



OPEN First responders' occupational injury and disease associated with periods of extreme bushfires

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There has been limited research on the health impacts of extreme bushfire exposure among emergency responders (ER) involved in suppressing extreme bushfires. This study aimed to evaluate the associations between extreme bushfires and ER's compensated injury and illness in Victoria, Australia. State-wide ER compensation claims from January 2005 to April 2023 were analysed. Logistic regression modelling was used to identify factors associated with compensation claims during the extreme bushfire periods in 2009 and 2019/20, compared to all other claims, adjusting for seasonality (summer). Of the 44,164 included claims, 1105 (2.5%) had recorded injury/disease onset dates within extreme bushfire periods, and 11,642 (26.4%) occurred in summer months. Over half of claims were made by police (52.4%), followed by ambulance officers/paramedics (27.2%) and firefighters (20.5%). Extreme bushfire period claims were associated with older workers (odds ratio/OR = 1.58, 95%CI = 1.30–1.92, ages ≥ 55 vs. 35–44 years). Mental disorders (OR = 1.61, 95%CI = 1.25–2.07), intracranial injuries (OR = 3.04, 95%CI = 1.69–5.48) and infections/parasites (OR = 3.11, 95%CI = 1.61–5.98) vs. wounds were associated with extreme bushfire period claims. Given the expected increase in extreme bushfire events and the ageing workforce, study findings underscore the importance of primary and secondary prevention in ER. This can include periodic health surveillance for older workers, access to early treatment, and ongoing support for mental health conditions.

Keywords Bushfire, Emergency responders, Firefighters, Health impacts, Workers' compensation

The Black Saturday bushfires, which took place in February 2009 in Victoria, Australia, claimed 173 lives, devastated numerous homes and inflicted significant environmental damage¹. The subsequent Australian Black Summer bushfires, which took place over a decade later in November 2019 to February 2020, were an unparalleled series of bushfires with far-reaching consequences, including widespread destruction of natural and built environment, loss of human and animal life, and ecological repercussions². Nine firefighters died in the Black Summer bushfires³. It is expected that the likelihood of extreme bushfire events will continue to grow due to a combination of trends in climate contributors to bushfire risk⁴. Black Summer and Black Saturday bushfires were extreme bushfires marked by their severe intensity and rapid spread, unpredictable nature, and significant damage to human lives, properties, and the environment, along with far-reaching economic and social repercussions^{4–6}. The growing risk of escalation of bushfires into extreme 'pyro-convective firestorms', as occurred in the Black Summer and Black Saturday bushfires, is of particular concern⁴.

The first-line response to bushfires is managed by emergency responders: these include firefighters (paid firefighters and volunteer and/or seasonal firefighters), defence personnel, paramedics and ambulance officers, police officers, and State Emergency Service (SES) volunteers. Emergency responders' occupational exposure to bushfires has the potential to adversely affect their physical and psychological health immediately and in the long term. Reviews of the health effects associated with bushfire smoke exposure in firefighters have reported psychological impacts (post-traumatic stress disorder (PTSD), suicide), respiratory issues (lung function decline, airway dysfunction, increases in airway inflammation, lung cancer mortality), cardiovascular disease (hypertension, dyslipidaemia, arrhythmia, cardiovascular diseases mortality), acute physical injuries, as well as

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dehydration^{7–9}. However, less is known about the effects of *extreme bushfire events* on emergency responders, in terms of injury and illness occurring whilst performing their duties or delayed onset effects.

Emergency response during extreme bushfires is potentially associated with greater exposure to smoke and heat, longer and irregular shifts with reduced breaks, and traumatic experiences when compared with regular duties in and outside of ‘normal’ annual fire seasons. During extreme bushfire response, breaks may be taken in close physical proximity to the fires, and emergency responders’ base camps may be subjected to smoke¹⁰. There are reports about emergency responders’ (including volunteers’) mental and physical health impacts of occupational exposure in the Black Saturday and Black Summer bushfires^{11–13}. The After the Fires study, a survey of > 4000 emergency responders from across Australia¹³, reported significant mental health impacts of the Black Summer bushfires on emergency responders, with relatively high rates of psychological distress and probable post-traumatic stress disorder (PTSD). Previous studies, however, have not evaluated the effects of extreme bushfires in comparison to normal duties. A better understanding specifically of the health impacts of extreme fire events on emergency responders will help to inform disaster preparedness and the development of primary and secondary preventive measures to protect and manage emergency responders’ health and wellness.

Despite the increasing frequency of extreme bushfires expected in Australia, which pose a significant challenge to the health and safety of emergency responders, it is unknown if there are changes in the injury/disease claims data corresponding with these extreme bushfires. This exploratory, retrospective study will look for associations. The purpose of this study was, therefore, to evaluate the associations between extreme bushfires and emergency responders’ work-related injury and illness in Victoria, Australia. This was addressed by identifying emergency responders’ workers’ compensation claims that arose during the Black Saturday and Black Summer bushfires and comparing these with all other claims, adjusting for seasonality.

Methods

setting

In Victoria, Australia, workers’ compensation is regulated by the government authority WorkSafe Victoria. The legislation mandates that employers carry insurance to cover medical expenses, rehabilitation, and income replacement for employees with injuries or illnesses during their employment. The modern workers’ compensation system was introduced in 1987, and therefore, workers’ compensation coverage was in place throughout the duration of this study. All Victorian Government employees, including emergency responders, are covered. Volunteers are generally not considered workers unless their entitlement to compensation is specified in an Act of Parliament¹⁴. Certain Acts provide that volunteers are entitled to compensation if they are injured while carrying out relevant duties, including the Country Fire Authorities Act 1958, which applies to casual firefighters. Claims under this Act, however, are managed by the Country Fire Authority (CFA); these claims were not captured in this study. First responders from other jurisdictions who may have contributed to the Victorian bushfire response would have been covered by their state’s own workers’ compensation system, and these are also not captured in this study.

