

Review

Exposure to Wildfires Exposures and Mental Health Problems among Firefighters: A Systematic Review

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Abstract: Firefighters are severely impacted by climate events, yet they are an underexamined population with regard to climate change research. This systematic review aims to synthesize the existing literature on the psychological effects of wildfire events on firefighters and to discuss some of the major gaps in disaster research relating to first responders and their mental health. A thorough search of the existing literature through June 2023 on the topic of wildfires and first responder psychological health was conducted through the databases PubMed, PsychINFO, and Embase. This search yielded 13 final studies which met the exclusion and inclusion criteria for this review. The final studies consisted of populations that responded to wildfire events from four different countries (two from Israel, one from Canada, two from Greece, and eight from Australia). The data gathered by this review suggest that firefighters may experience many environmental and occupational exposures during wildfire suppression, which are linked to an increased risk of PTSD and other psychological symptoms even months after the event. This review brings to light the need for further research of the compounded effect of the environmental and psychological exposures of first responders and the potential psychological effects of those exposures.

Keywords: wildfires; mental health; firefighters; PTSD; climate change



Citation: Bonita, I.; Halabicky, O.M.; Liu, J. Exposure to Wildfires Exposures and Mental Health Problems among Firefighters: A Systematic Review. *Atmosphere* **2024**, *15*, 78. <https://doi.org/10.3390/atmos15010078>

Academic Editor: Elisabete Carolino

Received: 13 November 2023

Revised: 20 December 2023

Accepted: 29 December 2023

Published: 8 January 2024



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1. Introduction

The fire service in the United States is essential, composed of emergency medical service workers who provide critical services such as fire suppression, technical rescues, and prehospital medical care to promote the safety and well-being of the community [1]. Recently, fire departments in the United States (US) have struggled to retain their service members. Between 2019 and 2020, the fire service experienced a 4% decrease in the workforce [1]. Volunteer firefighters, who make up 65% of the fire service, experienced the greatest losses in the US fire service [1]. These historic lows can be attributed to a host of different reasons such as low pay, poor working conditions, and disappointing career opportunities [2]. In 2020, amidst challenges to staffing departments across the country, firefighters in the US continued to respond alongside emergency health services to care for COVID-19 patients during the height of the pandemic. This resulted in severe negative impacts on the workforce. Prior to the pandemic, an estimated 50% of the force had already experienced some form of burnout [3].

In comparison to the 1,041,200 fire and EMS workers that make up the structural fire service, 20,000 firefighters in the US are wildland firefighters [1,4]. Their work is directly impacted by climate change, which is predicted to rapidly progress in the coming years. Climate change is one of the greatest threats to humanity as it will continue to accelerate waterborne diseases, the severity of heat stress, and the further exacerbation of health inequalities [5]. Climate change has also resulted in more arid, warm, and drier conditions,

which has led to longer, more intense wildfire seasons [6]. In fact, climate change-induced conditions have been shown to have significant effects on wildfires in the last few decades; one study found that these conditions contributed to the doubling of the forest fire area burned between 1984 and 2015 [7].

These fires have serious consequences on wildlife, human life, and the environment. One of the underappreciated effects of climate change on human health is its effects on mental health. Events like wildfires can be traumatic for both the residents of affected areas and those who are responding to them. Globally, posttraumatic stress disorder (PTSD), which is characterized by multiple prolonged mental symptoms after witnessing or experiencing a traumatic event or series of experiences, is an increasing concern for those who have been affected by climate events [8]. Individuals suffering from PTSD may experience nightmares, sleep disturbances, flashbacks of the stressful experience, depression, and anger, and in some cases, individuals may feel intense negative reactions to reminders of the event [8]. Around 1 in 11 people will be diagnosed with PTSD at some point during their lifetime [8], although populations like firefighters are particularly vulnerable to mental health disorders due to their increased level of exposure to traumatic events such as wildfires, especially within the months after an intense wildfire event [9].

Firefighters who respond to wildfire incidents, mainly wildland firefighters, may be more vulnerable to the psychological impacts of their work [4]. Recent research suggests that wildland firefighters report having a greater suicide risk than other types of firefighters [10]. One study found that 55% of 'clinically significant suicidal symptoms' were from wildland firefighters, in comparison to 32% of the reports being from other firefighters [10]. Overall, the data on workers in the fire service and their mental health are limited, and even less research has been devoted to the psychological impacts of the work of wildland firefighters. This review supports the call for further research examining the current state of mental health in the fire service and the risks that subgroups of the service experience [10].

As the prevalence and intensity of wildfires increase globally, firefighters will experience greater and potentially more extreme exposures to serious wildfire events. It is increasingly important to understand how the environmental and psychological exposures faced by firefighters and other first responders affect both their daily life and their long-term health.

This review has two aims: (1) to synthesize the current literature examining the effect of wildfire experiences on first responders' (i.e., firefighters') mental health symptoms and diagnoses; and (2) to report the major gaps that exist in disaster research with regard to first responders and psychological health. To our knowledge, there has not been a review that has focused on the mental health outcomes of firefighters responding to specific wildfire events.

