA itself. Various sizes of standard SCBA (cylindrical carbon-fibre wrapped cylinders) did not significantly affect any HR, perceptual or work

Table 6. Firefighter Fatigue Management Interventions

				performance variables during a single fixed duration bout of simulated activity. SCBA design had a significant impact on peak core temperature. Lower core temp in low-profile prototype vs standard cylindrical design may be attributed to less muscular work needed to move SCBA while completing equivalent amount of external work.
	• SCBA and Personal Protective Clothing		✓	• Comparison between personal protective clothing (PPC), PPC with full SCBA (SCBA), and PPC with only cylinder of SCBA (SCBAc). Completion time of rescue intervention: 635 seconds (PPC), 771 seconds (SCBAc), 804 seconds (SCBA); 22% (SCBAc) and 27% (SCBA) decrease in performance. Time spent above 85% of HR max: 48% PPC, 61% SCBAc, 57% SCBA. Air consumption: SCBA condition FF consumed 1338 +/- 257 L of air from breathing apparatus in 804 +/- 127 seconds. Mean HR increased by almost 5% for both SCBAc and SCBA. Motion of COM decreased in SCBAc and SCBA conditions; participants moved more slowly. Mean and peak breathing frequency lower during SCBA compared to PPC and SCBAc. RPE increased in SCBAc compared to PPC, SCBA further increased RPE compared to SCBAc. Rescue interventions lead to high physiological stress (HR, breathing frequency), executive function perturbation (accuracy). SCBA increases completion time, cardiac autonomic stress, and perceived exertion during rescue intervention.
	• Protective Helmet		✓	• The Shikoro-type helmet is a protective helmet with an additional shield covering over the face and neck, which originated from ancient Japanese armour helmets. The Shikoro-type helmet has double functions of the helmet and hood all-in-one which could be a more appropriate design while firefighting in hot and humid environments. Design differences between FF protective helmets did not induce significant differences in body temperature, total sweat rate, or PSI during exercise in hot and humid environment. Thermal benefits were found on face and neck. Shikoro beneficial to lower the cheek, neck, and ear temperature during exercise and increase the lowering rate of face temp in recovery after taking off helmet and hood. Shikoro increased forehead temperature. No differences in perception of warmth between helmets. No differences in RPE.
	• Stair Descent Devices	✓		• Six sled devices: fabric mat, corrugated, roll-up, inflatable, hard shell, wheeled. Across all devices, stair descent speeds were 15 percent faster for the wider staircase width (p<.001). Descent speeds were faster with the Roll-up, Corrugated, and Fabric Mat devices as compared with the Inflatable, Hard Shell, and Wheeled devices. Overall differences in cardiovascular demands between devices were subtle. The two single evacuator devices did show the highest (but not statistically significant) physiologic workload. Relative to the narrow 1.12 m wide stairs, the average heart rate was six percent lower on the 1.32 m wide stairs. The heart rate and ratings of perceived exertion data indicate that while these two single evacuator evacuation devices have the largest physiologic demands, the overall magnitude was less than that found with two-person hand-carried devices. The spine posture and muscle recruitment data indicate that the Wheeled device, largely due to the slower descent rate and the sustained forward flexion, has significantly higher time-integrated levels of Erector Spinae use, suggesting localized muscle fatigue could be a factor in longer multi-story evacuations.
	• Stair Descent Devices	✓		• Five stair descent devices: (10 Narrow - 38cm wide, four wheels to allow to be rolled through stair landings; (2) 2-wheel - 2 wheels in front, operator supports occupant as it is rolled through landings; (3) standard - similar to track style evacuation chairs; (4) long-track - occupant in reclined posture, tracks have speed governor and braking mechanism, chair is long and is turned on landings by

Table 6. Firefighter Fatigue Management Interventions

			pushing down on the handle; (5) rear-facing - occupant faces backwards, chair is long and is turned on landings by tipping forward and balancing occupants weight across the front wheels and lower handles. Overall, the standard, narrow, and 2-wheel devices allowed for quicker evacuations and were perceived as easier to use. Lower muscle recruitment on the stairs using devices than hand-carried evacuation devices. The number of wheels used to maneuver through the landing and the location of those wheels had a large impact on the shoulder and arm muscle activation levels. The devices that are rolled on two wheels and where the wheels are located in front of the occupant's center of mass (rear-facing and 2-wheel) resulted in significantly higher deltoid and bicep activation levels. There were no overall stair width effects for either the task performance measures or the EMG results.
• SCBA (Material & Shape)	✓		• The prototype consists of an assembly of five compressed-air pressure vessels constructed using a special plastic lining in place of conventional aluminum liners used in current SCBA cylinders. Blow moulded linings were covered with braided Kevlar and with carbon fibre. The entire assembly is secured inside a soft, flexible cover, allowing the design to flex horizontally and vertically at the connection points. The prototype SCBA was rated as a significant improvement over the standard SCBA in the areas of ROM, mobility, comfort, induction of fatigue, interaction with PPE, and operability when worn over a standard firefighter protective ensemble and performing a series of FGS exercises. However, as presented previously, some of the subjects' comments were not positive and indicated several limiting factors of the prototype.
• Portable Cooling Device	✓		• Cooling capacity of the device was about 144% (AVA=95 W vs. passive = 66 W) of passive cooling in a normal environment. Because the passive cooling environment was cool and dry (22°C, 35% RH), the passive cooling was effective. In warmer and more humid ambient environments, passive cooling would be less effective. Cooling device had little impact on recovery for first 30 mins but resulted in significantly lower rectal temperature during last 10 minutes, compared to passive cooling (At 40 min: passive: Δ rect temp 0.63 +/-0.17degC, active: Δ rect temp 0.88 +/-0.31degC, p=0.03. This cooling device appeared to work only for some individuals and not for others, which might be related to exercise background.
• SCBA (Material & Shape)		✓	• Responses to wearing SDBA (standard duration breathing apparatus) and EDBA (extended duration breathing apparatus), and to using 45 mm vs. 70 mm hose, were also compared. Using EDBA, achieving threshold Tcore was the primary cause of termination; shortness of air was the primary cause for termination in the two conditions using SDBA. The mean Tcore observed reached 39.18C in the EDBA conditions because of the greater work duration. The EDBA conditions resulted in 19% higher ventilation than the SDBA conditions. Hose size was independent of both heat gain and cardiovascular strain. The firefighters reported anecdotally that the larger hose was difficult to manoeuvre.
• SCBA and Personal Protective Clothing		✓	• Effect on postural sway of TPC and SCBA (two tank sizes). Wearing TPC and SCBA increased the dependent COP measures when compared to the control clothing condition, primarily when wearing the larger cylinder (significant). Wearing firefighter protective garments and breathing apparatus during 20 min of heavy physical exertion in a hot environment resulted in increased COP excursion when compared to non-stress conditions and the stress condition without TPC and SCBA. Also, subjects made more rapid and frequent postural adjustment with the added TPC and SCBA masses. Heavier SCBA cylinder did not amplify COP measures.