Workers’ compensation claims can be for medical expenses only or for lost time (with or without medical expenses). ‘Minor claims’ are those that have not reached the employer’s medical and like expenses threshold (minor medical only claims) or the time loss has not reached the employer’s excess of ten days (minor lost-time claims). Once these thresholds have been reached, the claim status transitions from ‘minor’ to ‘standard’.

Data source

Workers’ compensation claims data for emergency responders were supplied by WorkSafe Victoria. Victorian workers’ compensation data have been used in other studies of specific occupational or industry groups, including paramedics/ambulance personnel^{15,16}.

Sample

Workers’ compensation claims dating between 1 January 2005 and 28 April 2023 were included in the analysis (based on the date the insurer received the claim) if the claimant was 18 years or older at the time of injury and if the occupation was recorded as one of the three main emergency response occupations: ambulance officers and paramedics; police officers; and firefighters. These were based on Australian and New Zealand Standard Classification of Occupations (ANZSCO) codes 4412 (Fire and Emergency Services); 4413 (Police); 4111 (Ambulance Officers and Paramedics). For data extraction, scheme-specific occupation type codes were used: 3491 (Ambulance Officers and Paramedics); 3911 (Police Officers); 3995 (Senior Fire Fighters) and 4985 (Fire Fighters). Defence force personnel who were emergency responders in Victoria were not included in the analysis as Australia has a dedicated Military Compensation Scheme.

Exposure variables

Extreme bushfire period claims were defined as claims with an injury/disease date that coincided with the Black Saturday bushfires in Victoria: 7 February – 14 March 2009, or the Black Summer bushfires in Victoria: 1 November 2019–29 February 2020. Summer claims were determined from injury/disease dates occurring in December, January or February throughout the study period; summer months in Victoria were used to represent regular bushfire seasons. Extreme bushfire period claims mostly, but not entirely, overlapped with summer months in Victoria: to preserve the completeness of the summer months descriptive statistics, claims that occurred during periods of extreme bushfire were not excluded from the summer month claims.

Other variables

Sociodemographic variables were age in five groups (<25, 25–34, 35–44, 45–54 and ≥ 55 years); sex; and regionality based on the area of residence. The Australian Statistical Geography Standard remoteness structure was used to allocate remoteness area¹⁷. Socio-economic index based on place of residence was used, based on the Socio-Economic Index for Area (SEIFA)¹⁸. SEIFA deciles were grouped into five bands (quintiles) to reduce degrees of freedom in the modelling but still allow non-linear response patterns to be discerned. Higher SEIFA deciles indicate a relatively higher socio-economic advantage. Injury or disease cause was determined from the accident type group code in the workers' compensation data. The type of injury or disease was coded according to the Type of Occurrence Classification System (TOOCS) 3rd edition¹⁹. Two claim-related factors were captured: medical-only claims (vs. claims for lost time) and claim type: minor or standard claims. Minor claims are those that have not reached the threshold income and/or medical expense for reimbursement by workers' compensation and are captured by the scheme for tracking purposes only. They were included in this study as they are reflective of work-related injury and disease, regardless of who carried the financial costs.

Statistical methods

All categorical variables were displayed in frequency tables. Associations between the descriptive variables and each of the two exposure measures (summer period claims; extreme bushfire periods) were tested using chi-square tests. Logistic regression modelling was used to test the associations between sociodemographic, work-related, injury/disease and claim factors and extreme bushfire period claims vs. all other claims. Following univariate modelling, multivariable models of sociodemographic variables, work factors and claim factors were constructed; seasonality was included in the modelling to account for bushfire-risk seasons (summer). The first multivariable model included injury/disease type, while the second multivariable model included injury cause/mechanism. To avoid multicollinearity, injury/disease type and cause/mechanism were not captured in the same model. Firth's bias reduction method was used: a penalised likelihood-based method for logistic regression with rare events²⁰.

Results

In the period from January 2005 to April 2023, there were 44,164 emergency responders' workers' compensation claims received by the insurer: an average of 2409 claims per year. The vast majority (43,249, 97.9%) of claimants were residents of Victoria. Of the total 44,164 claims included in the analysis, 1105 (2.5%) had a recorded injury/disease onset date that fell within one of the two periods of extreme bushfires: 342 during the Black Saturday bushfires in 2009 and 763 during the Black Summer bushfires in 2019/20. There were 11,642 (26.4%) claims that had an injury/disease onset date corresponding with summer. The extreme bushfire periods did not fall entirely within summer months: of the 1105 extreme bushfire period claims, 829 occurred in summer months, and 276 did not. More than half of claims were by police officers (23,118; 52.4%), followed by ambulance officers and paramedics (12,000; 27.2%) and firefighters (9,046; 20.5%).

Table 1 provides an overview of claims overall; during heightened bushfire periods (i.e. summer); and during one of the two extreme bushfires. The majority of workers with a claim were in the 25–54 year age range; however, young workers (<25 years) were overrepresented in summer claims, while older workers (≥ 55 years) were overrepresented in extreme bushfire period claims. Emergency responders residing in major cities were slightly less likely to have summer claims and extreme bushfire period claims compared to those residing in regional and remote areas. In terms of occupational groups, firefighters made around a quarter of claims for injury/disease that occurred in summer (23.1%) and in extreme bushfire periods (24.6%).

The injury/disease cause overall was most commonly coded as "body stressing". Notably, in extreme bushfire period claims, the cause was relatively more likely to be mental (22.9% vs. 15.4% in other periods). This overrepresentation of mental cause for the claim was not observed for summer claims. Similarly, the main injury/disease type overall affected the musculoskeletal system, but mental health conditions were relatively common in extreme bushfire period claims; this was not observed in summer claims. In 313/44,164 (0.7%) of emergency responder claims, the breakdown agency was recorded as fire/smoke/flame specifically (results not shown in table). Intracranial injuries and infections and parasites were also overrepresented in extreme bushfire claims, but the case numbers were generally low. In terms of claim type, 29% were medical-only expense claims. More than one-third of all claims were minor claims.