2. Methods

This systematic review was conducted in accordance with the PRISMA Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines [11].

2.1. Search Strategy

Multiple thorough literature searches were conducted utilizing keywords in 3 databases: PubMed, PsychINFO, and Embase. All relevant articles published through June 2023 were evaluated based on inclusion and exclusion criteria. Various key terms relating to wildfires, mental health, and firefighters were used to search for articles in these databases. Keywords included 'firefight', 'psychological stress', 'social stress', 'posttraumatic stress', 'acute stress disorder', 'chronic stress', and 'stress reaction'. The search strategy is available in Appendix A.

2.2. Screening Strategy

After a thorough literature search, the relevant papers identified were electronically retrieved and screened for eligibility. Duplicate studies were removed via the electronic

platform Covidence, and the initial title and abstract screening was conducted. The final study selection was determined by a full-text screening of the remaining studies, and the references of those articles were also searched for other relevant studies against the inclusion and exclusion criteria.

2.3. Inclusion and Exclusion Criteria

After the literature search, studies were screened against inclusion and exclusion criteria, which included an initial screening by title and abstract and finally by full text. To be included in this review, studies had to be observational or longitudinal cohort studies of human populations. Due to the unpredictable nature of the environment produced by wildfires, the only required measured exposure for this review was experiencing a wildfire event as a first responder. Studies that included wildfires as well as other exposures such as noise, smoke, heat, PM_{2.5}, and others such as potentially traumatizing imagery or experiences were also included. Finally, all mental health outcomes were included in this review, including measures such as PTSD and symptoms relating to posttraumatic stress, sleep disturbances, anxiety disorders or symptoms, depression, substance abuse, and other symptoms relating to mental health. Studies that measured mental health outcomes after a wildfire event alongside other outcomes such as respiratory symptoms and coping mechanisms were included in this review. Other reviews, meta-analyses, case studies, and commentaries were excluded from this review. Papers examining populations of wildland firefighters that participated in the wildfire suppression but did not have direct, on-ground exposure of the wildfires, such as aerial firefighters, were not included in this review. There were no limitations for geographical location, race, age, gender, or other demographic controls such as marital status, preexisting health conditions, education, or income level.

2.4. Data Extraction and Quality Assessment

Extracted data included the wildfire event and location, population demographics, and mental health outcomes assessed. Each study was evaluated for qualitative/quantitative major findings. These results were divided by country and further by wildfire event, of which there were multiple studies examining the same wildfire event. A quality assessment was conducted in accordance with the BMJ Best Practice GRADE criteria for evaluating evidence, as there was heterogeneity in the reported outcomes in each included study. The studies were rated as very low, low, moderate, or high certainty against certain criteria. The criteria of the quality assessment were guided by the quality of the evidence of each study. A study that matched the criteria for 'very low' indicates that the exposure or intervention that the study investigated was more likely to have a very different true effect than from what the results may have shown in the study. A study that received the 'high' grade indicates that the authors of the study demonstrated reasonable belief that the measured outcomes were close to the true effect. Criteria for downgrading the quality evaluation of a study would 'include risk of bias, imprecision, inconsistency, indirectness, and publication bias'. Criteria for increasing the quality grading included the study having a 'large magnitude of effect, a dose-response gradient, and lastly, that any confounding variables would be more likely to decrease the effect rather than increase it' [12].

Two reviewers evaluated the studies. If any disagreement occurred on the grading of the studies, the reviewers discussed and came to a consensus about the final grading. Studies were assessed first by country and next by wildfire event to make direct comparisons between outcomes of first responders within the same event if available.

3. Results

3.1. Search and Selection Results

The initial search resulted in 455 studies. After 55 duplicate articles were removed, 400 studies remained to be screened. After the title and abstract screening, 211 studies were screened through a full-text evaluation, applying the inclusion and exclusion criteria. The remaining 13 studies were included in the review. The most common reasons for

studies being excluded were (1) the study did not include a wildfire event; (2) mental health outcomes were not assessed; or (3) the study population did not comprise firefighters/first responders to a wildfire event. Further details of the search process can be found in Figure 1.

