Mental health risk for wildland firefighters: a review and future directions

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ABSTRACT

Wildland fire is increasingly a consequence of the climate crisis, with growing impacts on communities and individuals. Wildland firefighters are critical to the successful management of wildland fire, yet very limited research has considered mental health in this population. Although a wealth of research in mental health risk and associated risk and protective factors exists for structural firefighters, unique demands of wildland firefighting such as the seasonal nature of work, the length and intensity of shifts, and the often geographically isolated working conditions, among other factors, require special consideration. The present review considers available literature on mental health in wildland firefighters, highlighting the importance of distinguishing occupation-related risks for firefighters from occupation-specific risks of wildland fire service work, and offers concrete evidence-based recommendations for future work in this high-priority research area.

Keywords: epidemiology, firefighters, mental health, natural disaster, occupational health, potentially traumatic event, PTSD, risk, wildland fire.

Mental health has been identified as a top-three health research priority by 78% of wildland firefighting personnel surveyed (Pelletier *et al.* 2022), yet research on mental health outcomes in this population remains limited (Groot *et al.* 2019; Koopmans *et al.* 2020; Bonita *et al.* 2024). As fire seasons continue to worsen in length and severity in our rapidly changing climate (Hope *et al.* 2016; Tymstra *et al.* 2020), understanding mental health risks associated with wildland firefighting is an increasingly urgent priority for mitigating the human and economic costs of wildland fire and enhancing wildland fire preparedness.

Contextualising mental health in fire service work

Firefighting is a profession with inherently high risk for occupational exposure to potentially traumatic events (PTEs) involving direct or indirect exposure to actual or threatened death, injury, or sexual violence (APA 2013). Other such high-risk professions include (but are not limited to) law enforcement, prehospital and emergency health care, and the military. In addition to elevated risk of occupational PTEs, these professions have in common the provision of occupationally specialised training to newly recruited personnel to help prepare them for the physical, mental and emotional impacts of their work. For these reasons, among others,[1]

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[1]It is currently unknown whether many common symptom measurement scales validated in general population samples adequately capture the experience of mental ill-health in high-risk occupational groups. Limited scale validation work comparing the factor and/or network structures of common post-traumatic stress disorder (PTSD) symptom measures (Smith and Paton 1997; Creamer *et al.* 2003; Wagner 2011; Yuan *et al.* 2022) as well as emerging moderated psychological network analyses comparing groups on how symptoms relate to one another (Isvoranu *et al.* 2021) suggest that important differences in the structure of PTSD symptoms exist between populations. In other words, current clinical standards developed for general population assessment may not capture the same dimensions of post-traumatic experience in civilians vs firefighters, police, paramedics, etc. with equal sensitivity. Indeed, this possibility is already partially accommodated in diagnostic criteria for PTSD in the DSM-5, which includes specific language unique to first responders regarding what constitutes traumatic exposure (APA 2013). Other yet uncharacterized differences requiring a diversity of measures to explore are also possible, though recent work with public safety personnel suggests that the seven-factor hybrid model of PTSD symptoms as indexed by the PCL-5 may be reliably compared across public safety personnel occupations (Boehme *et al.* 2023). More work of this nature is needed to confirm generalisability of measures and outcomes between populations.

it is difficult at present to confidently generalise findings from the wealth of research on trauma-related conditions conducted in general population samples to these special populations, including characterisation of prevalence, risk and protective factors, and intervention efficacy.

Considering high-risk occupations, available data suggest that although overall rates of any previous exposure to occupational PTEs are similar across groups, non-military high-risk personnel appear to report a generally higher prevalence of exposure to specific occupational PTEs compared with military personnel. For instance, Carleton *et al.* (2018) surveyed over 4400 Canadian public safety personnel and found that, regardless of mental health status, more than 80% of participants among all occupational groups reported occupational exposure to sudden violent or accidental death and more than 70% reported occupation-related life threatening illness or injury, compared with 40 and 15%, respectively, of Canadian Armed Forces personnel surveyed about deployment-related exposure to the same event(s) in a separate, nationally representative sample (Sareen *et al.* 2017), and approximately 5.6 and 25%, respectively, in a large sample of American military veterans (Moye *et al.* 2022). Moreover, the frequency of specific, objectively defined PTEs (e.g. exposure to fire or explosion) and their subjective impact on personnel (i.e. which type of PTEs are considered most distressing) is variable across occupational groups (Carleton *et al.* 2018), as are rates of trauma-related symptoms and diagnostic prevalence (e.g. Berger *et al.* 2012; Klimley *et al.* 2018; Petrie *et al.* 2018; Syed *et al.* 2020). Accordingly, considerably more occupation-specific *and* cross-occupational comparison work is needed to better situate understandings of occupational mental health in diverse high-risk groups. For the purposes of the present paper, we focus primarily on comparing wildland and structural firefighting given the inherent overlap of occupational duties between these two groups. Where possible, we include limited discussion of other occupational groups on the basis of occupational features that may be considered overlapping between groups (e.g. unpredictable deployment). However, it is critical to note that these discussions regarding potential insights gleaned from examining what appear to be shared occupational features are speculative at present and remain to be directly tested in most cases. This issue is further expanded below in our discussion of occupation-related vs occupation-specific risk.