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	• SCBA (Material & Shape)	✓	• Prototype: vapor penetration-resistant front closure, an integrated hood with facepiece gasket, SCBA air exhaust system, and magnetic glove-sleeve interfaces. After 20 min of treadmill exercise, there was no significant difference in Tre (rectal temp) or Tin (intestinal temp) among subjects wearing the SE, the PEWH (prototype ensemble with hose attached to intake port), and PENH (prototype ensemble with hose not attached). These prototype design features limited many routes of heat exchange between the body and the external environment. Although subjects wearing the PE experienced a greater physiological “burden” compared with the SE, the increased burden may be tolerable under these environmental conditions given the added protection afforded by the PE.
	• SCBA breathing valve	✓	• The effect of the self-contained breathing apparatus (SCBA) with compressed air (BA-A) on ventilatory mechanics, work of breathing (WOB), pulmonary function, and respiratory muscle fatigue, was compared with that of a low resistance breathing valve (LRV). The added effect of the SCBA regulator caused the total WOB to be greater with BA-A. The increase in total WOB was due in part to increases in inspiratory muscle work (55%), combined with a smaller absolute, but greater relative increase (133%) in expiratory muscle work (55%). The greater inspiratory and expiratory muscle WOB likely contributed to the development of inspiratory and expiratory muscle fatigue. Respiratory muscle fatigue may reduce respiratory muscle performance after intense bouts of exercise with the SCBA. The SCBA significantly impaired ventilatory mechanics, pulmonary function, and respiratory muscle strength compared with a low resistance breathing valve due to the combination of increased expiratory breathing resistance and the increase in exercising lung volumes.
	• SCBA (Material & Shape)	✓	• Two conventional, cylindrical shaped SCBA (Device A, B). Device A (steel), Devices B and C (carbon fiber composite). Device B despite its greater volume (+13%) was considerably lighter (22%) than Device A. Device C (rucksack shape to distribute weight towards body’s centre of gravity). Firefighters rated devices B and C to be better than device A. Despite its lower weight (3.3 kg), the physiological strain with device B was not significantly less than with device A. This is probably due to the larger volume of device B which makes it more difficult to pass through and to turn in low and narrow spaces. Decrease of physiological strain and improvements of performance in terms of faster execution of the exercise were only observed with the rucksack device. Device C weighed 1.3 kg less than device A, the physiological strain (HR) was significantly lower than with the other devices (A, B).
	• Hose Nozzle	✓	• Substantial disadvantages of the standard fire hose nozzle - up to 60% of overall strain and static portions of more than 15%. AWG (pistol nozzle) and Quadrafog (ergonomic nozzle) led to substantially lower overall strain and smaller static portions. Only in pure straight stream was there no difference between standard and other models. Overall AWG fire nozzle exhibited most balanced strain profile and overall strain of up to no more than 30% for alternating operation (the most stressful task). The ergonomically designed nozzle led to high strain of hand's abduction musculature to counter forces when nozzle is operated under high pressure.
	• Bed to Staircase Transfer Devices	✓	• Objective and subjective measures support the use of the Drew People Mover and the Transfer Sling. Compared to the under-axilla transfer, the Transfer Sling and the Drew People Mover reduced the recruitment of selected back muscles and potentially improve spinal posture.

Table 6. Firefighter Fatigue Management Interventions

	• Lateral Transfer Device	✓	• Compared to the standard bedsheet transfer, both the bridge board and the single-rod interventions assisted one or both FFPs. The dual rod intervention did not work well. The bridgeboard's effect was focused on the FFP located on the stretcher-side of the transfer. The single rod significantly reduced the Erector Spinae recruitment for both FFPs. Combining the single rod with a bridgeboard reduced the increased Latissimus Dorsi activity found with the single rod by itself. FFPs in both roles rated the single rod conditions as the easiest exertion.
	• Stair Descent Devices	✓	• First intervention: foot strap that attached to the backboard to prevent the patient from sliding toward the leader. Second intervention: hand truck-type device that allowed the backboard to be rolled down the stairs changing the carrying task into a push and pull task. Third intervention: ''tank treads'' that allow a stretcher to be rolled down the stairs by bridging the steps. Fourth intervention: change in the handle configuration of the stair chair. Only the extended handle on the stair chair failed to reduce back muscle recruitment. The foot strap is easily implemented with materials most EMS crews have on hand and will add little time to the patient preparation. Preventing the patient from sliding down the board, in addition to helping out the FFP in the leader role will likely make the transfer less uncomfortable for the patient. The DCS and potentially the backboard wheeler, in transforming the carrying task to a push pull task, will likely be the most beneficial approaches to preventing back injuries associated with the transport of patients.

*Exclusions: Systematic/Scoping/Literature Review: FF Cognitive PPE (1), FF Cognitive Administrative (1), FF Physical PPE (1), FF Physical Training (1), FF Physical Administrative (1)

Recommended Interventions for Police

We extracted 21 articles related to burnout, cognitive fatigue, and physical fatigue interventions (Table 7). Mindfulness-Based Resilience Training (MBRT) was a prominent training intervention for burnout, with 3 articles devoted to this intervention. All three articles (Christopher et al., 2016; Christopher et al., 2018; Turgoose et al., 2017) demonstrated positive effects on burnout and psychological health outcomes. Christopher and colleagues (2018) evaluated a MBRT program over a 3-month period in a randomized controlled trial, finding improvements in burnout compared to a control group, and trend-level reduction of salivary cortisol levels, indicating recovery of impaired cortisol regulation. However, there were no significant group differences after 3 months, which the authors allude to low adherence to ongoing mindfulness practice.

Administrative strategies involving shift rotas were common interventions to minimize cognitive fatigue (e.g., Smith et al., 1998; Bell et al., 2015; Amendola et al., 2011). Smith et al., (1998) found few substantial differences between 12-hr and 8-hr shifts rotas; a flexible system led to improved sleep quality and day shift alertness compared to a rigid system. Bell and colleagues (2015) compared police officers who worked 4 consecutive 10-hr shifts with officers who worked 3 consecutive 13:20-hr shifts, over a 6-month period. Officers working 13:20-hr shifts received less sleep, had worse quality of sleep, experienced more fatigue, increased daytime sleepiness, slower reaction time, increased lapses in concentration, and reported worse quality of life than officers working 10-hr shifts. On average, officers working 13:20-hr shifts had 5.83 hrs of sleep between shifts. Finally, Amendola et al., (2011) compared two compressed work schedules (five consecutive 8-, four consecutive 10-, and three consecutive 12- hour work shifts). The authors observed no measurable impact on performance (driving and shooting) between 10- and 12- hour work schedules; there was no impact of shift length on cardiovascular health, gastrointestinal problems, and work stress. Authors found that officers placed in 10-hr shift schedules received longer sleep duration, compared to officers in 8-hr shift schedules, but perceived quality of sleep did not differ between shift schedules. Officers working 10-hr shift schedules also reported significantly higher quality of work-life than those on 8-hr shifts. There may be potential cost savings for agencies that implement 10-hr shifts as officers in that group averaged significantly less overtime than those on 8- and 12- hour shifts.