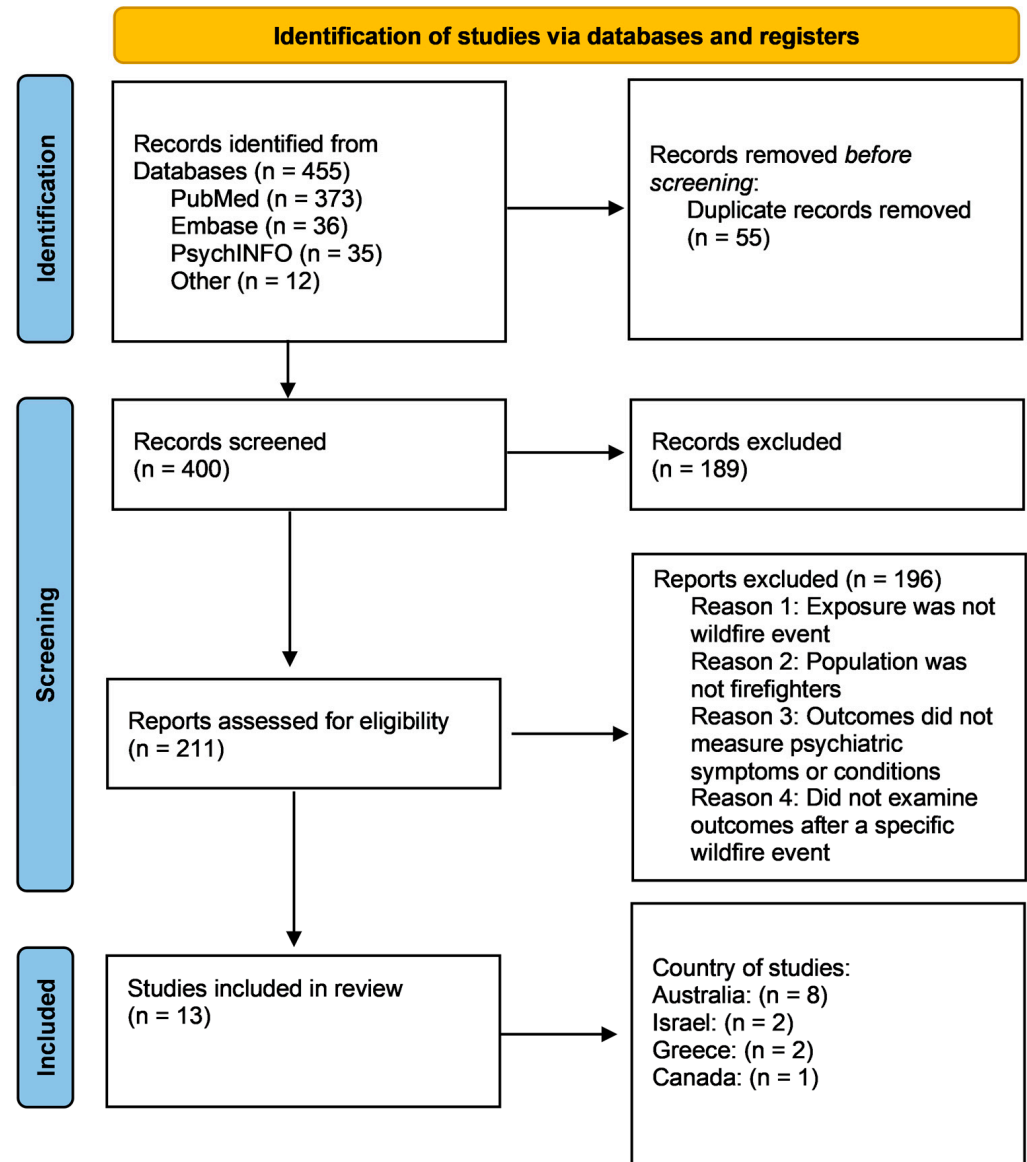


Figure 1. PRISMA flow diagram.

3.2. Quality Assessment

At the beginning of the quality assessment process, all the studies started with a ‘low’ grading. This is because, in accordance with the GRADE quality assessment criteria, studies that include observational data start at a ‘low’ grading and must meet criteria for ‘upgrading’ to receive a higher quality assessment. Out of the 13 observational studies that were included in this review, 8 of the studies were given a ‘very low’ grading, and the remaining 5 were given a ‘low’ grading [12].

The most common reason for downgrading the studies was risk of bias. For more information about the GRADE systematic review quality grading, view the ‘GRADE Series’ which includes more detailed guidance on following the BMJ Best Practice GRADE quality assessment [13]. For the specific gradings of each study in this review, see Table 1.

3.3. Study Characteristics

Of the 13 studies selected for this review, 6 papers utilized data from the same longitudinal cohort study. The included studies assessed populations from four different countries, including Australia ($n = 8$), Greece ($n = 2$), Israel ($n = 2$), and Canada ($n = 1$), who responded to five unique wildfire events. The ages of the participants in the studies ranged from 17 years old [14] to 46 years old [15]. Out of the 13 studies, 3 reported both male and female participants [9,15,16] while the other 10 studies solely studied male participants. Eight of the studies evaluated volunteer firefighters, one evaluated both volunteer and career firefighters [17], one included career only [18], and three were unspecified. Sample sizes ranged from 58 [15] to 998 participants [9], and researchers reported a mix of qualitative, descriptive, and predictive findings. The results below are presented first by country and then by wildfire event as these events were highly specific and occurred at different time periods.