Current status of research on wildland firefighters' mental health

Several recent systematic reviews address the general topic of firefighters' health risks, including mental health, in relation to wildland fire exposure. For instance, Groot and colleagues (2019) reported that across 11 eligible studies considering mental health outcomes, post-traumatic stress disorder (PTSD) prevalence estimates ranged from approximately 10 to 37%. Although these estimates all exceed general population prevalence estimates in most countries for which such data are available (Koenen *et al.* 2017), the authors note that baseline prevalence of mental health conditions in wildland firefighters has not been well established. Further, 7 of the 11 studies included in the review of Groot *et al.* were conducted in a single longitudinal sample of Australian firefighters following the Ash Wednesday bushfire disaster, all rated low quality owing in part to a low initial response rate of 31%. Of the remaining four studies, two concerned the Carmel Mountain fire disaster in Israel, one concerned a fire disaster in Greece, and the final study considered a different, large-scale Australian bushfire. In other words, the entirety of the eligible literature comprised just five samples of mixed structural and wildland firefighters exposed to four large-scale disasters. Moreover, predictors of mental health risk varied across studies, both in the sense that no two studies examined the same set of risk and protective factors, and that, across studies that did examine a specific factor (e.g. years of service), associations with mental health were inconsistent.

The work of Bonita and colleagues (2024) extends this review with similar findings. A total of 13 eligible studies included 9 of the same studies reviewed by Groot *et al.* One additional study published in 2018 comprised a longitudinal update of a 2008 study sample included in the work of Groot *et al.* (Psarros *et al.* 2018); thus, 10 samples of firefighters were considered in both reviews. One study (Innes and Clarke 1985), which focused on general psychological distress rather than a specific mental health condition, was included by Groot *et al.* but not included in the work of Bonita and colleagues, leaving only three additional studies of mental health outcomes with unique samples published after 2019 and included in the review of Bonita *et al.* All 13 studies included were rated as low or very low quality, and as in the work of Groot *et al.,* all studies concerned anomalous large-scale wildfire disaster events and reported on both wildland and structural firefighters. Estimates of PTSD prevalence were similar to those observed by Groot *et al.*, ranging from approximately 10 to 30%. Depression and anxiety disorders were also examined in a single study (Cherry *et al.* 2021) with estimates of prevalence at 14.3 and 15.8%, respectively, while the prevalence of insomnia was reported to be 23.5% in another sample surveyed 10 years post-disaster (Psarros *et al.* 2018). Both reviews highlight an urgent need for more research to better characterise prevalence and predictive factors for PTSD and other mental health conditions.

Focusing specifically on wildland firefighters, Held and colleagues (2024) systematically reviewed a total of 142 studies of environmental health impacts, and found just 11 studies considering psychological or sociological health indices, including several of the studies reviewed in previous work. Additional studies not previously reviewed tended

to explore sleep problems. Sample sizes were generally small (median $N = 37$) and constructs examined in this literature were reported to largely encompass cognitive performance and stress mitigation. Mental health and social support were identified as important areas for future study, with recommendations to consider both current mental health and mental health history when studying these outcomes. Expanding the study of occupational health in wildland firefighters by including non-operational staff (e.g. dispatchers) was also suggested as an important area for future work. Only two studies in this review considered PTSD symptoms in wildland firefighters, whereas another study considered subjective experiences of suicidal thoughts in relation to job stress.

These reviews comprise the most up-to-date synthesis of a limited literature, suggesting overall that prevalence rates of commonly studied mental health conditions such as PTSD, depression, anxiety, sleep problems and substance use are likely substantially elevated in firefighters exposed to large-scale wildland fire disaster events. However, baseline prevalence of mental health conditions in wildland firefighters remains to be clearly established (Groot *et al.* 2019) to contextualise mental health observed post-disaster, and to date, there is no strong evidence regarding risk and protective factors.