The results of multivariable modelling of extreme bushfire period claims (vs. all others) results are shown in Table 2. In the first multivariable model, which included sociodemographic factors, work factors and claim factors as well as *injury/disease*, older workers aged ≥ 55 years were at higher risk of extreme bushfire claims (vs. all other claims), Odds ratio/OR 1.58 [95% confidence interval/CI 1.30, 1.93]. Sex, regionality and socio-economic index for the area were not statistically significantly associated with bushfire periods. In terms of occupational group, firefighters (vs. police) were associated with extreme bushfire periods, OR 1.19 [1.01, 1.40]. As expected, there was a very strong association between summer months and bushfire periods, OR 8.94 [7.79, 10.3]. In terms of injury types, intracranial injuries (OR 3.04 [1.67, 5.48]), mental disorders (OR 1.61 [1.25, 2.07]) and infections & parasites (OR 3.11 [1.61, 5.98]) were associated with extreme bushfire periods. Claim factors: *medical only claims* and *minor claims* were negatively associated with extreme bushfire periods in the univariate modelling, signifying more lost time and/or greater medical expense in extreme bushfire period claims. These associations, however, were not statistically significant in the multivariable models. In the second multivariable model, the same patterns were observed for sociodemographic factors, work factors and claim factors. This model contained a variable specifying the cause (or mechanism) of injury/disease. The results showed that injury/disease caused by heat, radiation & electricity (OR 1.95 [1.26, 3.03]) and mental causes (OR 1.65 [1.32, 2.05]) were associated with extreme bushfire periods.

<i>Worker factors</i>	Summer claims		Extreme bushfire period claims		All claims
	Summer	Spring, autumn, winter	Black Saturday or Black summer	All other time periods	
Total	11,642 (26.4%)	32,522 (73.6%)	1105 (2.5%)	43,059 (97.5%)	44,164 (100%)
<i>Age at injury</i>					
< 25 yrs	572 (4.9%)‡	1245 (3.8%)	50 (4.5%)‡	1767 (4.1%)	1817 (4.1%)
25–34 yrs	3022 (26.0%)	8022 (24.7%)	274 (24.8%)	10,770 (25.0%)	11,044 (25.0%)
35–44 yrs	3407 (29.3%)	9815 (30.2%)	289 (26.2%)	12,933 (30.0%)	13,222 (29.9%)
45–54 yrs	3215 (27.6%)	9462 (29.1%)	306 (27.7%)	12,371 (28.7%)	12,677 (28.7%)
≥ 55 yrs	1426 (12.3%)	3978 (12.2%)	186 (16.8%)	5218 (12.1%)	5404 (12.2%)
<i>Sex</i>					
Male	8804 (75.6%)†	24,251 (74.6%)	829 (75.0%)	32,226 (74.8%)	33,055 (74.9%)
Female	2838 (24.4%)	8271 (25.4%)	276 (25.0%)	10,833 (25.2%)	11,109 (25.2%)
<i>Regionality</i>					
Major Cities	7360 (63.4%)‡	21,541 (66.3%)	684 (62.0%)†	28,217 (65.6%)	28,901 (65.5%)
Inner Regional	3353 (28.9%)	8979 (27.6%)	340 (30.8%)	11,992 (27.9%)	12,332 (28.0%)
Outer Regional/Remote	905 (7.8%)	1960 (6.0%)	79 (7.2%)	2786 (6.5%)	2865 (6.5%)
<i>Socio-economic Index for Area of Residence</i>					
Quintile 1 (lowest)	1101 (9.5%)‡	2690 (8.3%)	98 (8.9%)	3693 (8.6%)	3791 (8.6%)
Quintile 2	1548 (13.3%)	4179 (12.9%)	150 (13.6%)	5577 (13.0%)	5727 (13.0%)
Quintile 3	2544 (21.9%)	6884 (21.2%)	225 (20.4%)	9203 (21.4%)	9428 (21.4%)
Quintile 4	3258 (28.1%)	9321 (28.7%)	340 (30.8%)	12,239 (28.5%)	12,579 (28.6%)
Quintile 5 (highest)	3160 (27.2%)	9367 (28.9%)	291 (26.4%)	12,236 (28.5%)	12,527 (28.4%)
<i>Work factors</i>					
<i>Occupation</i>					
Ambulance officers and paramedics	3023 (26.0%)‡	8977 (27.6%)	271 (24.5%)†	11,729 (27.2%)	12,000 (27.2%)
Police officers	5930 (50.9%)	17,188 (52.9%)	562 (50.9%)	22,556 (52.4%)	23,118 (52.4%)
Firefighters	2689 (23.1%)	6357 (19.6%)	272 (24.6%)	8774 (20.4%)	9046 (20.5%)
<i>Injury/disease factors</i>					
<i>Cause</i>					
Falls, slips and trips	1738 (14.9%)‡	4894 (15.1%)	149 (13.5%)‡	6483 (15.1%)	6632 (15.0%)
Hitting object	405 (3.5%)	1108 (3.4%)	34 (3.1%)	1479 (3.4%)	1513 (3.4%)
Being hit by moving object	1361 (11.7%)	3372 (10.4%)	104 (9.4%)	4629 (10.8%)	4733 (10.7%)
Sound and pressure	181 (1.6%)	444 (1.4%)	11 (1.0%)	614 (1.4%)	625 (1.4%)
Body stressing	4553 (39.1%)	13,913 (42.8%)	434 (39.3%)	18,032 (41.9%)	18,466 (41.8%)
Heat, radiation and electricity	189 (1.6%)	200 (0.6%)	26 (2.4%)	363 (0.8%)	389 (0.9%)
Chemicals and substances	338 (2.9%)	797 (2.5%)	29 (2.6%)	1106 (2.6%)	1135 (2.6%)
Biological	266 (2.3%)	949 (2.9%)	16 (1.5%)	1199 (2.8%)	1215 (2.8%)
Mental	1849 (15.9%)	5029 (15.5%)	253 (22.9%)	6625 (15.4%)	6878 (15.6%)
Other	762 (6.6%)	1816 (5.6%)	49 (4.4%)	2529 (5.9%)	2578 (5.8%)
<i>Injury/disease type^</i>					
Intracranial Injuries	64 (0.6%)‡	169 (0.5%)	14 (1.3%)‡	219 (0.5%)	233 (0.5%)
Fractures	389 (3.3%)	1055 (3.2%)	37 (3.4%)	1407 (3.3%)	1444 (3.3%)
Wounds	1422 (12.2%)	3374 (10.4%)	108 (9.8%)	4688 (10.9%)	4796 (10.9%)
Burns	61 (0.5%)	119 (0.4%)	6 (0.5%)	174 (0.4%)	180 (0.4%)
Other injuries	556 (4.8%)	1164 (3.6%)	47 (4.3%)	1673 (3.9%)	1720 (3.9%)
Traumatic joint, ligament, muscle tendon	2047 (17.6%)	6181 (19.0%)	175 (15.8%)	8053 (18.7%)	8228 (18.6%)
Musculoskeletal system	4202 (36.1%)	12,663 (38.9%)	380 (34.4%)	16,485 (38.3%)	16,865 (38.2%)
Mental disorders	1984 (17.0%)	5308 (16.3%)	261 (23.6%)	7031 (16.3%)	7292 (16.5%)
Digestive system	102 (0.9%)	310 (0.9%)	14 (1.3%)	398 (0.9%)	412 (0.9%)
Skin and subcutaneous tissue	59 (0.5%)	123 (0.4%)	< 5 (< 0.5%)	<i>cell suppression</i>	182 (0.4%)
Nervous or sensory organs	242 (2.1%)	601 (1.9%)	20 (1.8%)	823 (1.9%)	843 (1.9%)
Respiratory system	50 (0.4%)	160 (0.5%)	8 (0.7%)	202 (0.5%)	210 (0.5%)
Circulatory system	38 (0.3%)	109 (0.3%)	< 5 (< 0.5%)	<i>cell suppression</i>	147 (0.3%)
Infections and parasites	51 (0.4%)	149 (0.5%)	11 (1.0%)	189 (0.4%)	200 (0.5%)
Neoplasm Cancer	100 (0.9%)	207 (0.6%)	11 (1.0%)	296 (0.7%)	307 (0.7%)
Continued					