3.4. Individual Wildfire Events and Study Findings

3.4.1. Israel

Two papers focused on firefighters responding to the Carmel Forest Fire [14,19]. In 2010, the Carmel Forest Fire, considered the deadliest wildfire event in Israel's history, burned nearly 12,250 hectares of land and killed 44 people, including 3 firefighters [14]. In a study of 65 Israeli firefighters from the same department, researchers evaluated firefighters one month after they responded to the Carmel Cohort Disaster [14]. Using the Posttraumatic Stress Diagnostic Scale (PDS) scale, researchers found that 12.3% of the participants qualified for probable PTSD. With the less 'conservative' PTSD criteria, 18.5% of the participants met the qualifications for having probable PTSD. The study also focused on the posttraumatic growth of the participants [14]. Posttraumatic growth is characterized as the positive mental growth that occurs after someone experiences extremely stressful life events [20]. Researchers reported no significant deviations of experiences of PTSD between participants of different family status, income, seniority, or education [14]. In the second study of the Carmel Cohort Disaster, researchers evaluated the psychological symptoms of 204 firefighters and police officers [19]. One year after the wildfire event, 25% of the firefighters reported experiencing at least one acute-stress symptom. Additionally, 10% of the firefighters reported experiencing continuous symptoms of trouble sleeping, recurring stressful dreams, and avoidance [19].

3.4.2. Canada

One paper examined the Fort McMurray Disaster, which started on 30 April and ended on 1 June 2016. These fires became the costliest natural disaster to date in Canadian history, burning 579,767 hectares of land, leveling over 2400 houses and other structures, and damaging hundreds more. Over 90,000 people were displaced during this time. The study aimed to estimate the prevalence of mental ill health in a cohort of 282 firefighters that responded to the 2016 Fort McMurray wildfires [9]. The study initially screened 998 respondents and ended with conducting 192 clinical interviews according to the DSM-5 (SCID) assessment. In the sample of 192 male and female respondents, 78 (40.6%) met diagnosis criteria for PTSD, another 59 (30.7%) for anxiety disorder, and 55 (28.5%) for a depressive disorder. Cohort prevalence estimates suggest that within the cohort, 21.4% would be diagnosed with PTSD, with a potential range of 15.7% to 29.1% [9]. Additionally, the estimated prevalence of anxiety disorders was from 11% to 22.5% and depressive disorders was from 9.9% to 20.8% [9].

3.4.3. Greece

Two studies focused on firefighters responding to the Greek Wildfires of 2007. In one study that evaluated 102 male firefighters one month after the wildfire event, 18.6% met criteria for PTSD under the ICD-10 criteria [18]. The researchers found that participants with coping styles more aligned with minimization and blame had greater odds of PTSD

while adjusting for confounders [18]. A second study evaluated the same cohort of male firefighters from the previous study [17]. Researchers reported that 23.5% of the participants experienced insomnia, and 10 of the 102 participants scored high on the depression SCL-90 scale [17]. Researchers reported that in addition to the 18.6% who met a diagnosis for PTSD, 23.5% met diagnostic criteria for insomnia. In multiple logistic regression analyses, those with a greater self-reported fear of dying, those with increased scores on the State-Trait Anxiety Inventory for neuroticism and depression, and those with insomnia had greater odds of being diagnosed with PTSD [17].

3.4.4. Australia

Eight papers focused on firefighters responding to both the summer 2019–2020 bushfires [15] and the 1983 Ash Wednesday wildfires (six from the same cohort and one additional) in Australia [16,21–26]. The Ash Wednesday Fires started on 16 February 1983, killing 75 people and burning more than 200,000 hectares of land [27,28]. A series of studies on 469 firefighters responding to the Ash Wednesday Fires evaluated the mental health effects of the disaster on firefighters. Using the 12-Question General Health Questionnaire and the Structured Interview (SCID) guided by the DSM-III guidelines for diagnosing PTSD, an initial study found that at 4, 11, and 29 months postwildfire event, 32%, 27%, and 30% of firefighters met diagnostic criteria for PTSD, with 35% of respondents meeting criteria at all three visits [25]. At 11 months, those with PTSD, compared to those without, had significantly greater fire exposure, hours fighting fires, perceived threat, and adverse recent life events [23]. Later studies identified three different types of PTSD in the cohort; in participants who responded at all three time points, 50.2% had no disorder, 9.2% acute PTSD, 21% chronic PTSD, and 19.7% delayed onset PTSD [21]. At 11 months postwildfire event, distress scores from the Inventory of Events (IES) accounted for only 14% of the variance of the GHQ-12 used for PTSD diagnosis [26]. Avoidance subscale scores on the IES at 4 and 8 months were significantly greater in the PTSD group compared to the non-PTSD group. A family history of psychiatric disorder had a nonsignificant trend difference between the PTSD and non-PTSD groups [24]. In longitudinal examinations, GHQ-12 scores at 4 months significantly predicted GHQ-12 scores at 11 and 29 months [22]. A final study of the cohort of firefighters responding to the Ash Wednesday Fires found that at 7 years after the wildfire event, 28% met diagnostic criteria for PTSD based on the GHQ-12. Adverse life experiences and intrusion measured via the IES significantly predicted GHQ-12 scores [16].

The single study in Australia examined firefighters responding to the summer 2019–2020 bushfires, also referred to as the ‘Black Summer’. The Black Summer wildfires comprised one of the worst bushfires in Australia’s history, killing and displacing nearly 3 billion animals, directly killing 33 people including 9 firefighters, and burning nearly 24 million hectares of land [15]. In a study of 58 male and female firefighters, nearly half ($n = 28$) of participants self-reported experiencing PTSD symptoms in the 12 months after the wildfires, while 8 of the participants who sought mental health help during that time were diagnosed with PTSD [15]. The final study investigated long-term PTSD symptoms and coping mechanisms in Australian Volunteer Firefighters. The study aimed to build upon the previous research of the McFarlane studies [21–26] and included participants from one of the original McFarlane studies [21] (Table 2). The study found that 28% of the participants ($n = 75$) exhibited PTSD-related symptoms 84 months after the disaster [16].