Recent empirical work informing research on wildland firefighters

Most work on mental health in relation to wildland fire has, to date, focused on mental health risks for firefighters exposed to wildland fire events, including both structural and wildland firefighters. In contrast, very little research has specifically examined mental health in wildland firefighters. Below, we review recent work that can inform future study of this occupational group.

Granberg and colleagues (2023) surveyed over 700 American wildland firefighters to assess factors associated with job morale. Mental health of the sample was assessed via self-reported diagnostic status, and results demonstrated high prevalence rates for PTSD (22.3%), depression (43.6%), anxiety (48.9%), suicidal thoughts exacerbated by job stress (16.5%) and substance abuse disorders (22.7%). Neither individual demographic (e.g. gender) nor organisational (e.g. work–life balance) factors were predictive of prevalence for any outcome. In general, firefighters' health and well-being scores were not associated with morale, which was most negatively associated with work–life balance concerns. PTE exposure was not assessed in this study. In another cross-sectional study of over 2600 wildland firefighters, rates of PTSD (13.7%), depression (17.3%), generalised anxiety (12.8%), past-year suicidal ideation (20.1%) and heavy alcohol use (22%) were slightly lower than prevalence rates observed by Granberg and colleagues, but still reportedly

2–10 times higher across conditions compared with the general population (O'Brien and Campbell 2021).

Similarly elevated rates of mental health conditions have been reported in wildland fire dispatchers (Verble *et al.* 2024). Surveying over 400 dispatchers using validated self-report symptom questionnaires, Verble *et al.* found that prevalence was high in the sample for probable PTSD (33%), severe levels of depression (25%) and anxiety (25%), potential for alcohol abuse (59%) and high levels of suicide risk (10%). Depression and anxiety symptoms specifically were self-reported by a majority of respondents to be aggravated by job stress, and for both conditions, non-white respondents were more likely than white respondents to report severe symptoms. Almost the entire sample (94%) reported work-related PTEs, and open-response questions revealed generally high levels of worry about firefighters' safety, feelings of guilt and hypervigilance. PTSD scores were significantly positively correlated with scores for depression, anxiety, suicidal thoughts and sleep problems, but neither PTSD, depression, anxiety nor suicidal thoughts were associated with alcohol abuse; anxiety and depression were also both associated with sleep problems. Risk of alcohol abuse was only significantly associated with sleep problems. Other recent work also supports evidence of high rates of binge drinking and other substance use in wildland firefighters, and suggests that use of substances varies between the fire season and off-season (e.g. Scott *et al.* 2024).

Cherry and colleagues (2021) surveyed over 1200 mixed structural, industrial and wildland firefighters ($n = 329$ wildland) who were deployed to the 2016 Fort McMurray/Horse River wildfire to examine respiratory symptoms and mental health outcomes associated with particulate exposure and subjective distress related to the fire. A significant strength of this study was controlling for baseline respiratory disease and mental ill-health drawn from physician records when examining post-fire outcomes. Approximately 25% of firefighters had clinical diagnosis of a mental health condition within the 3 years prior to the wildfire, a rate that was slightly but significantly lower than that observed in community controls (28.5%). Prevalence of PTSD, depression and anxiety disorders was reported to be high (21, 16 and 14%, respectively). However, in the 2 years following the fire, new-onset diagnoses of mental ill-health were statistically similar between groups (11.5% in firefighters vs 10.6% in controls). No relationship between particulate exposure and clinical diagnostic status was observed, but scores on self-report symptom screening tools for PTSD, depression and anxiety all increased significantly with particulate exposure. Examining mental health outcomes in relation to firefighters' self-reported worst moments during the fire showed that firefighters who reported experiencing feelings of psychological threats to their safety were significantly more likely to score above screening cut-offs for PTSD, depression and anxiety, while experiences of witnessing devastation caused by the fire was associated with elevated likelihood

of PTSD only, and experiencing inter-crew stress predicted anxiety symptoms. However, the authors also noted that in a subsample of those who completed structured clinical interviews at 2-year follow-up, only 42% of firefighters with PTSD diagnoses reported experiencing threats to their life during fire events, whereas the remainder reported other traumas unrelated to fire suppression activities (e.g. road accident fatalities).

Taken together, these studies suggest that rates of PTSD, depression, anxiety and substance abuse are substantially elevated in fire service personnel including wildland fire dispatchers, though as noted, a majority of firefighters diagnosed with PTSD who were surveyed after deployment to a wildland fire event attributed their symptoms to PTE experiences unrelated to fire suppression. This finding underscores that exposure to wildland fire events is one of many occupational PTEs presenting risk of mental ill-health in this population, as well as the importance of evaluating history of PTE exposure when examining the psychological impact of a particular incident to account for psychological impact in context.