Engineered solutions to reduce physical fatigue involved the design and weight of body armour. Schram et al., (2018) studied the effects of three designs of body armour and normal station wear on comfort and perceived exertion while performing police tasks. Mean weights of Individual Light Armour Vests (ILAV) were 4.12kg, 3.54kg, and 3.24kg, for designs A, B, and C, respectively. Officers favoured ILAV B but due to its length, it may potentially interfere with officer mobility and readiness. The other ILAVs (A and C) and normal station wear led to discomfort of the neck and shoulders and was assessed to be detrimental to occupational task performance.

Summary of Interventions Across Occupations

We summarized the available evidence of interventions for all three first responder groups (Table 8).

Table 7. Police Fatigue Management Interventions

Type of Fatigue	Type of Intervention	Intervention	Effective? Yes/ Maybe	Effective? No	Effect
Burnout	Training	• Mindfulness-Based Resilience Training	✓		• MBRT (mindfulness-based resilience training) is feasible and acceptable to LEOs due to high levels of class attendance, overall low attrition rate. Relative to NIC (no intervention control), MBRT participants had improved psychological health outcomes (burnout, organizational stress, sleep disturbance) and potential mechanisms (psychological flexibility and non-reactivity). No significant immediate effects on anxiety, depression, or suicidal ideation. Burnout: Pre-training - 2.43 (0.31) [NIC], 2.36 (0.35) [MBRT]; Post-Training - 2.44 (0.36) [NIC], 2.20 (0.29) [MBRT]; Three-month follow-up - 2.37 (0.34) [NIC], 2.25 (0.29) [MBRT]. Cortisol: Post-training sampling day 3, MBRT participants [M = 14.99] had higher waking salivary cortisol than NIC [M = 11.46]. MBRT had lower 45 min salivary cortisol. Cortisol results suggest MBRT may lead to reduced cortisol increase after awakening while at the same time increasing the level at awakening. No significant group differences after 3 months possibly due to low adherence to ongoing mindfulness practice.
		• Mindfulness-Based Resilience Training	✓		• Increased mindfulness through mindfulness-based resilience training (MBRT) was related to increased resilience (b=0.41, SE=0.11,p< .01), which in turn was related to decreased burnout (b=−0.25, SE=0.12,p= .03).
		• Imagery-Guided Training	✓		• The purpose of the training sessions was to prepare officers to successfully cope with job-related stress. Reported sleep difficulties were also found to develop differently over time between the two groups. Those in the intervention group decreased their self-reported sleep difficulties, while those in the control group increased theirs (time × group interaction p < 0.05). Significant differences between imagery-trained police and the control group were also found on psychological variables. Over time, imagery-trained officers reported less vital exhaustion, controls reported significantly more (time × group interaction p < 0.05). At time 3, imagery-trained officers (M = 36, SD = 12.17) reported significantly less vital exhaustion than controls (M = 32, SD = 18.49). By obtaining adequate amounts of rest, police officers in the intervention group are likely bolstering their physical and psychological resiliency. Similarly, in addition to improved resiliency, obtaining adequate rest may provide officers with additional physical energy and cognitive resources, an important result given that previous research has indicated that difficulties in sleep are negatively correlated with improved work performance
		• Stress Training	✓		• Training was divided into two parts. The first part included psychological education about stress, compassion fatigue, secondary traumatic stress and burnout. The second focused on self-help strategies that can be used to reduce or build resistance against compassion fatigue and stress more generally. The self-help section of the intervention was further broken down into six sections: 1. Identifying physiological signs of stress; 2. Self-care; 3. Anxiety and stress management, e.g. relaxation strategies; 4. Social support and debriefing; 5. Mindfulness; and 6. Compassion satisfaction. Most officers rated that they learned a lot from the training, which was reflected in the knowledge measure scores. These findings suggest that a training intervention of this nature is useful. However, more work is

Table 7. Police Fatigue Management Interventions

				required to determine whether an increase in knowledge leads to uptake of self-help strategies and in turn that these are effective.
		• Mindfulness-Based Resilience Training	✓	• Although there were statistically significant improvements from pre-to-post MBRT for most self-report measures, there were no significant changes in cortisol awakening response (CAR). Authors found weak statistical evidence for changes in mindful outcome at the mid-point of the training. All of the variables, except for family functioning and pain interference, significantly improved from the mid-point to the end of the training.
Cognitive	PPE	• Melatonin	✓	• Compared to placebo, and to no treatment, melatonin (5 mg) taken at bedtime improved problems related to sleep and increased alertness during working hours, especially during the early morning. In letter-target performance tests visual search speed and accuracy were either unchanged or slightly improved. Memory scanning speed and perception of mental load were adversely affected. Melatonin has beneficial effects on sleep and alertness, but that its effects on performance need careful evaluation.
	Training	• Peer-Led Session (SHIELD)	✓	• Intervention: 12, 30-minute, team-based scripted peer-led sessions during first 12 months. No additional intervention team meetings held after 6 months. Team format fosters social support and accountability. Control: same battery of tests and surveys over 2 years. SHIELD program was feasible and in the short-term, effective in promoting health of law enforcement officers and support personnel. Team program well received with high attendance and adherence. SHIELD program improved sleep quality and quantity and reduced personal stress at 6 months. These positive changes in sleep and stress in the short term, however, did not persist at 24 months. It may be that the sleep and stress improvements observed from the SHIELD wellness program in the short term are not as easily reinforced as the other behaviors like diet (since peer workers see what each other eat but not likely to know about sleep habits). A booster session on sleep and stress may be needed to continue the positive impact of the program. The effect size was computed by taking the difference between baseline and the average of the follow-ups and then taking the difference of this difference between the intervention and control groups and standardizing using the pooled individual level standard deviation at baseline. Mean effect size at 6 months: sleep quality = 0.32, sleep quantity = 0.23. At 12 months: sleep quality = 0.09, sleep quantity = 0.11. At 24 months: quality = 0.18, quantity = 0.04
		• Leisure Time Physical Activity	✓	• The association between sleep quality and mean levels of awakening cortisol parameters varied significantly by LTPA. Sleep quality was significantly associated with mean levels of awakening cortisol parameters in officers who were inactive or insufficiently active, but not among those who were sufficiently active. Among officers who were inactive or insufficiently active, the adjusted mean levels of awakening cortisol parameters were significantly higher for those with good sleep quality compared to those with poor sleep quality. Neither the magnitude of increase in cortisol following awakening nor the CAR responder rate differed by sleep quality in officers who reported sufficient LTPA. Relative to officers who met LTPA guidelines, those who reported insufficient LTPA indicated a higher overall prevalence of poor sleep quality (60% vs. 48.2%), a higher global sleep quality score (6.9 ± 3.4vs. 6.0 ± 3.3), and earlier average waking times (7:27AM ± 1.9 vs.7:37AM ± 2.6, p = 0.01).
		• Mental Imaging Training	✓	• After intervention program, trainees experienced fewer sleepiness and awakening problems compared to reference group. Mental imaging training during day