Table 1. GRADE quality assessment.

Author, Title	Reviewer 1	Reviewer 2	Consensus
Amster et al. (2018) [19], Occupational Exposures and Psychological Symptoms Among Firefighters and Police During a Major Wildfire: The Carmel Cohort Study.	Very low	Very low	Very low
Leykin et al. (2013) [14], Posttraumatic Symptoms and Posttraumatic Growth of Israeli Firefighters, at One Month following the Carmel Fire Disaster.	Very low	Very low	Very low
Cherry et al. (2021) [9], Prevalence of Mental Ill-Health in a Cohort of First Responders Attending the Fort McMurray Fire.	Low	Low	Low
Theleritis et al. (2020) [18], Coping and Its Relation to PTSD in Greek Firefighters.	Low	Low	Low
Psarros et al. (2018) [17], Personality characteristics and individual factors associated with PTSD in firefighters one month after extended wildfires.	Low	Low	Low
Doley et al. (2016) [16], An Investigation Into the Relationship Between Long-term Posttraumatic Stress Disorder Symptoms and Coping in Australian Volunteer Firefighters.	Low	Low	Low
McFarlane (1986) [25], Long-term psychiatric morbidity after a natural disaster.	Very low	Very low	Very low
McFarlane et al. (1987) [23], Life events and psychiatric disorder: the role of a natural disaster.	Very low	Very low	Very low
McFarlane et al. (1988) [21], The longitudinal course of posttraumatic morbidity. The range of outcomes and their predictors.	Very low	Very low	Very low
McFarlane et al. (1988) [24], The aetiology of posttraumatic stress disorders following a natural disaster.	Very low	Very low	Very low
McFarlane et al. (1988) [26], Relationship between psychiatric impairment and a natural disaster: the role of distress.	Very low	Very low	Very low
McFarlane (1989) [22], The aetiology of posttraumatic morbidity: Predisposing, precipitating, and perpetuating factors.	Very low	Very low	Very low
Smith et al. (2020) [15], Supporting Volunteer Firefighter Well-Being: Lessons from the Australian “Black Summer” Bushfires.	Low	Low	Very low

Table 2. Characteristics of included databased studies on wildfire exposures and mental health outcomes in firefighters, ordered by country.

Study	Location and Wildfire (Year of Event)	Population	Outcome Assessment Time	Mental Health Outcomes (Setting and Measures)	Major Findings
Amster et al. (2018) [19]	Israel, Carmel Forest Fire (2010)	n = 204 male (97%) firefighters and police. Mean age = 36.5 years.	~1 year	In-person interview: fatigue, stress-related symptoms, PTSD symptoms including difficulty sleeping, recurrent dreams, and avoidance.	Approximately one year after the wildfire event, 25% reported at least one acute stress-related symptom after the wildfire event. A total of 10% reported PTSD-related symptoms.
Leykin et al. (2013) [14]	Israel, Carmel Forest Fire (2010)	n = 65 males (59 firefighters, 6 police officers). Ages 17–59 years.	1 month	In-person interview: Posttraumatic Stress Diagnostic Scale (PDS); Impact of Event Scale—Revised (IES-R); Posttraumatic Growth—Short Form (PTGI_SF).	One month after the wildfire event, 12.3% and 18.5% of firefighters met criteria for PTSD and probable PTSD, respectively. The intrusion subscale mean score was significantly higher than the avoidance and hyperarousal subscales ($F(2, 128) = 20.57, p < 0.001$). The mean IES-R score was 15.60 (0–54) and was significantly different than zero ($t(64) = 8.52, p < 0.001$). Adjusting for gender; age/ethnicity; religion; marital status; highest education level; income level.
Cherry et al. (2021) [9]	Canada, Fort McMurray Fire (2016)	n = 998 (n = 895 male, n = 103 female) screened. n = 192 (n = 176 male, n = 16 female) assessed. Mean age of participants assessed = 38.1 years.	~4.5 years	Online questionnaires: PCL-5 screening for PTSD and the Hospital Anxiety and Depression Scale (HADS); subsample with clinically high scores were assessed through in-person structured clinical interview (SCID-5) and diagnosed via <i>Diagnostic and Statistical Manual for Mental Disorders</i> , fifth edition (DSM-5).	A total of 4.5 years after wildfire exposure, the most frequent diagnoses were PTSD (n = 78), anxiety disorder (n = 59), and depressive disorder (n = 55). The estimated prevalence within the cohort was 21.4% diagnosed with PTSD, 15.8% with an anxiety disorder, and 14.3% with a depressive disorder.
Theleritis et al. (2020) [18]	Greece, Greek Fires of Ilia (2007)	n = 102 male firefighters. Mean age = 40.0 years.	1 month	In-person interview: PTSD diagnosis (<i>ICD-10</i> research diagnostic criteria); fear of dying during exposure (self-reported Likert-style questionnaire); Coping Styles (AECOM-CSQ self-administered questionnaire); Anxiety Inventory; psychiatric diagnoses confirmed using Mini-International Neuropsychiatric Interview.	One month after the wildfire event, 18.6% of the sample was diagnosed with PTSD. Adjusting for covariates, the coping styles, minimization (OR 1.14; 95%CI 1.01, 1.28), and blame (OR 1.11; 95%CI 1.00, 1.24) were significantly associated with PTSD of those diagnosed. Adjusted for age, education level, family status, employment status, presence of a disease, experience from other disasters, and fear of death/dying.
Psarros et al. (2018) [17]	Greece, Greek Fires of Ilia (2007)	n = 102 male firefighters. Mean age = 40.0 years.	1 month	In-person interview: PTSD diagnosis (<i>ICD-10</i> research diagnostic criteria); fear of dying during exposure (self-reported Likert-style questionnaire); State-Trait Anxiety Inventory; psychopathology and depression (SCL-90); those scoring high on the SCL-90 were additionally screened with the Hamilton Depression Rating Scale; extraversion and neuroticism (modified short Greek Eysenck Personality Inventory (EPI)); Athens Insomnia Scale (AIS); psychiatric diagnoses confirmed using Mini-International Neuropsychiatric Interview.	One month after the wildfires, 18.6% were diagnosed with PTSD and 23.5% were diagnosed with insomnia. Of the 10 participants who scored high on the SCL-90, only 1 met criteria for major depressive disorder via the HDRS-17. Those with a greater self-reported fear of dying compared to no fear (OR 2.89 95%CI 1.04, 8.10), those with increased scores on the SCL-90 for neuroticism (OR 1.34 95%CI 1.02, 1.75) and depression (OR 1.20 95%CI 1.08, 1.34), and those with insomnia (OR 3.24 95%CI 1.10, 9.53) were more likely to have PTSD.