Worker factors	Summer claims		Extreme bushfire period claims		All claims
	Summer	Spring, autumn, winter	Black Saturday or Black summer	All other time periods	
Other diseases	70 (0.6%)	147 (0.5%)	< 5 (< 0.5%)	<i>cell suppression</i>	217 (0.5%)
Other claims/missing	205 (1.8%)	683 (2.1%)	< 5 (< 0.5%)	<i>cell suppression</i>	888 (2.0%)
<i>Claim factors</i>					
Medical only claims	3481 (29.9%)†	9304 (28.6%)	280 (25.3%)†	12,505 (29.0%)	12,785 (29.0%)
<i>Claim type</i>					
Minor claim	4386 (37.7%)	11,972 (36.8%)	356 (32.2%)†	16,002 (37.2%)	16,358 (37.0%)
Standard claim	7256 (62.3%)	20,550 (63.2%)	749 (67.8%)	27,057 (62.8%)	27,806 (63.0%)

Table 1. Worker, work, injury/disease and claim related factors in all claims, claims that arose during summer and those that arose during extreme bushfire periods. ^Injury to nerves and spinal cord are grouped with other injuries due to small cells. *Cell suppression* is indicated where cells are suppressed not due to low cell counts, but to prevent low counts in other cells being re-calculated by subtraction from the total. † $p < 0.05$ or ‡ $p < 0.0001$ statistical difference between this group and all other claims in chi-square testing.

Discussion

In this retrospective analysis of workers' compensation claims in the Australian state of Victoria, emergency responders' claims that originated during the extreme bushfire periods known as Black Saturday (2009) or Black Summer (2019/20) were compared with all other claims; statistical comparisons accounted for seasonality (i.e. summer months, corresponding with heightened bushfire risk in Victoria). Extreme bushfire period claims were increased among older workers; injury/diseases were more likely to be caused by mental stressors and by heat/radiation/electricity. Intracranial injuries, infections and parasites, and mental disorders were increased in extreme bushfire period claims. In terms of the practical significance of the findings, mental disorders are of particular concern as these constituted a relatively large proportion of all claims (17%), whereas intracranial injuries and infections/parasites were relatively rare (0.5% each).

Front-line bushfire firefighters experience multiple physical hazards such as smoke exposure, intense heat, low oxygen, excess noise and long working hours with limited rest and suffer short- and long-term occupation-related health impacts after bushfire exposure⁷⁻⁹. Health impacts associated with bushfires include psychological disorders, injuries, and respiratory effects⁷⁻⁹. Using workers' compensation data, this is the first study on emergency responders to show injury/disease and workers' characteristics associated with periods of extreme bushfires. The associations between extreme bushfire periods and claim characteristics identified in this study were based on the reported dates of injury/disease onset, and it can't be confirmed that these claims were directly caused by extreme bushfires. Other challenges such as extreme weather, stress and anxiety in the community and possibly disorderly conduct in the general public may have contributed. In Australia and globally, extreme bushfires are expected to become increasingly frequent. Thus, future large, prospective cohort studies with long follow-ups and the use of wearable monitors for exposure tracking would be needed to assess the direct exposure to extreme bushfires and the effects of cumulative exposures among emergency responders.