Table 7. Police Fatigue Management Interventions

			decreases the cumulative burden of stressors to be processed during sleep, enhancing total sleep quality.
	• Music-Based Neuro-Training	✓	• Uses individualized music compositions derived from one's own brain wave patterns to improve sleep duration and quality, A ''musical map'' is created to correlate brain activity ratios associated with two primary functional resting states—active and relaxed. There were statistically significant improvements in 4 behavioral measures: sleep quality (94%), insomnia (89%), mood (74%), and daytime function (82%). For the sleep quality assessment, 25% of the first responders (five of 20) and 16.7% of the crossover controls (one of six) experienced a significant positive change after BM. Volunteers classified as operations support showed the largest gains in sleep quality and mood scales, whereas the first responder group showed the largest gains in insomnia and daytime function scores. Effect sizes ranged between 3.5 and 7.0 for sleep quality, 31.1 to 40.9 for insomnia, 3.1 to 5.9 for mood, and 8.5 to 10.8 for daytime function negatives over the experimental and crossover control groups. For the sleep quality assessment, the effect sizes are as follows: ops support=7.0, first responder=5.7, and control=3.5.
Administrative	• Work Scheduling (Shifts)	✓	• Before intervention, 4 consecutive night shifts most popular (viewed as appropriate for adapting to night work without negative consequences of longer spells of night work). After intervention 4 + 4 was preferred by largest proportion; 2 + 2 too many shifts between night and day orientations; 7 + 7 too straining. Participants preferring 4 or 7 consecutive night shifts found night work less demanding and were able to sleep at different times of the day, they were more frequently night types and preferred night work.
	• Napping	✓	• Napping behavior before night work can be an effective countermeasure to alertness and performance deterioration in a large sample and in real-life conditions. Before extended night work, napping behavior is a self-managed prophylactic strategy adopted by most drivers in the sample (retrospective: 85%, prospective: 87%). Its efficacy lies in its capability to reduce the levels of homeostatic pressure toward sleep proportionally to nap duration and according to its timing.
	• Work Scheduling (Shifts Length)	✓	• Few substantial differences were found between trial (12 hr) and control (8h) shift rota groups both at Time 1 and at Time 2 after a 6-month trial period. There may be differences linked to the nature of implementation of 12h rotas. A flexible system (easier for officers to negotiate timing of work to fit their personal circumstances) contributed to improved sleep quality and maintenance of day shift alertness from T1 to T2 compared to a rigid system. Flexible 12 hr system had slightly less sleep around their night duty compared to 8 hr night shifts.
	• Work Scheduling (Shifts Length)	✓	• When compared with the control group (officers working 10-hr shifts), officers working 13:20-hr shifts got less sleep, had worse quality of sleep, experienced more fatigue and more daytime dysfunction due to sleepiness, had slower reaction times, experienced more lapses in concentration, and reported a worse QoL. There were no shift-dependent (i.e., daytime vs. nighttime) differences in sleep assessment or QoL within groups. However, officers working the third shift or night shift had higher cortisol levels than those working first shift or daytime shifts. Officers working 13:20-hr shifts averaged only 5.83 hr of sleep between shifts, and routinely experienced sustained wakefulness of more than 18 hr during workdays. The PSQI and STROOP data indicate that officers in the present study get far less sleep than needed, demonstrate fatigue and daytime dysfunction due to sleepiness, and have sleep scores similar to those with clinical sleep pathologies.

Table 7. Police Fatigue Management Interventions

				However, 2 months after returning to 10-hr shifts, the daytime dysfunction due to sleepiness disappeared, and sleep quality returned to pre-study levels.
		• Work Scheduling (Shifts Length)	✓	• Compressed schedules (10- and 12-hour) did not have a measurable impact on performance. No significant differences in driving performance based on shift length, though this result should be interpreted with some caution given the fact that we used a composite index of a number of risky driving behaviors. Also did not observe any significant differences in shooting performance. Increases in shift length, even from 8 to 12 hours, did not impact the amount of self-initiated activities of police. No negative or positive impacts of shift length on measures of health (cardiovascular health, gastrointestinal problems, and work stress). 8-hour shifts have some disadvantages over 10-hour shifts. Officers working the 10-hour shifts got more sleep per night than those on 8-hour shifts (one half hour more per night). However, the perceived quality of sleep did not significantly differ across groups. Also, findings regarding quality of work life demonstrated that those working 10-hour shifts had a significantly higher quality of work life than those on the 8-hour shifts. Officers working 10-hour shifts averaged significantly less overtime per 2-week period than those on 8- and 12-hour shifts. This result suggests a potential cost savings for agencies that implement CWWs, especially 10-hour shifts.
		• Work Policies	✓	• Law enforcement agencies can counter fatigue conditions in their officers by making incremental adjustments in the following policy areas: secondary employment, consecutive hours worked, and court appearances. Although these policy areas exist, agency chiefs' frequent conceptualization of the fatigue problem—namely, that individual officers can assess their own sleep requirements and decide for themselves how to meet those requirements—has downplayed the potential threat of fatigue-caused accidents and hence the need to adopt specific qualitative measures to minimize such risk. Supervisors often rely on informal conversations with their officers—not on instituted policies or rules—to address the issue of perceived tiredness.
	Engineering	• Phototherapy Lighting & Orange-Tinted Goggles	✓	• Tested the efficacy of a workplace intervention combining intermittent exposure to bright wide-spectrum light at night, orange-tinted goggles in the morning, and a stable daytime sleep/darkness schedule in police officers on patrol. The intervention led to an improved, but incomplete, circadian re-entrainment to the shifted sleep schedule. This resulted in more stable psychomotor performances throughout a series of seven consecutive night shifts. The usefulness of phototherapy lamps in workplaces that are characterized by considerable exposure to environmental synchronizers requires further experimental validation.
Physical	Training	• Predictive Capacity Tests	✓	• Fitness testing and movement quality as predictor of back injuries in police officers. A substantial amount of variance in back injury incidence was explained with torso muscle endurance, hip asymmetry, and the pelvic rock test, but as a medical screen, it was still weak. While 64% injuries were predicted, the model was much better at predicting those who did not sustain a back injury with 95% correctly predicted. Observations over the past 5 years with the group of police officers is that they are aggravating injury in the weight room during strength and conditioning sessions. Thus, the 'fitter' officers may have higher exposure to musculoskeletal risk given their training, obscuring the link between fitness and movement competency, and injury rates.
		• Predictive Capacity Tests	✓	• Possible implications for capacity/fitness testing: The only significant correlation amongst the fitness variables tested and the overall movement score was that of the Biering-Sorensen extension (r=0.33). A plausible rationale is that superior endurance allows individuals to maintain spine-sparing movement patterns for