Table 2. Cont.

Study	Location and Wildfire (Year of Event)	Population	Outcome Assessment Time	Mental Health Outcomes (Setting and Measures)	Major Findings
Doley et al. (2016) [16]	Australia, Ash Wednesday Fires (1983)	n = 277 (n = 271 male, n = 6 female). Mean age = 42.2 years.	7 years	Mailed self-completed questionnaires: PTSD symptoms via the 12-Item General Health Questionnaire (GHQ-12); Impact of Events Scale (IES); Ways of Coping Questionnaire (WOQ); Life Events Inventory: The List of Threatening Experiences.	Seven years after the bushfire event, 28% of respondents met criteria for psychiatric impairment on the GHQ-12. When considering predictors of psychiatric impairment, adverse life events (B 0.408, $p < 0.001$) and intrusion measured via the IES (B 0.276, $p < 0.001$) were significant.
McFarlane. (1986) [25]	Australia, Ash Wednesday Fires (1983)	n = 469 firefighters. Mean age = 35.1 years.	4, 11, 29 months	In-person interview: PTSD symptoms assessed via the 12-item General Health Questionnaire (GHQ) at 4, 11, and 29 months after the event. Clinical interview conducted with subsample (n = 49) 8 months after the event.	The prevalence of PTSD diagnosis was 32%, 27%, and 30% at 4, 11, and 29 months, respectively. Between 4 and 11 months, there was a significant drop in identified cases ($z = 1.80$, $p < 0.05$) but not between 4 and 29 months ($z = 0.62$, $p > 0.05$). A total of 53% of those with PTSD at 4 months postevent were also diagnosed 29 months postevent. A total of 35% of respondents were found to have PTSD at all three occasions.
McFarlane et al. (1987) [23]	Australia, Ash Wednesday Fires (1983)	n = 469 firefighters. Mean age = 35.1 years.	4 and 11 months	In-person interview: At 4 months postevent, General Health Questionnaire (GHQ-12) and Inventory of Events (IES). At 11 months, GHQ-12.	GHQ-12 scores at 11 months postevent were significantly correlated with fire exposure ($p = 0.007$), perceived threat ($p = 0.004$), property loss ($p = 0.000$), recent life events ($p = 0.000$), and previous fires experienced ($p = 0.006$). A total of 30% of the sample was found to have PTSD disorder. Compared to those without a diagnosis, those with PTSD had significantly greater fire exposure ($t = -2.3$, $p = 0.02$), hours fighting fires ($t = -3.0$, $p = 0.003$), perceived threat ($t = -2.5$, $p = 0.01$), property loss ($t = -4.7$, $p = 0.000$), and recent life events ($t = -3.16$, $p = 0.000$). Adjusting for marital status; age; origin of birth; individual experience of disaster; extent of personal losses, both material and personal; personal history of psychiatric illness/treatment.
McFarlane et al. (1988) [21]	Australia, Ash Wednesday Fires (1983)	n = 469 firefighters. n = 315 final participants included. Mean age = 35.1 years.	4, 11, 29 months	In-person interview: At 4 months postevent, General Health Questionnaire (GHQ-12) and Inventory of Events (IES). At 11 months postevent, brief life events inventory, IES, and GHQ-12. At 29 months, brief life events, IES, GHQ-12, and Eysneek Personality Inventory (EPI).	Three types of PTSD were defined including delayed onset, acute, and chronic. Of the participants that responded at all three timepoints, 50.2% had no disorder, 9.2% had acute PTSD, 21% chronic, and 19.7% delayed onset (3.2% persistent, 5.4% 11 months only, and 11.1% 29 months only).