Compared to regular bushfire seasons, claims due to mental illnesses and disorders were significantly more likely to arise in extreme bushfire periods. High overall levels of psychological distress have been previously reported in emergency responders^{21,22}; stressful events at work have been reported to have a stronger association with PTSD symptoms than stressful events that were not related to the emergency responders' work²³. Ecological grief (emotional response to climate-change losses) might have posed or amplified as a risk factor for mental disorders among emergency responders²⁴. In our study, the association between periods of extreme bushfires and mental health claims suggest that these events are an additional stressor for an occupational group that is already experiencing considerable psychological distress. The physical and psychosocial job demands during extreme bushfires, involvement with members of the public who may be in distress, heightened scrutiny by media and the public, and prolonged time away from usual support networks, including family, may all contribute to this. This association is a novel finding which can contribute to the development of preventive measures. Preparedness for extreme bushfires should include measures addressing pre-event factors, such as optimising worker mental health and education; during-event factors, such as safety strategies; and post-event factors, including psychological aftercare, both immediate and longer-term. An association between mindfulness and psychological health in Australian firefighters exposed to trauma has been demonstrated²⁵; as mindfulness can be trained, this can potentially serve as a tool to optimise pre-event mental health as well as response to during-event factors. Mental health first aid training for emergency responders may also help to bolster disaster preparedness and prevent adverse psychological health outcomes. An evaluation of the Stress First Aid model's impact on firefighters found that these trainings were well received; the study findings indicated that the program was successful in improving the perceived behavioural health response capability²⁶. Uptake of mental health services has been reported to be suboptimal for first responders, with less than half of those in need seeking treatment²⁷; in particular, reported uptake of in-house programs and services is low. In a survey of employed firefighters, among those with current probable PTSD, less than 10% had received mental health treatment in the last month²⁸; concerns about stigma were identified as reasons for not seeking treatment. To assist with screening for mental health issues and to promote mental health service seeking, telehealth could

	Univariate		Multivariable: Sociodemographic factors Occupation Injury/disease Claim type			Multivariable: Sociodemographic factors Occupation Cause/mechanism Claim type		
	OR	[95% CI]	OR	[95% CI]		OR	[95% CI]	
<i>Worker factors</i>								
<i>Age at injury</i>								
< 25 yrs	1.28	[0.94, 1.73]	1.14	[0.83, 1.56]	1.17	[0.86, 1.61]		
25–34 yrs	1.13	[0.95, 1.33]	1.12	[0.94, 1.33]	1.13	[0.95, 1.35]		
35–44 yrs	1 [REF]		1 [REF]		1 [REF]			
45–54 yrs	1.11	[0.94, 1.30]	1.10	[0.93, 1.29]	1.09	[0.92, 1.29]		
≥ 55 yrs	1.60	[1.32, 1.92]*	1.58	[1.30, 1.93]*	1.58	[1.30, 1.92]*		
<i>Sex</i>								
Male	1 [REF]		1 [REF]		1 [REF]			
Female	1.00	[0.87, 1.14]	1.09	[0.94, 1.27]	1.08	[0.93, 1.26]		
<i>Regionality</i>								
Major Cities	1 [REF]		1 [REF]		1 [REF]			
Inner Regional	1.17	[1.03, 1.34]*	1.14	[0.98, 1.32]	1.14	[0.99, 1.33]		
Outer Regional/Remote	1.18	[0.93, 1.49]	1.03	[0.79, 1.34]	1.03	[0.79, 1.35]		
<i>Socio-economic Index for Area</i>								
Quintile 1	1.13	[0.89, 1.42]	0.94	[0.73, 1.21]	0.94	[0.72, 1.21]		
Quintile 2	1.14	[0.93, 1.39]	1.00	[0.80, 1.25]	1.00	[0.80, 1.25]		
Quintile 3	1.03	[0.87, 1.23]	0.94	[0.79, 1.14]	0.95	[0.79, 1.14]		
Quintile 4	1.18	[1.00, 1.38]	1.15	[0.98, 1.36]	1.14	[0.97, 1.34]		
Quintile 5	1 [REF]		1 [REF]		1 [REF]			
<i>Work factors</i>								
<i>Occupation</i>								
Ambulance officers and paramedics	0.93	[0.81, 1.08]	0.91	[0.78, 1.07]	0.92	[0.78, 1.08]		
Police officers	1 [REF]		1 [REF]		1 [REF]			
Firefighters	1.25	[1.08, 1.45]*	1.19	[1.01, 1.40]*	1.19	[1.02, 1.40]*		
<i>Injury/disease factors</i>								
<i>Reported season of onset</i>								
Summer	8.97	[7.81, 10.29]*	8.94	[7.79, 10.26]*	8.92	[7.77, 10.24]*		
Autumn, winter, spring	1 [REF]		1 [REF]		1 [REF]			
<i>Cause^</i>								
Falls, slips and trips	1 [REF]				1 [REF]			
Hitting object	0.98	[0.67, 1.43]			1.04	[0.71, 1.53]		
Being hit by moving object	0.98	[0.76, 1.26]			1.00	[0.77, 1.30]		
Sound and pressure	0.82	[0.45, 1.49]			0.68	[0.36, 1.28]		
Body stressing	1.04	[0.86, 1.26]			1.15	[0.95, 1.40]		
Heat, radiation and electricity	3.17	[2.07, 4.86]*			1.95	[1.26, 3.03]*		
Chemicals and substances	1.16	[0.78, 1.73]			1.05	[0.70, 1.58]		
Biological	0.60	[0.36, 0.99]			0.72	[0.43, 1.21]		
Mental	1.66	[1.35, 2.04]*			1.65	[1.32, 2.05]*		
Other	0.85	[0.62, 1.18]			0.79	[0.57, 1.10]		
<i>Injury/disease type^</i>								
Intracranial Injuries	2.87	[1.63, 5.06]*	3.04	[1.69, 5.48]*				
Fractures	1.13	[0.77, 1.66]	1.17	[0.79, 1.73]				
Wounds	1 [REF]		1 [REF]					
Burns	1.62	[0.72, 3.63]	1.33	[0.58, 3.03]				
Other injuries	1.24	[0.87, 1.75]	1.15	[0.81, 1.63]				
Traumatic joint, ligament, muscle tendon	0.95	[0.74, 1.21]	1.04	[0.81, 1.33]				
Musculoskeletal system	1.01	[0.81, 1.25]	1.09	[0.87, 1.37]				
Mental disorders	1.62	[1.29, 2.04]*	1.61	[1.25, 2.07]*				
Digestive system	1.58	[0.91, 2.77]	1.60	[0.89, 2.85]				
Skin and subcutaneous tissue	0.85	[0.29, 2.51]	0.76	[0.26, 2.27]				
Nervous or sensory organs	1.09	[0.67, 1.75]	0.97	[0.59, 1.60]				
Continued								