Table 7. Police Fatigue Management Interventions

			extended periods of time by delaying the onset of fatigue. Had the movement screen in this study incorporated a fatigue component, the correlation between extensor endurance and movement quality may have been even stronger and movement quality scores may have been very different.
Engineering	• Body Armor	✓	• SRBA (stab resistant body armour) and appointment weight significantly slowed participants' time to exit a low car seat, turn, and sprint by a mean of 16%. The time to complete a simulated ground mobility task was also 14% slower when participants were loaded. Time to complete the grapple task was 15% slower when participants were loaded. Participants completed 42% fewer chin-ups while loaded, this indicates that upper body performance is compromised while wearing SRBA and equipment.
	• Body Armor	✓	• Different designs of Individual Light Armour Vests (ILAV): ILAV A was the heaviest, ILAV C was lightest. Mean weights: 4.12 kg (A), 3.54 kg (B), 3.24 kg (C). ILAV B received more favourable comments than either of the other two types of ILAV, though not as favourable as comments regarding normal station wear. While it seems to have been the most comfortable type of body armour for most officers, considerations should be given to the possible operational impacts of ILAV B, given it was long and, according to participants, placed pressure on the belt, hips, and key police equipment, potentially interfering with officer mobility and ready deployment. Conversely, the other ILAVs (A, C, N) were found to be more uncomfortable on the neck and shoulders, and detrimental to occupational task performance when this was assessed both subjectively and objectively.

*Exclusions: Systematic/Scoping/Literature Review: Police Burnout Training (1), Police Cognitive Training (1), FF Physical PPE (1), FF Physical Training (1), FF Physical Administrative (1)

Table 8. Summary of Interventions for First Responder Occupations

Type of Fatigue	Type of Intervention	General Description of Intervention	# of Studies + Effect	# of Studies – Effect
Paramedic				
Cognitive	PPE	Melatonin Supplement		1
	Training	Cognitive Training	1	
	Administrative	Critical Incidence Debriefing		1
		Work Scheduling (Shifts)	1	
	Engineering	Real-Time Fatigue Assessment Platform	1	
Physical	PPE	Chemical-Impermeable PPE	1	
		Adhesive ACD-CPR Glove	1	
	Training	30:2 Compression Ventilation CPR Ratio	1	
		Physical Exercise Training Program		1
	Engineering	Powered Stretchers	1	
		Automated CPR Device	2	
		Stretcher Design	5	
		Lifting Aids (Shoulder Straps)	1	
Firefighter				
Burnout	Training	Stress Management Workshop for Supervisors		1
		Mindfulness-Based Resilience Training	1	
Cognitive	PPE	Zolpidem	1	
		Napping	1	
	Training	Music-Based Neuro-Training	1	
	Administrative	Incident Rehabilitation		1
		Work Scheduling (Shifts)	2	
	Engineering	Mental Health App	1	
		Reduce Firehouse Environment Stimuli	1	
Physical	PPE	Wearable (Ambient and Physiological)	2	
		Aspirin	2	
		Cooling	3	1
		Caffeine	1	1
		Protective Clothing		4
		Rehydration Fluid		1
	Training	Functional Exercise Training	1	1
		Predictive Capacity Testing	5	1
		Compression Ventilation CPR Ratio	1	
		Pacing Strategy	1	
	Administrative	Incident Rehabilitation	1	
		Rest Breaks	1	1
		Pre-Warming		1
		Pro-Active H&S Management System		1
	Engineering	SCBA (Material and Shape)	5	1
		SCBA and Personal Protective Clothing		2
		Protective Helmet		1
		Stretcher Design (Stair Descent Devices)	5	
		Portable Cooling Device	1	
		SCBA Breathing Valve	1	
		Hose Nozzle	1	
Police				
Burnout	Training	Mindfulness-Based Resilience Training	3	
		Imagery-Guided Training	1	
		Stress Training	1	
Cognitive	PPE	Melatonin	1	
	Training	Peer-Led Sessions	1	
		Leisure-Time Physical Activity	1	
		Mental Imaging Training	1	
		Music-Based Neuro-Training	1	
	Administrative	Work Scheduling (Shifts)	1	
		Napping	1	
		Work Scheduling (Shift Length)	3	
		Work Policies	1	
	Engineering	Phototherapy Lighting & Orange-Tint Goggles	1	
Physical	Training	Predictive Capacity Tests	2	
	Engineering	Body Armor	2	

+ Effect: Minimized effect of fatigue, intervention does not increase fatigue, need further investigation
– Effect: Increased effect of fatigue, No statistically significant effect.

Discussion

Fatigue remains a pervasive problem in first responder occupations. Overall, fatigue of various types (cognitive, physical, burnout) is highly prevalent; it has been hypothesized that fatigue of any nature leads to both acute and longer-term adverse outcomes (Kajimoto, 2007; Iridiastadi & Nussbaum, 2006). A cursory analysis of 403 papers revealed a generally consistent distribution of fatigue papers devoted to the three occupations, with a slightly larger proportion of papers focused on firefighters (38.7%) compared to EMS personnel/ paramedics (22.8%).

The number and distribution of articles devoted to the five operationally-defined fatigue types differed between occupations. Both EMS and police work had a higher distribution of cognitive types of fatigue, while firefighting work had a higher distribution of physical fatigue articles. Burnout appears to be relevant in EMS and police work but less represented in the firefighting literature. According to studies on the severity of burnout among firefighters, reported burnout in US, South Korean, French, and Kazakhstan all appear to be minimal (Jo et al., 2018; Vaulerin et al., 2016; Vinnikov et al., 2019; Sattler et al., 2014; Smith et al., 2019). These occupation-specific fatigue type distributions, particularly related to physical fatigue, are not surprising, as work exposures and demands are different between occupations. Based on expert-assessed and worker-reported abilities and work activities in the O*NET database, EMS and police work both require abilities related to "problem sensitivity" (recognizing problems), and deductive and inductive reasoning. Many abilities deemed most important to firefighting work are related to physical capacity (static strength, arm-hand steadiness, multi-limb coordination). Additionally, work activities, based on the degree in which a descriptor is required to perform the occupation, indicates that firefighter work activities involve physical activities ("handling and moving objects", "performing general physical activities") in addition to "assisting and caring for others" and "monitor processes, materials, or surroundings". Both EMS and police work require activities related to "assisting and caring for others", "resolving conflicts and negotiating with others", "making decisions and solving problems", "performing for or working directly with the public" (www.onetonline.org).

Fatigue risk factors also show similarities in the distributions of sub-categories between EMS and police, where work organization and personal/social & cultural are dominating factors. In firefighting services, there is a consistent distribution between all risk factor sub-categories, with higher representation in personal/ social & cultural and physical environment sub-categories. In all three occupations, outcomes were mainly related to (physical) health. EMS articles in outcomes were more distributed, with (physical) health closely followed by performance and wellness outcomes. In this scoping review, (physical) health include musculoskeletal disorders, cardiovascular disease, acute injuries such as trips, slips, falls, and accidents. Finally, trends between occupations based on distribution of interventions were varied. In EMS articles, engineering controls were well-represented with 7 articles, followed by administrative, training, and PPE. On the other hand, training was most represented in police articles with 12 papers. There were more intervention articles for firefighting, with 18 dedicated to PPE and closely followed by engineering, training, and administrative controls. We observed, for the most part, that EMS and police literature had similar distributions in the number of articles based on fatigue type, risk factors, and outcomes. Apart from the distribution between outcome sub-categories, the literature indicates that the focus of research was distinctive in firefighting.