Another important factor for understanding mental health is sleep problems, which are thought to comprise both a risk factor for and symptom of trauma-related disorders such as PTSD and depression (e.g. Wright *et al.* 2011; APA 2013; Cox *et al.* 2018; Short *et al.* 2020). Vincent and colleagues (2018) reviewed literature on sleep outcomes in wildland firefighters with the aim of comparing data on active fire suppression and prescribed burn scenarios and found that emergency deployment scenarios were associated with greater decrements in sleep quantity and levels of fatigue. Differences in sleep outcomes observed between fire suppression and planned operations were suggested to arise from differences in the predictability and timing of planned operations as well as differences in the quality of sleep locations (e.g. tent vs motel) including variation in temperature, noise and smoke exposure, leading, collectively, to lower levels of fatigue and overall physiological strain during planned operations. However, the literature on sleep outcomes in association with planned fire operations was very limited. Data on sleep outcomes generally in relation to mental health in wildland firefighters are also very limited to date. Systematic review of sleep outcomes in firefighters broadly suggests that feelings of daytime sleepiness are associated with depressive symptoms (Frost *et al.* 2021), but more work is needed to explore this association given strong associations between sleep and mental health.

Considering the current state of mental health research related to wildland fire exposure, we reiterate previous literature regarding the urgency of research exploring mental health symptoms including PTSD, depression, anxiety, suicidal thoughts, substance abuse and sleep outcomes in wildland firefighters, ideally using prospective longitudinal designs. Below, we further highlight three notable observations from existing literature that offer high-priority avenues for future study.

Occupation-related vs occupation-specific risk

First, we find that a clearer distinction must be made between studying 'health risks for firefighters exposed to wildland fire events' and 'health risks for wildland firefighters'. Recent reviews have included studies of both structural and wildland firefighters deployed to wildland fire events, with a primary focus on the health risks of fire or smoke exposure, and a lesser focus to date on mental health outcomes. Much of the available literature on mental health in wildland firefighters comes from a single Australian disaster-exposed sample. Little other work to date focuses exclusively on wildland fire service personnel, in contrast with a vast body of similar work in structural firefighting samples (e.g. see Wagner *et al.* 2020; Igboanugo *et al.* 2021; Kyron *et al.* 2021; Garmon-Jones *et al.* 2023; Serrano-Ibáñez *et al.* 2023 for systematic reviews). Health risks unique to firefighters and health risks that are unique to a particular type of fire service work are related but distinct considerations. The former question concerns *occupation-related* risks of firefighting, whereas the latter concerns *occupation-specific* risks.

Although exposure to smoke or other airborne environmental contaminants is an obvious occupation-related health concern for all firefighters, there also exist numerous factors that differ between structural and wildland fire services, including length and intensity of shifts, remoteness of the work, seasonal nature of the work, and length and frequency of deployments, which may also contribute uniquely to health outcomes broadly (e.g. differences in the types of smoke and particulates to which firefighters tend to be exposed) and mental health outcomes specifically (e.g. remote vs urban deployment, changing incident team memberships). Few studies to date have directly explored potential occupation-specific differences in mental health outcomes and risk.

The work of Stanley and colleagues (2018) offers a strong model for future studies in this area. The authors surveyed over 1100 American firefighters to directly compare suicide risk between wildland and structural firefighters and found that wildland firefighters were nearly twice as likely to report clinically relevant suicidal symptoms; further, this difference was mediated by feelings of thwarted belongingness, leading the authors to suggest possible protective effects of social connectedness in the structural fire service. However, just 1.8% ($n = 20$) of the sample were wildland firefighters, precluding generalisability. As such, these findings will require more work in larger samples to confirm. We highlight them here to underscore the value of conducting such controlled statistical comparisons in future work rather than to advance the results of Stanley and colleagues as definitive evidence of occupation-specific differences.

Emerging work on health behaviour change in wildland firefighters suggests that activities and employment opportunities during the off-season may also be relevant for understanding health outcomes. Scott and colleagues (2024)

reported that 31% of wildland firefighters surveyed were unemployed during the off-season, while another 30% were employed only part-time, leading the authors to suggest that sources of off-season stress such as unpredictable income may be important to account for in understanding health outcomes in this unique occupational group. Overall, alcohol consumption was higher during the off-season, whereas consumption of smokeless tobacco and sugar-sweetened beverages were elevated during the fire season, further suggesting that exploration of substance use in relation to stress experiences, psychosocial factors, physical pain and sleep variability associated with shift work is warranted. Finally, many firefighters reported prior work- or hobby-related exposure to environmental respiratory contaminants, which may also influence overall health as well as mental health outcomes (e.g. Cherry *et al.* 2021; Wolffe *et al.* 2023) and should be accounted for in work on occupation-related and occupation-specific health risks. As part of contextualising prevalence of mental health conditions, baseline and off-season factors should be integrated into research to aid in identifying mental health risk factors unique to wildland firefighters alongside general risk factors associated with fire service work.