	Univariate		Multivariable: Sociodemographic factors Occupation Injury/disease Claim type			Multivariable: Sociodemographic factors Cause/mechanism Claim type		
	OR	[95% CI]	OR	[95% CI]		OR	[95% CI]	
Respiratory system	1.83	[0.89, 3.73]	1.97	[0.94, 4.11]				
Circulatory system	0.75	[0.21, 2.66]	0.68	[0.19, 2.45]				
Infections and parasites	2.65	[1.42, 4.96]*	3.11	[1.61, 5.98]*				
Neoplasm Cancer	1.69	[0.91, 3.15]	1.12	[0.58, 2.16]				
Other diseases	0.92	[0.35, 2.38]	0.80	[0.30, 2.09]				
Other claims/missing	0.22	[0.09, 0.57]*	0.25	[0.10, 0.63]*				
<i>Claim factors</i>								
Medical only claims	0.83	[0.72, 0.95]*	0.86	[0.74, 1.01]	0.88	[0.76, 1.03]		
<i>Claim type</i>								
Minor claim	0.80	[0.70, 0.91]*	0.94	[0.81, 1.09]	0.91	[0.78, 1.05]		
Standard claim	1 [REF]		1 [REF]		1 [REF]			

Table 2. Modelling of emergency responder claims for injury/diseases that arose during periods of extreme bushfires vs. all other claims. ^Cause and injury/disease type are entered into separate models to prevent multicollinearity, OR; Odds ratio, 95% CI; 95% confidence interval, *, $p < 0.05$ or $p < 0.0001$ (Statistically significant).

provide a means to increase uptake and improve access to services in first responders²⁹. A stepped telehealth care approach could be developed and included in post-event measures.

Workers' compensation claims by older workers were associated with extreme bushfire periods. A number of factors may have contributed to this, ranging from older workers' potentially increased participation in emergency response as resources are stretched during extreme bushfire periods; longer shifts; increased injury/disease susceptibility in older workers; or a greater likelihood for injury or disease to result in a workers' compensation claim. We cannot determine if older workers had greater exposure during these periods or whether their injury/diseases were more likely to result in significant health care costs or work absence, therefore increasing the likelihood of a claim. In the Victorian working population overall, workers' compensation claim rates (per hours worked in each age group) have been reported to increase with age, reaching a maximum rate in workers aged in their early 60s³⁰. Nationally, the workforce is ageing: in the mid-1990s, workers aged 50–64 years accounted for 11% of employed persons; in 2023, this percentage had increased to 21%³¹. The increase in older workers' claims observed during extreme bushfire periods is, therefore, a growing concern. Older workers are more likely to have chronic health conditions, which may put them at higher risk of work-related injury and disease. Additionally, older emergency responders may have been exposed to multiple extreme bushfires, which could have a cumulative effect on their health. To address this, preparedness for extreme bushfires could include tailored prevention measures for emergency responders aged 55 years and above. This could be achieved through pre-deployment medical assessment for older emergency responders, as well as improved periodic physical and mental health surveillance at work. The latter could be offered as a virtual tool to further lower barriers to participation²⁹.

The strengths of this study are its sample size, population-based design, specificity in terms of exposure time periods (comparing to other time periods and adjusting for seasonality), and selection of relevant occupational groups. The occupational group is not captured in health data such as hospital admissions and most other clinical datasets: workers' compensation data provide unique insights into work-related health impacts but are under-utilised in investigating health effects among high-risk occupational groups.

This study also has limitations that need to be acknowledged. The research was based on workers' compensation claims; while not every occupational health issue results in a claim, this applies to mental health issues in particular. From previous research, we know that 18–23% of surveyed emergency services workers reported having a current diagnosis of a mental health condition²². It has also been reported that the most common stressors in these occupational groups (ambulance, fire and rescue, police and emergency services employees) were exposure to traumatic events while working²³. Overall, 14% of surveyed emergency services workers lodged a workers' compensation claim in relation to a mental health condition³². The results presented in our study could be an underestimate of the incidence of work-related mental health issues in this group; however, there is no evidence to suggest that the associations presented in the modelling, i.e. the internal consistency of the data, is affected by under-claiming.