Fatigue Measurement & Risk Assessment Tools

The many definitions, theories, specific fatigue processes, and manifestations of fatigue have led to a large diverse set of tools and procedures to measure fatigue. In a workshop of experts from multiple perspectives and disciplines, 57 measures of fatigue were identified (Yung, 2016). The selection of valid, reliable, and practical tools has been a continuing challenge in both workplaces and has been the focus in research. In our previous work, we have attempted to address the sensitivity, reliability and effects of diurnal variation on field usable measures (Yung & Wells, 2017a), identify measures for physically demanding work over consecutive days (Yung et al., 2014), understand the pattern of fatigue development and contributions from central and peripheral sites (Yung & Wells, 2017b), identify measures for light precision work over a workday (Yung & Wells, 2017c), and identify measures related to health outcomes and performance (Yung et al., 2017). Since fatigue is task dependent, multiple complementary measures, compared to a single measure, provides a comprehensive picture of fatigue development. These studies suggest that when measuring fatigue among individual workers, a battery of measures reflecting multiple mechanisms including central and peripheral processes should be strongly considered.

Individual measurement using tools to detect precise physiological responses may not be feasible or practical. Instead, we should consider the SOBANE strategy for risk assessment: screening, observation, analysis, and expert-required tools (Malchaire, 2004). These levels are compatible to categorizes found in the Ontario MSD Prevention guideline: hazard identification, detailed screening, observational evaluation, and comprehensive analysis (www.msdprevention.com). Briefly, screening tools are generally more cost effective, requires minimal training or prior experience, and can be used to assess risk among larger samples of workers. However, screening tools are sometimes ambiguous. Observational evaluation typically assesses specific jobs or tasks based on observable attributes (e.g., body posture, movement frequency), a level of risk is generated based on posture- or task- specific scores. Comprehensive analysis will require an occupational health and safety or ergonomic practitioner to collect/ record information, assess risk, and interpret data. Often, comprehensive analysis requires combining measurements to create new variables with greater interpretive power. These methods are generally more expensive and more time consuming. We however note that MSD risk assessment tools in all levels lack clear information about their sensitivity and specificity.

For each first responder occupation, we identified commonly used measurement tools in the study of different fatigue dimensions (Tables 2 to 4). We found that for burnout, the primary measurement tools were psychological inventories, surveys, and questionnaires.

The Maslach Burnout Inventory (MBI; Maslach & Jackson, 1981; Maslach et al., 1996) consists of 22 items covering 3 subscales of burnout: emotional exhaustion, depersonalization, and reduce personal accomplishment. The MBI is self-administered requiring 10 to 15 minutes to complete (Maslach et al., 1986). A study found that emotional exhaustion and depersonalization scales can discriminate between burnout and non-burnout patients, however empirical cut-off points may be nation-specific (Schaufeli et al., 2001). Another widely used instrument is the Malach-Pines Burnout Measure (Malach-Pines, 2005; Pines & Aronson, 1988), accounting for 5% of all studies that measure burnout (Schaufeli et al., 2001). The Malach-Pines Burnout Measure is a 21-item self-administered questionnaire, assessing the level of an individual's physical, emotional, and mental exhaustion. According to Schaufeli et al. (2001), the Malach-Pines Burnout Measure lacks context-specificity, in that its items do not refer to the work situation; therefore, it has been viewed as more limited as it does not discriminate between clinical burnout and other depressive symptoms. Similar to the MBI, cut-off points of the Malach-Pines Burnout Measure are arbitrary; a total score between 2 and 3 is considered "normal" while scores greater than 5 indicates "major crisis". Rather than selecting a single tool, Schaufeli et al., (2001) recommends using both to complement one another. The Malach-Pines Burnout Measure was able to correctly identify non-burned out cases, and therefore had a higher level of specificity than the MBI, while MBI had superior sensitivity.

Heart rate measures and surveys, scales, and questionnaires were common measures of cognitive fatigue. Heart rate may reflect changes to emotional stress (Chang et al., 2009), and its parameter, heart rate variability, provides insight into the autonomic regulation of heart rate. Heart rate variability has been used to assess arousal, work stress, and fatigue. Both heart rate and heart rate variability may be indices of chronic sleep deprivation (Takase et al., 2004). Chern-Pin Chua et al., (2012) examined the utility of heart rate variability as a measure of an individual's sleepiness level, finding that RR-interval power spectral density (PSD) in the 0.02- to 0.08- Hz frequency range correlated strongly with lapses calculated from the psychomotor vigilance task (PVT). RR-interval PSD and PERCLOS eye-tracking system classified PVT performance with similar sensitivity and specificity among individuals with total sleep deprivation. Measures of vigilance, attention, working memory, visual object learning, psychomotor speed, and visual tracking have been used as part of a test battery to assess cognitive performance (Taylor et al., 2019). Although these objective measures allow us to explore different aspects and specific functions of cognition, these tests may be time-consuming and may be susceptible to learning or practice effects; Taylor and colleagues (2019) recommend simulation studies to track work performance that may be related to adverse events (e.g., near misses, accidents, etc.).

Surveys, scales, and questionnaires can be used in large-scale field studies. Subjective measures may also provide information on behavioral responses related to poor sleep quality or shift work; for instance, individuals perceiving poor daytime sleep may engage in compensatory behaviors and activities, such as overeating and excessive caffeine intake (Lammers-van der Holst et al., 2006). Common surveys include the Pittsburgh Sleep Quality Index, Epworth Sleepiness Scale, and Chalder Fatigue Questionnaire. A popular questionnaire-based assessment tool, but not as extensively represented in the first responder literature, is the Swedish Occupational Fatigue Inventory (SOFI); SOFI provides information about qualitative aspects of fatigue, for application to the work environment. SOFI reflects both physical and mental fatigue based on 5 dimensions: lack of energy, physical exertion, physical discomfort, lack of motivation, and sleepiness (Åhsberg et al., 1997); it has been used extensively to measure physical work, mental work, and shiftwork (Åhsberg et al., 2000). Patterson et al., (2018) systematically reviewed 14 fatigue survey instruments, evaluating their reliability and/or validity. Information on the sensitivity and specificity of these instruments remain absent and the quality of evidence was low. Patterson et al., (2018) recommend developing an EMS-specific fatigue survey instrument. Objective measures, beyond heart rate and its parameters, have been employed, but its use is often limited to smaller-scale workplace evaluations, and require more expertise to collect, analyze, and interpret data (i.e., comprehensive analysis). Objective approaches may provide data on physiological responses directly linked to current state (Smith & Mason, 2001). Critical flicker fusion frequency (CFF), psychomotor vigilance task (PVT), oculomotor behaviour (e.g., blink duration or frequency), polysomnography, and actigraphy are a few objective measures of cognitive fatigue. These measures remain elusive in large-scale studies due to cost, practicality, and efficiency. Biomathematical models have been proposed to estimate the impact of fatigue on performance and could be a useful risk assessment tool (James et al., 2018). However, there are few biomathematical models available for first responder occupations, and an occupation-specific biomathematical model warrants further investigation.