Table 2. Cont.

Study	Location and Wildfire (Year of Event)	Population	Outcome Assessment Time	Mental Health Outcomes (Setting and Measures)	Major Findings
McFarlane (1988) [26]	Australia, Ash Wednesday Fires (1983)	n = 355 firefighters. Mean age = 35.1 years. Matched controls for marital status, ethnic background, experience during the fire, and GHQ-12 scores at 11 months postevent.	11 months	In-person interview: At 11 months postevent, brief life events inventory, General Health Questionnaire (GHQ-12), and Inventory of Events (IES). N = 49 completed a structured clinical interview to validate PTSD detection via the GHQ-12.	At 11 months postevent, distress (IES scores) accounted for only 14% of variance of the GHQ-12 ($B = 0.32, p < 0.000$).
McFarlane (1988) [24]	Australia, Ash Wednesday Fires (1983)	n = 45 firefighters randomly selected from cohort with n = 11 meeting criteria for PTSD.	4 and 8 months	In-person interview: General Health Questionnaire (GHQ-12) and Inventory of Events (IES). Structured clinical interview.	Those with and without PTSD were not significantly different in their experience of the wildfire and losses, injury, exposure, or perceived threat. In a two-tailed <i>t</i> -test, IES avoidance subscales at 4 months ($t = 2.66, p \leq 0.01$) and GHQ scores at 4 ($t = 3.06, p \leq 0.01$) and 8 months ($t = 2.50, p \leq 0.05$) were significantly higher in the PTSD group. Having a family history of psychiatric disorders showed a nonsignificant trend difference between the PTSD and non-PTSD group ($\chi^2 = 2.82, p = 0.09$).
McFarlane. (1989) [22]	Australia, Ash Wednesday Fires (1983)	n = 395 (11 months) and 337 (29 months) firefighters. Mean age = 36.1 years.	4, 11, 29 months	In-person interview: At 4 months postevent, General Health Questionnaire (GHQ-12) and Inventory of Events (IES). At 11 months postevent, brief life events inventory, IES, and GHQ-12. At 29 months, brief life events, IES, GHQ-12, and Eysneck Personality Inventory (EPI).	The prevalence of PTSD diagnosis was 32%, 27%, and 30% at 4, 11, and 29 months, respectively, as previously reported. At 4 months, the GHQ-12 score was not significantly predicted by the posttraumatic distress as measured by the IES. Symptoms at 4 months significantly predicted GHQ-12 scores at 11 and 29 months. Adjusting for age and social class.
Smith et al. (2020) [15]	Australia, Black Summer Bushfires (2019–2020)	n = 58 male and female firefighters. Mean age = 46.	~1 year	Telephone or video individual interviews using semistructured script regarding self-experience; mental health and well-being impact of wildfires; help-seeking behaviors; organization support of mental health and well-being.	Within a year of the event, 28 respondents reported experiences of PTSD symptoms, 8 with a clinical diagnosis of PTSD. Thirty-two respondents reported not seeking mental health support in the following year since the event.

4. Discussion

To the best of our knowledge, a systematic review has yet to investigate the association between experiencing a wildfire event and mental health impacts on firefighters. Generally, the results from 13 studies published between the years of 1986 and 2022 describe increased levels of PTSD and other psychological symptoms in cohorts of firefighters after responding to wildfire events. These results are most applicable to men in the fire service, as most of the studies limited their participants to only males or included limited female firefighters. In addition, these results appeared to be long-lasting, with PTSD symptoms continuing years after experiencing a wildfire event. However, given the limited studies examining longitudinal diagnosis, further evidence is needed.

All the included studies reported an increased risk for PTSD diagnosis in firefighters who responded to wildfire events. These results did not appear to be country-specific, as multiple studies from multiple countries suggested the same increasing risk of PTSD. This is in line with other research on natural disasters, which suggests experiencing a traumatic event as a first responder increases risk for PTSD and mental health-related problems [29]. All but one of the included studies used up-to-date PTSD diagnostic criteria for structured clinical interviews to understand the burden of PTSD diagnoses within their respective cohorts.

This study evaluated self-reported experiences of the firefighters during the fires and the mental health support they received after the fires [15]. Part of their evaluation included gathering information on the number of participants that sought mental health care after the fires, and those who received a diagnosis [15]. This study did not use structured clinical interviews to newly diagnose or reevaluate diagnoses but instead relied on the self-reporting of diagnoses from participants who had previously sought mental health care [15]. Unfortunately, the lack of adequate help-seeking behavior on the behalf of firefighters is likely a contributor to underreported rates of PTSD. For example, while nearly half ($n = 28$) of participants in one included study reported experiencing posttraumatic stress symptoms during the year after the fires, more than half of the participants did not seek professional support during that time [15]. Of those 28 participants that sought support, not all of them received care from licensed clinicians who were able to provide diagnoses. Instead, some sought comfort from spiritual leaders or online peer support spaces. Without the researchers performing structured clinical interviews to diagnose these participants, the prevalence of PTSD within this cohort most likely went underreported.