Factors identified as important for understanding mental health in the structural firefighting service can also serve as useful reference to expand this research area. For instance, over several large-scale systematic reviews, convergent international evidence across heterogeneous measurement tools appears to suggest that individual sociodemographic and personality characteristics are of relatively lesser importance for understanding firefighters' mental health risk in comparison with indices of non-traumatic organisational strain (e.g. job stress, social support) and, to a less consistent degree, factors related to workplace PTE exposure (e.g. number or severity of incidents; Wagner *et al.* 2020; Kyron *et al.* 2021; Garmon-Jones *et al.* 2023), generally suggesting that mental health risk skews heavily towards occupation-related rather than person-related factors. Non-traumatic job stress in particular has been identified in systematic reviews as a key variable for understanding symptoms of both PTSD and depression (Igboanugo *et al.* 2021; Serrano-Ibáñez *et al.* 2023), while empirical work suggests that, of individual-level factors tested, relatively more consistent associations between mental health outcomes are observed with measures of self-efficacy (Chiang *et al.* 2021; Jitnarin *et al.* 2022) and hostility (Hienrichs *et al.* 2005; Wagner *et al.* 2016). Notably, in this literature, some potential risk and protective factors (e.g. biomarkers) have been under-explored to date. Similarly, there is a great deal of conceptual overlap between many commonly studied predictors of mental health in firefighters (e.g. self-efficacy, coping, and hardiness/resilience; see Schwarzer and Warner 2013), with little resolution yet on potential issues of collinearity and/or which of several closely related factors might emerge as most important. As such, the above suggestions do not comprise an exhaustive list of potential risk and protective factors for mental health outcomes but rather serve as a current, best-evidence template for comparing structural and wildland firefighters.

Examining data collected from other high-risk occupational groups with shared occupational features may also offer insights to inform future work in wildland firefighters. For instance, the United States National Guard comprises part-time military service members who live as civilians but must be prepared for rapid deployment (National Guard 2024). Research in large samples has estimated the lifetime prevalence of deployment-related PTSD at approximately 5.5% (Russell *et al.* 2015), with elevated rates of PTSD observed in the post-deployment period (e.g. Goldberg *et al.* 2022), but lower risk of PTSD for those deployed with their regular unit compared with those deployed as individual augmentees (Ursano *et al.* 2018). Deployment preparedness, unit cohesion and psychological hardiness have all been associated with lower post-deployment rates of mental health symptoms (Ursano *et al.* 2018; Hoopsick *et al.* 2021; Griffith 2022), whereas identifying strongly with one's occupational role (i.e. military identity) has been associated with elevated rates of anxious, depressive and PTSD symptoms (Vest *et al.* 2022). These may be relevant constructs to consider in the study of wildland firefighters' mental health. Bryan and colleagues (2018) also highlight the potential importance of distinguishing between occupational stress injury and moral injury for National Guard personnel, where moral injury is defined as arising from events in which an individual 'perpetuates, fails to prevent, bears witness to, or learns about acts that transgress deeply held moral beliefs and experiences' (p. 37). This concept may also be of value in research on wildland firefighters, considering increasing pressures faced by these personnel as fire seasons continue to worsen and incident teams are faced with increasingly difficult risk-management decisions related to the safety of their colleagues and at-risk communities.

Given the complexity of this occupational health landscape, process models such as structural equation models (SEMs), and other emerging statistical techniques such as psychological network modelling (e.g. Fried and Robinaugh 2020), offer promise for identifying key variables among the numerous constructs associated with mental health. For instance, in a recent study of structural firefighters, psychological network analysis showed that sleep quality and fatigue were more strongly associated with mental health symptoms compared with sleep quantity (Zhang *et al.* 2023). At the same time, unexpectedly, between-shift recovery factors were not directly associated with sleep outcomes. Rather, between-shift recovery was indirectly associated with sleep outcomes through age, years of service, subjective well-being and via life/social functioning, which was in turn indirectly associated with sleep quality through mental health problems (Zhang *et al.* 2023). In this analysis, mental health symptoms, between-shift relaxation and physical

fatigue emerged as the strongest network nodes, indicating that these constructs may serve as the most efficient targets for interventions promoting occupational wellbeing. In contrast, and despite strong documented associations between sleep and mental health, sleep quality and quantity demonstrated some of the lowest strength in the network after controlling for other factors. These hypotheses remain to be directly tested, and no work we are aware of considers the network structure of occupational health in wildland firefighters.