Heart rate and its parameters were frequently used in studies of physical fatigue. Measures of heart rate has been used as an index of physiological strain and metabolic rate and has been used in occupational studies of construction workers (e.g., Chang et al., 2009; Roja et al., 2006), manufacturing (e.g., Jensen et al., 1993; Christensen, 1986), and transportation (e.g., Patel et al., 2011). Heart rate is related to oxygen consumption (VO2), which in turn reflects energy expenditure, particularly in physically demanding jobs (Malchaire et al., 1984). Recently, heart rate measures optimized with an adaptive neuro-fuzzy inference system (ANFIS) may improve the classification of work rate, with improved accuracy, sensitivity, and specificity compared to current practice (% Heart Rate Reserve classification) (Kolus et al., 2016). A General ANFIS model may be desirable for obtaining accurate VO2 estimations, with reasonable accuracy (+/- 5%), from large population work environments. An individualized ANFIS model is desirable for small population work environments, to obtain accurate VO2 estimates (Kolus et al., 2014). The Borg's Rating of Perceived Exertion (RPE) scale was developed as a psychophysical scale for physical strain, the scale from 6 to 20 was designed to increase linearly with exercise intensity and heart rate (Borg, 1990). As verification, Borg's RPE scale has been shown to strongly correlate with heart rate ($r = 0.74$, $p<0.001$) and blood lactate ($r = 0.83$, $p<0.001$); the Borg RPE scale was not influenced by gender, age, exercise modality, physical activity level, and coronary artery disease status (Scherr et al., 2013). Perceived exertion using Borg's scale or alternative tools for subjective perception of effort/fatigue/exertion (e.g., visual analog scale, Borg's category-ratio 1-10 scale) have been frequently reported in first responder literature.

Observational risk assessment tools, such as Rapid Upper Limb Assessment (RULA), has been used to assess exposures to risk factors associated with risk of musculoskeletal disorders through evaluation of postures, movement frequencies, and forceful exertions. However, these tools may not be amenable for fatigue measurement as they often lack a time component or take into consideration cumulative exposures. Observational tools for physical fatigue are limited but a generic occupational tool for muscle fatigue is available based on evaluating work patterns within a 5-minute data collection period (Rodgers Muscle Fatigue Analysis; Rodgers, 1992). Further investigations are warranted for a physical fatigue observational tool for first responder occupations.

Fatigue & Outcome Relationships in First Responder Occupations

In a previous scoping review in production work, fatigue has been shown to be an important intermediary factor in the human factor-quality linkage (Yung et al., 2020); up to 42% of quality deficits was explained by fatigue. In that study, physical fatigue (46% of papers) was a primary contributor to quality deficits. We investigated similar work factor-outcome linkages in the three first responder occupations; the primary types of fatigue related to outcomes were cognitive fatigue, physical fatigue, and burnout. Based on the number of linkages in the reviewed articles, cognitive fatigue appears to be more frequently linked to health (injury, accident risk, musculoskeletal disorders, cardiovascular disease), wellness (depression, anxiety, dissatisfaction), and work performance. Risk factors associated with an increase in cognitive fatigue include work organization (e.g., shift length, number of shifts, shift pattern, work stress), environmental stimuli (e.g., alarm response, excessive noise), and personal capacity (e.g., chronotype). Increasing fatigue generally led to adverse outcomes, however Sterud et al., (2007) did not observe a significant relationship between burnout and alcohol use, nor strong relationships between burnout and alcohol-related problems and consumption. However, Sterud et al, (2007) found that for paramedics who reported using alcohol to cope with feelings of distress and tension, there was a relationship to higher levels of depersonalization and more frequent alcohol consumption and problem drinking. Patterson et al., (2012) did not find a relationship between shift duration (24 vs. <12 hrs) and safety outcomes among EMS personnel/paramedics. The authors assert that the lack of association may be due to unmeasured workload levels during shifts, where the intensity of workload better predicts negative safety outcomes. Longer shifts with more opportunities to rest during downtime may mask potential relationships (Patterson et al., 2012). Yadav et al., (2016), in a study of police officers, did not find changes in blood pressure as a result of shift schedule, which appeared to be consistent with other reports.

Of the 22 retained articles, the majority (15) were cross-sectional observational studies; therefore, these studies could not draw conclusions with regards to the direction of the reported relationships. Two studies were longitudinal designs: a 3-year follow-up study on firefighters to investigate risk factors associated with mental and physical strain (Lusa et al. 2006) and a 12-day protocol of police officers monitoring sleep-wake cycles and cardiovascular health (Yadav et al. 2016). Lusa and colleagues (2006) found that work-organizational and psychosocial factors were strongly associated with increased perceived work-related physical and mental strain. Unfair distribution of work tasks was a significant risk factor for perceived physical strain (odds ratio = 8.5, CI: 1.5-49.6). Poor work ability due to musculoskeletal symptoms was strongly associated with physical strain (odds ratio = 5.6, CI: 2.2-13.8). As indicated earlier, Yadav et al., (2016) did not find changes in blood pressure but found an increase in amplitude of heart rate among officers during "out-of-phase" duty schedules; out-of-phase duty schedules is associated with a sleep-wake cycle that is more fragmented, compromising sleep quality. Four studies were quasi-experimental designs, three of which were firefighting studies (Ives et al., 2016; Park et al., 2011; Colburn et al, 2017) and one studied police (Venkatappa & Vinutha Shankar, 2012). All four studies indicate positive relationships between fatigue and adverse outcomes; firefighter studies investigated the effect of exercise-induced heat stress, firefighting gear, and physical fitness. In the single police study (Venkatappa & Vinutha Shankar, 2012), the physical environment (i.e., traffic noise) was related to sleep disturbance and subsequent psychosomatic symptoms. The variation of outcomes, between sub-categories, ranging from health to performance to wellness, and within each sub-category, limits our ability to ascertain statistical relationships; more empirical studies are needed to improve the ability to predict the impacts of fatigue in all three occupations.

Fatigue Management Interventions Identified in First Responder Occupations

Interventions and controls to mitigate fatigue were categorized using the Hierarchy of Hazard Control – HOC (NIOSH, 2015), which is a widely accepted system that is standard practice for controlling risks. The Hierarchy of Hazard Control consists of selecting controls (or interventions) based on five broad methods: elimination, substitution, engineering controls, administrative controls, and personal protective equipment (PPE). Elimination and substitution are most effective but most difficult to implement in an existing process. Elimination is the removal of the hazard while substitution is the replacement of a hazard. Engineering controls involve isolating the worker from the hazard, by removing the hazard at the source, and may be physical changes to the workplace (WorkSafeBC, 2020). Administrative controls are workplace initiatives that involve changing the way people work, these can be safe work procedures or alterations in work scheduling. PPE and clothing can be used with an existing process and protect the worker from the hazard.