Volunteer firefighters are covered by a volunteer firefighter compensation scheme, but these data were not routinely captured in the Victorian workers' compensation data provided for this research. Therefore, the results of this study are related only to paid emergency services workers, while volunteer firefighters may have different health experiences. It should be noted that the volunteer firefighter workforce in Australia is large, with an estimated 0.8% of the population volunteering with a bushfire service; considering only rural populations, this proportion reaches 4.5%³³. Victoria alone has 52,992 listed Country Fire Authority volunteers. Volunteer

firefighters typically serve on a part-time basis and often have other primary occupations, while professional firefighters are more likely to serve full-time and respond to a higher volume and variety of emergency situations. It is therefore expected that the health impacts of extreme bushfires differ between the two groups. To better understand these differences, a study of volunteer firefighters' workers compensation claims in relation to extreme bushfire periods is recommended.

Since this is a retrospective analysis based on exposure dates determined from the injury/disease onset dates in the workers' compensation claim, this may not indicate direct exposure to the Black Saturday or Black Summer bushfires, as geocoding of the place of exposure and exact time of day was not available. The absence of geocoding and occupational exposure data will introduce 'noise' in the analysis: we cannot ascertain whether the person who made the claim was involved in the extreme bushfire event at the time of injury. Unmeasured confounding factors such as previous injury/disease occurrences, extreme weather-induced behaviour change, job stress, spikes in working hours during extreme bushfires may have influenced increases in injury/disease claims. Late-onset illness resulting from extreme bushfire exposure may have been missed if the onset dates recorded in the claim are outside of the extreme bushfire occurrence dates. However, as the study was conducted state-wide at a population level, the overall association is likely to be related to the extreme bushfires, given the occupational sectors selected for this analysis. The additional 'noise' picked up using this methodology implies that the study does not have a high sensitivity in identifying associations and therefore, the presented statistically significant findings are robust.

A final study limitation that should be noted is the coinciding of the aftermath of the 2019 Black Summer bushfires and the onset of the COVID-19 pandemic in Victoria. The pandemic had a profound effect on health service utilisation in Victoria³⁴, and therefore, the uptake of health services in 2020 following the Black Summer bushfires may have been affected. However, the analysis in this study used injury/disease onset dates in November 2019–February 2020 as markers for the second of the two extreme bushfire periods. This method is unlikely to be directly affected by the pandemic, which did not take hold in Victoria until after February 2020. However, a slight under-estimate of work-related injury/disease associated with this time period is conceivable: service use may have been impacted by COVID in the months following the bushfire exposure, and therefore, injured workers may have been less likely to reach the medical expense threshold to qualify for claiming compensation. The results presented here can, therefore, be considered robust, while the underlying associations may have been underestimated.

Conclusions

This study showed that during periods of extreme bushfires in Victoria, among emergency responders, older workers were disproportionately impacted, as evidenced from injury and disease workers' compensation claim rates. During periods of extreme bushfires (compared with regular bushfire periods), workers' compensation claims were more common for mental disorders, intracranial injuries and respiratory diseases: mental disorders are of particular practical concern as these were much more common than the two latter groups. We can expect the occurrence of extreme bushfires to increase around the world, and in the context of an ageing workforce in Australia and many other countries, these findings emphasise the importance of primary and secondary prevention in the emergency services workforce. This can include free health assessments for older workers as well as providing access to early treatment and ongoing support for mental health conditions.

Data availability

Availability of data and materials The claims data on which this study is based cannot be made available by the researchers but compensation claims data can be requested directly from the data custodians, WorkSafe Victoria, through their data request processes. Conditions apply, including ethical approval. <https://www.worksafe.vic.gov.au/research-worksafe>.

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References

1. Australian Institute for Disaster Resilience. Bushfires - Black Saturday: Australian Government - National Emergency Management Agency. [15 February 2024]. (2014). <https://knowledge.aidr.org.au/resources/bushfire-black-saturday-victoria-2009/>
2. Australian Institute for Disaster Resilience. Bushfires - Black Summer: Australian Government - National Emergency Management Agency. [15 February 2024]. (2020). <https://knowledge.aidr.org.au/resources/black-summer-bushfires-vic-2019-20/>
3. Parliament of Australia. -20 Australian bushfires - frequently asked questions: a quick guide: Parliamentary library; [4 April 2024]. (2019). https://parlinfo.aph.gov.au/parlInfo/download/library/prspub/7234762/upload_binary/7234762.pdf
4. Abram, N. J. et al. Connections of climate change and variability to large and extreme forest fires in southeast Australia. *Commun. Earth Environ.* **2** (1), 8 (2021).
5. Cunningham, C. X., Williamson, G. J. & Bowman, D. M. Increasing frequency and intensity of the most extreme wildfires on Earth. *Nat. Ecol. Evol.* :1–6. (2024).
6. Climate Council of Australia. BE PREPARED: CLIMATE CHANGE AND THE AUSTRALIAN BUSHFIRE THREAT. [(2013). <https://www.climatecouncil.org.au/uploads/c597d19c0ab18366cfb7b9f6235ef7c.pdf>
7. Koopmans, E., Cornish, K., Fyfe, T. M., Bailey, K. & Pelletier, C. A. Health risks and mitigation strategies from occupational exposure to wildland fire: a scoping review. *J. Occup. Med. Toxicol.* **17** (1), 2 (2022).
8. Groot, E., Caturay, A., Khan, Y. & Copes, R. A systematic review of the Health impacts of Occupational exposure to Wildland fires. *Int. J. Occup. Med. Env.* **32** (2), 121–140 (2019).
9. Navarro, K. Working in smoke: wildfire impacts on the Health of firefighters and Outdoor workers and Mitigation Strategies. *Clin. Chest Med.* **41** (4), 763– (2020).
10. McNamara, M. L. et al. Base Camp Personnel exposure to Particulate Matter during Wildland Fire suppression activities. *J. Occup. Environ. Hyg.* **9** (3), 149–156 (2012).