Network analysis could be of significant value in this population to provide novel insight into which occupation-specific factors may be most influential for wildland firefighters' mental health. Unlike traditional process models (e.g. SEM), no *a priori* assumptions are required as to the nature of associations between variables in a psychological network (Epskamp *et al.* 2018), rendering the technique ideal for exploratory application. The quantification of variables' relative importance (influence) within the overall network structure supports generating testable hypotheses for future research integrating characterisation of symptoms with applied prevention/intervention design aims (Borsboom 2017), which can help advance this literature beyond observational studies while still working within common resource-related constraints (e.g. reliance on cross-sectional convenience samples and self-report survey measures). Moderated network analyses (e.g. Isvoranu *et al.* 2021) can also support cross-occupational or other group comparisons to explore occupation-specific phenomena. Finally, the techniques of psychological network analysis are rooted in basic univariate statistical methods (partial correlations), rendering them more amenable to widespread uptake compared with relatively more niche statistical approaches such as graph analysis or Bayesian modelling. However, like SEMs, this technique generally requires large samples to produce reliable, replicable network structures, which may present challenges to feasibility and/or require multi-site collaborative work to collect large enough datasets.

Large-scale disaster vs routine fire service work

With few exceptions (e.g. Granberg *et al.* 2023; Verble *et al.* 2024), most of the existing literature on mental health in wildland firefighters comprises studies conducted following anomalous, large-scale disaster events. However, wildland fire is a natural, seasonal occurrence, and few wildland fires constitute disaster events (Tymstra *et al.* 2020), or PTE exposures, for highly trained, specialised personnel. Conversely, evidence suggests that firefighters frequently experience PTEs of many kinds during non-disaster fire events and via participation in duties unrelated to fire suppression (e.g. MacDermid *et al.* 2019). Indeed, in the work of Cherry *et al.* (2021), only 42% of firefighters with clinically diagnosed PTSD subjectively reported traumatic workplace experiences related to active fire suppression. At the same time, the psychological impact of a large-scale wildland fire disaster may be substantially greater in comparison with other forms of occupational PTE. Relative psychological impact across PTEs is currently unknown.

In structural firefighters, mental health risks of 'routine' PTE exposure have been extensively explored (e.g. see Wagner *et al.* 2020 for review). In contrast, these relatively more routine experiences are, at present, drastically understudied in wildland firefighters. Limited meta-analytic data further suggest that, in structural firefighters, prevalence of probable PTSD may be *lower* on average in the wake of large-scale disaster exposure compared with routine service, possibly owing to protective effects related to the scale of organisational response after disaster (White *et al.* 2023). This is, at present, a speculative hypothesis. More work is needed that delineates the impacts of routine fire service work from the impacts of large-scale disaster exposure in both structural and wildland firefighters. Particularly for wildland firefighters, whose shifts, deployments and rest/recovery opportunities are inherently more unpredictable during the fire season, considerably more quantitative and qualitative work is needed to better understand firefighters' experiences and insights regarding potential differences between the psychological impacts of routine service work and exposure to disaster events.

As noted, very limited data regarding differences between active fire suppression and prescribed burn scenarios suggest that sleep outcomes may differ according to whether firefighters are engaged in emergency compared with planned fire scenarios (i.e. Vincent *et al.* 2018). No other work we are aware of addresses this question in wildland firefighters.

What constitutes relevant 'occupation-related exposure' for mental health risk?

Finally, when researching mental health risks associated with fire service work, the operationalisation of 'occupational exposure' requires closer consideration. In much research on workplace mental health, 'exposure' is generally considered synonymous with PTEs, and typically encompasses features such as number or severity of PTEs or the subjective distress associated with PTEs, in accordance with current diagnostic criteria for trauma-related disorders (APA 2013). However, fire service work also inherently involves exposure to conditions of considerable physiological strain associated with factors such as length or intensity of shifts and recovery time, as well as routine exposure to numerous environmental contaminants and known carcinogens (e.g. polyaromatic hydrocarbons). These routine physiological and/or environmental exposures may constitute important sources of occupational stress contributing to mental health risk. Little work to date explores this question, though emerging evidence suggests it is an important consideration.