Across all three first responder occupations, we did not find any controls that were related to either elimination or substitution. Overall, in all three occupations, training was the primary type of control to mitigate burnout. In all three occupations, PPE and engineering controls were the foci of studies to combat physical fatigue. To reduce cognitive fatigue, there was a strong focus on administrative controls and training interventions. In a study on EMS and firefighters, the Kelly schedule was compared to a 48/96 schedule (Caputo et al., 2015). The 48/96 schedule led to favorable improvements in sleep, including an increase in the number of hours slept, and a small significant reduction in daytime sleepiness. Additionally, participants reported improvements in feelings of burnout, time for personal schedules, and perceptions of work satisfaction (Caputo et al., 2015). Fast shift rotation schedules (e.g., 7N7D7O) resulted in better physiological adaptation than slow shift rotations (e.g., 4N4D4O) among firefighters (Kazemi et al., 2018). Among articles on police, evidence of shift length indicates few substantial differences between 12 hr and 8 hr shifts after a 6-month period, a flexible system improved sleep quality and day shift alertness compared to a rigid system (Smith et al., 1998). When comparing a group of officers working 4 consecutive, 10-hr shifts to a group working 3 consecutive, 13:20-hr shifts, the 13:20-hr group experienced poor sleep, more fatigue, more daytime sleepiness, slower reaction time, increased lapses in concentration, and reported worse quality of life (Bell et al., 2015). Compressed work schedules (five consecutive 8-, four consecutive 10-, and three consecutive 12- hour work shifts) were compared (Amendola et al., 2011). There were no impacts on performance, cardiovascular health, and work stress between 10- and 12-hr schedules. Officers working 10-hr shifts reported higher quality of work-life and received longer sleep duration than officers in 8-hr schedules; there may be potential overtime cost savings when 10-hr shifts are implemented, compared to 8- and 12-hr shifts. In a study comparing the shift patterns based on the number of on/off consecutive night shifts, 4-night shifts followed by 4 recovery days (either days off or day shifts – '4 + 4'), were preferred with respect to family life, health, sleep, and demands of night work, over '2 + 2' and '7 + 7' (Nabe-Nielsen et al., 2016). However, the authors indicate large variation of preference, and a "one-size-fits-all" solution may be difficult to implement. Additionally, self-rostering may compromise health if the choice of working hours were guided by economic incentives and other needs that disregard health and sleep (Nabe-Nielsen et al., 2016). Napping has also been studied as a fatigue countermeasure in firefighting (Dawson et al., 2015) and police services (Garbarino et al., 2004). Dawson et al., (2015) interviewed 30 experienced volunteer firefighters, over half the participants supported napping as an informal fatigue risk management strategy. Garbarino et al., (2004) found that napping before night work may be effective to reduce reductions in alertness and performance; napping behaviour was a self-employed informal strategy adopted by 85% to 87% of police officers.

Our scoping review provides no assessment on the quality of the study but is a cursory analysis on the type, description, and the potential effect of interventions identified in the peer-reviewed literature. An effective intervention was defined as controls that demonstrate statistically significant effect to mitigate fatigue, or a probable/unknown effect (article reports reduction of fatigue but lack statistical analysis, requiring further investigation). Interventions that demonstrate no statistical significance, an increase in fatigue, or a null effect was categorized as not effective. No single intervention was supported by overwhelming evidence, but we found limited support for stretcher design, predictive capacity testing, SCBA design (material and shape), and mindfulness-based resilience training. Articles indicate that changes to protective clothing, to reduce physical demands and fatigue, were not effective solutions in firefighting work.

Strengths & Limitations

The scoping review provides insight towards the extent, impact, and management (i.e., measurement, risk assessment, hazard controls) of fatigue based on a broad range of fatigue types for first responder occupations. Categorizing by fatigue type might be useful in targeting appropriate controls and focus future research investigations. This examination also provides a reminder that fatigue has been conceptualized in many ways and organizations should consider all aspects. For instance, based on the number of articles, there was a stronger focus on cognitive fatigue in EMS and police work, but in firefighting, there was a stronger focus on physical fatigue. We assigned studies into fatigue types, based on the study description, measured fatigue responses, and the types of task attributed to fatigue. Different research groups might arrive to different interpretations, and therefore different categorizations. Our scoping review focused on a large breadth of potential outcomes, ranging from physical health, wellness, and work performance. In all three occupations, burnout, cognitive fatigue, and physical fatigue were associated with adverse health and performance effects; these results highlight the importance of managing fatigue, of any type, to prevent longer term outcomes.

There are several limitations of this research. First, this scoping review was limited to the selected keywords determined a priori with the consultation of a research librarian. A separate search dedicated to specific risk assessment tools or specific interventions might result in a different pool of published literature. Even within the current scope of literature, there is a possibility of missing some relevant literature not detected by keywords or systematic extraction criteria. However, given the considerable body of evidence, this common limitation would have unlikely affected the results. Second, we limit our search to articles written in the English language; articles from countries where English is not common language for academic publications may be underrepresented. Third, tasks and activities performed in first responder occupations, and consequently work exposures, may also differ between countries. Types of fatigue, risk factors, outcomes, and interventions might not be consistent cross-nationally; however, we observed similar prevalence of fatigue between countries for each first responder occupation. Fourth, we limited our review to front line staff, excluding articles on single events (e.g., plane crashes, natural disasters, terrorist attacks), those that did not focus on civilian first responders (e.g., wildland firefighters, military police, border police or patrol, correction officers, intelligence officers), those that involved air ambulances. A targeted review should be dedicated to fatigue related to single events and to specialized occupations. Fifth, a formal quality appraisal was not conducted for each study; all studies were verified to be from peer-reviewed articles. The intent of our scoping review was to examine the extent, range, and nature of research activity, to help us identify gaps in current literature and to identify broad commonalities between first responder occupations, which all will contribute to developing a Canadian First Responder Fatigue Risk Management Standard.

Conclusions

First responders are at high risk of suffering decrements in performance related to fatigue. These performance decrements not only endanger the personal health and safety of these responders, but also the health and safety of their fellow responders and the public they serve. Fatigue is also related to longer-term health outcomes, including musculoskeletal disorders, cardiovascular disease, and mental health disorders. An evidence-informed fatigue risk management standard will enable first responder organizations with a framework to deal with fatigue and its hazards in a continuous improvement process.

The scoping review provides insight towards the extent, impact, and management of fatigue based on a broad range of fatigue types for first responder occupations. Categorizing by fatigue type might be useful in targeting appropriate controls and focus future research investigations. In all three occupations, burnout, cognitive fatigue, and physical fatigue were associated with adverse health and performance effects; these results highlight the importance of managing fatigue, of any type, to prevent longer term outcomes. Although a range of measurement tools have been identified in the peer-reviewed literature, future investigations are needed to identify tools specific to first responder occupations and information on the sensitivity and specificity of these instruments. No single interventions were supported by overwhelming evidence; high quality research, including randomized control trials, may help identify and inform effective risk mitigation strategies for first responders.

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