11. Main, L. C. et al. Firefighter's Acute Inflammatory response to Wildfire suppression. *J. Occup. Environ. Med.* **62** (2), 145–148 (2020).
12. Smith, E., Holmes, L., Larkin, B., Mills, B. & Dobson, M. Supporting Volunteer Firefighter Well-Being: lessons from the Australian Black Summer bushfires. *Prehospital Disaster.* **37** (2), 273–276 (2022).
13. Lawrence, D. et al. *After the Fires: The Impacts of the 2019-20 Black Summer Bushfires on the Wellbeing of Emergency Services Personnel* (Graduate School of Education, The University of Western Australia, 2021).
14. WorkSafe Victoria. 2.5.6 Claims by certain types of workers: Victoria State Government; [https://www1.worksafe.vic.gov.au/vwa/claimsmanual/Claims_Manual/2-claims-management/2-5-6-claims-by-certain-types-of-workers.htm]
15. Roberts, M. H., Sim, M. R., Black, O. & Smith, P. Occupational injury risk among ambulance officers and paramedics compared with other healthcare workers in Victoria, Australia: analysis of workers' compensation claims from 2003 to 2012. *Occup. Environ. Med.* **72** (7), 489–495 (2015).
16. Xia, T. & Collie, A. Work-related injury and illness in the Victorian healthcare sector: a retrospective analysis of workers' compensation claim records. *Aust Health Rev.* **44** (1), 24–30 (2020).
17. Australian Bureau of Statistics. Australian Statistical Geography Standard (ASGS). Volume 5 - Remoteness Structure 2016 [30 November 2023]. <https://www.abs.gov.au/AUSSTATS/abs@.nsf/DetailsPage/1270.0.55.005July%202016?OpenDocument>
18. Australian Bureau of Statistics. Census of Population and Housing: Socio-Economic Indexes for Areas (SEIFA), Australia 2016 [30 November 2023]. <https://www.abs.gov.au/AUSSTATS/abs@.nsf/DetailsPage/2033.0.55.0012016?OpenDocument#Data>
19. Safe Work Australia. Type of Occurrence Classification System (TOOCS) 3rd Edition 2022 [30 November 2023]. <https://data.safeworkaustralia.gov.au/about-our-datasets/type-occurrence-classification-system-toocs-3rd-edition>
20. Firth, D. Bias reduction of maximum likelihood estimates. *Biometrika.* **80** (1), 27–38 (1993).
21. Beyond Blue. *A Summary of the Three Phases of Beyond Blue's Research Examining Mental Health and Wellbeing in Australia's Police and Emergency Services Sector* (Beyond Blue, 2020).
22. Kyron, M. J. et al. Mental health and wellbeing of Australian police and emergency services employees. *Arch. Environ. Occup. H.* **77** (4), 282–292 (2022).
23. Kyron, M. J., Rikkers, W., LaMontagne, A., Bartlett, J. & Lawrence, D. Work-related and Nonwork stressors, PTSD, and psychological distress: prevalence and attributable Burden among Australian police and emergency services employees. *Psychol. Trauma-U.S.* **14** (7), 1124–1133 (2022).
24. Comtesse, H., Ertl, V., Hengst, S. M. C., Rosner, R. & Smid, G. E. Ecological grief as a response to environmental change: a Mental Health risk or functional response? *Int. J. Environ. Res. Public Health* ; **18**(2). (2021).
25. Counson, I. et al. Mental health and mindfulness amongst Australian fire fighters. *Bmc Psychol.* ; **7**(1). (2019).
26. Jahnke, S. A. et al. Evaluation of the implementation of the NFFF Stress First Aid Intervention in Career Fire departments: a Cluster Randomized Controlled Trial. *Int. J. Environ. Res. Public Health* ; **20**(22). (2023).
27. Rikkers, W. & Lawrence, D. Mental health help-seeking experiences and service use among Australian first responders. *Aust J. Psychol.* **73** (2), 125–133 (2021).
28. Kim, J. E. et al. Firefighters, posttraumatic stress disorder, and barriers to treatment: results from a nationwide total population survey. *PLoS One.* **13** (1), e0190630 (2018).
29. Wright, H. M. et al. Preventative Care in First Responder Mental Health: Focusing on Access and Utilization Stepped Telehealth Care. *Front. Health Serv.* **2**, (2022).
30. Berecki-Gisolf, J., Clay, F. J., Collie, A. & McClure, R. J. The impact of aging on work disability and return to work: insights from workers' compensation claim records. *J. Occup. Environ. Med.* **54** (3), 318–327 (2012).
31. Australian Bureau of Statistics. Labour Force, Australia, Detailed Canberra: ABS. [2 February 2024]. (2023). <https://www.abs.gov.au/statistics/labour/employment-and-unemployment/labour-force-australia-detailed/latest-release>
32. Kyron, M. J., Rikkers, W., O'Brien, P., Bartlett, J. & Lawrence, D. Experiences of police and emergency services employees with workers' compensation claims for Mental Health issues. *J. Occup. Rehabil.* **31** (1), 197–206 (2021).
33. Cull, M. *Value beyond money: Australia's special dependence on volunteer firefighters* (The Conversation, 2020).
34. Podubinski, T., Townsin, L., Thompson, S. C., Tynan, A. & Argus, G. Experience of Healthcare Access in Australia during the First Year of the COVID-19 Pandemic. *Int. J. Env Res. Pub He* **18**(20), (2021).

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Author contributions

JBG. conceptualisation, data curation, analysis, interpretation, writing—original draft WW, MRS, DCG, RFH, TD, AC, KWB. writing—review and editing JBG. responsible for the overall content as the guarantor.

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Declarations

Competing interests

The authors declare no competing interests.

Ethics approval and consent to participate

The research was performed in accordance with the Declaration of Helsinki. This study was approved by the Monash University Human Research Ethics Committee, Project ID 39,153. The need for informed individual consent was waived by the Monash University Human Research Ethics Committee; only de-identified data were used, and results were reported in a non-re-identifiable format.

Additional information

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