In a recent study, Wolffe and colleagues (2023) surveyed more than 10,500 UK-based structural firefighters to examine associations among occupation-related contaminant exposures and mental health outcomes. As has been demonstrated in previous work (e.g. Igboanugo *et al.* 2021), organisational factors were associated with mental health outcomes. Specifically in this sample, full-time firefighters were significantly more likely to report at least one mental health condition, and those who attended fires at least once a week were more likely to score above screening cut-offs for depression (Wolffe *et al.* 2023). Further, 61% reported sleep problems, which were associated with a four-fold increased likelihood of mental ill-health. Numerous significant associations were observed between indices of environmental exposure and mental health outcomes. A two-fold increase in the likelihood of having any mental health condition, and of anxiety specifically, was observed in firefighters who reported noticing soot in their nose/throat for more than 1 day after a fire, as well as for those who remained suited in personal protective equipment (PPE) for more than 4 h after a fire. Odds of having any mental health condition and of anxiety specifically were also 1.4 times higher for individuals with poorly fitting PPE, and these same odds were similarly elevated in firefighters who endorsed the belief that contaminated PPE should be celebrated as a badge of honour, in those who infrequently sent PPE for professional decontamination, and in those who reported that cleaning was not taken seriously at their workplace. Continuing to smell smoke after washing was also associated with elevated odds of scoring above screening cut-offs for depression.

The physiological impacts of fire service work may simultaneously contribute to overall physiological and psychological stress and/or mental health risk along several dimensions. For example, physiological strain and exposure to environmental contaminants may each uniquely alter regulatory activities within the body's stress systems. Robust associations between symptoms of anxiety and cardiovascular or respiratory conditions have been extensively documented, and as a result of these comorbidities, differentiation of physiological symptoms that may mimic symptoms of anxiety (e.g. shortness of breath) has been highlighted as an important component of diagnostic evaluation (e.g. Meuret *et al.* 2020; Ye *et al.* 2021). Inflammatory processes have also been implicated in our understanding of mental health conditions. Evidence from systematic review data suggests that neurovegetative symptoms of depression such as insomnia, appetite changes and fatigue are associated with inflammation, and that inflammation may promote susceptibility to depression (e.g. Beurel *et al.* 2020; Majd *et al.* 2020). The potential psychological impacts of physiological strain and/or environmental exposure are also important to account for in firefighters' mental health. Pelletier and colleagues (2022) interviewed wildland firefighters and found that the unknown long-term health risks and impacts of the work were a source of worry for many.

These findings collectively indicate a clear and urgent need to differentially assess and understand the physiological impact of fire service work as part of occupational stress exposure in relation to mental health symptoms for accurate diagnosis and intervention. In recent work, Held and colleagues (2024) specifically recommended that environmental exposure should be studied in tandem with physical job demands, as higher-intensity work may be associated with elevated environmental exposure (e.g. through increased respiration). We reiterate this recommendation and further suggest that future work should take a broad, inclusive view of occupational stress exposure in relation to mental health, including physiological, environmental and PTE-related stress exposure. Additionally, research on wildland firefighters' rates of physical injury suggests that more experienced personnel and personnel working on specialised teams are less likely to sustain injuries that prevent them from redeploying (Britton *et al.* 2013), but no comparable data are available for mental health outcomes. As such, indices of occupational exposure should be studied in concert with factors related to years of fire service work and levels of training.

Finally, given the specialised training that firefighters and other high-risk personnel receive, it is important to note that many PTEs that may be considered 'objectively' distressing to members of the general population may be minimally distressing or not at all distressing to individuals within these special populations. This possibility is supported in literature on structural firefighters by a widespread inconsistency in observed associations between features of PTE exposure (e.g. severity, frequency) and the development of trauma-related symptoms (e.g. Wagner *et al.* 2020). Consequently, expanding our understanding of occupational exposure must include accounting for both objective and subjective features of exposure, as well as interactions between them, to better understand mental health risk.

The impact of media coverage as an emerging priority

As wildland fire seasons become more severe, increasing attention has been focused on wildland fire management and response in mainstream media. The potential psychological impacts of being involved in wildland fire suppression activities covered in news media, positively or negatively, are currently unknown, and will be an important question for occupational mental health. Previous work in emergency response personnel including structural firefighters suggests that media attention related to post-mortem inquiries following workplace fatality is associated with increased rates of depressive and PTSD symptoms as well as higher likelihood of stress leave (Regehr *et al.* 2003). A recent study surveyed over 600 professional first responders, reporting that a majority (88%) were engaged with

local, national and international news shared on social media networks online, and that users of social media scored significantly higher on measures of perceived stress (Tucker *et al.* 2022), with qualitative data indicating a perceived link between negative or inaccurate media coverage and increased stress, primarily in police. To date, very little empirical work addresses this question in firefighters. We speculate that media coverage focusing on criticism or other negative aspects of wildland fire suppression could have a potentially negative impact on firefighter morale, possibly exacerbating trauma-related symptoms directly, or indirectly through contributing to non-traumatic occupational strain and burnout, which are consistently associated with PTSD and depression in structural firefighters (e.g. Serrano-Ibáñez *et al.* 2023).

Limitations to current research

Existing literature on mental health in wildland firefighters, as in research on most other high-risk occupations, is currently largely reliant on cross-sectional convenience samples and self-report survey measures validated for use in the general population. In addition to the potential limitations this poses to measurement generalisability highlighted above, self-report measures are also subject to reporting biases arising from factors such as social desirability and mental health stigma. However, although incorporating more objective clinical assessment into research design can help to address these biases, the use diagnostic-standard assessments in high-risk occupational samples is associated with significantly lower estimates of PTSD prevalence compared with probable prevalence estimates derived from most validated symptom scales (White *et al.* 2023). This pattern has been observed even when comparing multiple assessment tools within a single sample (e.g. Meyer *et al.* 2012), suggesting at least two (non-exclusive) possibilities: (1) that diagnostic measures are less sensitive but more specific, whereas self-report symptoms scales demonstrate higher sensitivity at the expense of specificity; and/or (2) that measurement biases related to under-reporting of symptoms may be at least as likely in clinician-administered assessment compared with self-report (e.g. potentially due to relative differences in participants' feelings of anonymity, especially where stigma is prevalent). Other potential explanations are also possible, but regardless of mechanism, a clear and central limitation to this literature pertains to a need to better delineate exactly what is being measured, and to ensure that we do not implicitly assume that clinical and self-report tools are necessarily informative *in the same way*. There are valuable reasons to use both assessment strategies in occupational samples, including direct exploration of how measurement strategies impact the outcomes we observe. Documenting the impact of measurement on outcomes can allow the research context to guide the selection of measurement strategy; a more conservative (specific) approach to

characterising prevalence in a sample may be called for when our aim is to identify personnel in need of immediate intervention, whereas a more sensitive measure may be ideal for preventive screening. Some of the limitations of self-report tools can also be addressed through enhancing empirical research design, such as by including appropriate control comparisons that attempt to equate potential self-report biases between conditions, or by statistically accounting for social desirability and/or stigma in analyses of symptom severity (e.g. Wagner *et al.* 1998).

Conclusion

At present, available data suggest that risk of psychological morbidities such as PTSD are elevated in wildland firefighting, but with scant, inconsistent findings regarding risk and protective factors, and no high-quality data on long-term mental health for career wildland firefighters. Extensive work exploring mental health risks of structural firefighting provides a strong foundation for the design and execution of more targeted studies in this unique occupational group. Delineating occupation-related from occupation-specific risks within and across structural and wildland firefighters will provide clarity regarding broad-spectrum occupation-related compared with organisation-specific risk and protective factors.

The study of mental health symptoms in routine wildland fire service work is also an urgent priority to provide better context for research conducted following large-scale disaster events. Wildland fire is a natural, seasonal occurrence. Owing to climate change, however, wildland fire seasons globally are worsening in length and severity. It is urgent to understand occupational health impacts of day-to-day wildland fire service work in our changing climate in addition to understanding the psychological impacts of large-scale wildfire disaster events.

A further important distinction can be made in considering how the construct 'exposure' is operationalised in research. Research that takes an inclusive view of occupational stress exposure including PTEs, physiological strain and environmental exposure is of high priority given the intense physical and psychological demands of wildland firefighting.

Key recommendations for future work

- Expand characterisation of occupational PTE exposure in wildland fire to include non-fire-suppression activities, physiological strain and environmental exposure as occupation-specific PTEs
- Explore relative contributions of and interactions between objective and subjective features of PTE exposure to the development of trauma-related symptoms

- Situate post-exposure symptoms and diagnoses within pre-operational, off-season and routine exposure contexts, and include consideration of the impacts of media coverage during the fire season
- Combine descriptive characterisation aims with theoretically informed (e.g. SEM) or exploratory (e.g. network analysis) techniques designed to advance knowledge of risk factors and inform intervention design
- Advance understanding of occupation-related vs occupation-specific risk through controlled cross-occupational comparisons
- Collect multiple mental health measures where possible to explore measurement validity cross-occupationally as well as the impact of measurement sensitivity and specificity on key outcomes.

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