Considering that the impacts of climate change are experienced by firefighters around the world, it will also be important to investigate the long-term impacts that these events will have on the workforce. Further monitoring of how the pandemic has impacted the first responder workforce will be crucial for the future of first responders in the US and globally.

4.1. Risk Factors

When considering the risk of developing a mental disorder, certain demographic risk factors may be relevant. Of the included studies which investigated risk factors amongst the participants, there were two significant risk factors that increased the likelihood of the participants developing psychological morbidities, including a history of mental illness and working as a firefighter on a temporary basis [17]. It is unclear why those who work as firefighters on a temporary basis may have a higher prevalence of developing a mental disorder post wildfire experience, but some studies of volunteer firefighters suggest that there are differences between the psychological and behavioral outcomes of volunteer and career personnel [30]. For example, it was found that volunteer firefighters had a higher risk of PTSD symptoms and other mental health symptoms in general [31], whereas in another study, mental health problems such as alcohol abuse was more prevalent in career firefighters [32].

Finally, sex-based differences and presentations of mental health illnesses may contribute to the findings. Women and men may have the same psychological illness but

present differently. Although higher rates of mental illnesses have been found in women, men are less likely to be diagnosed for their condition due to multiple factors such as the high stigma surrounding mental health and the lack of access to resources [33]. One of the potential explanations for this is due to the widespread stigma surrounding mental health issues in men. In one included study, the researchers avoided recruiting participants through their fire organization because they believed they would yield fewer participants because of mental health stigma [15]. Out of the 13 studies included in this review, only 3 of the studies included women [9,15,16]. While this may be in part because women do not make up a majority of the population of firefighters, recent data show that in the US, women make up around 10% of the fire service as a whole and remain as significant contributors to the workforce and therefore should be included whenever possible in related research [1]. As so few studies in this review included female firefighters, sex-based differences in the effect of wildfire exposure and PTSD and other mental health problems cannot be assessed, and this remains an area of future research.

4.2. Longitudinal Outcomes (PTSD Time Frame and Health Outcomes)

Amongst the studies selected for this review, PTSD and other mental health outcomes were assessed longitudinally; some assessed mental health as early as 1 month after the exposures and others as late as 84 months after the exposures [14,16–18], though many studies assessed symptoms within 6 months of wildfire exposure [14,17,18,21–25]. PTSD symptoms tend to present themselves within 3 months after the event, although in some cases, delayed expression occurs when the patient does not meet the PTSD criteria until more than 6 months after the incident [34]. Some studies suggest that incidents of delayed-expression PTSD occur in as many as 25% of cases [35]. Therefore, in the five studies that examined PTSD outcomes at a single time point within 6 months of the wildfire event, true levels of PTSD may have been severely underestimated due to the nature of the course of the mental disorder. This is further bolstered by the series of studies by McFarlane, which suggests that PTSD symptoms developed at 4, 11, and 29 months after the wildfire event, with 35% of participants having PTSD at all four periods [25].

PTSD and other stress-related conditions, especially those which remain untreated, can lead to significant health consequences long-term. Chronic stress and mental suffering can be detrimental to both long-term physical and long-term mental health. Aside from the immediate physical effects that often appear alongside stress, such as fatigue, individuals are also at a higher risk for long-term physical health deterioration, which can include difficulty digesting, headaches, weight gain, body aches and pain, trouble with memory, and an increased risk for sudden cardiac events or stroke [36]. Acute, long-term stress was also shown to negatively affect cardiovascular health [37]. Chronic stress was found to be associated with the progression of atherosclerosis and can provoke acute cardiac events [37]. Additionally, the body's physical response to prolonged stress can trigger myocardial ischemia in patients who have preexisting heart blockages or coronary obstructions and in those without the condition [37]. In 2022, half of the deaths of on-duty firefighters were attributed to overexertion and stress-related causes [38].

Chronic stress has been linked to the damaging of nerve cells in the brain [39]. Multiple studies demonstrated that chronic stress can lead to the shrinking of the dendrites of nerve cells in multiple parts of the brain including the hippocampus and the amygdala [39]. The hippocampus is responsible for learning and memory, but it is also important in the function of emotional behavior [40]. The hippocampus and the amygdala are also the first parts of the brain to present with damage in neuropsychiatric conditions and neurodegenerative diseases like Alzheimer's disease [40]. Additionally, chronic stress was found to cause deterioration of nerve cells in the prefrontal cortex (PFC) of the brain, which is responsible for emotional, thought, and behavioral regulation [41]. Since firefighters experience multiple exposures of environmental and psychological stressors, it is important that cumulative effects of exposures are investigated regarding long-term cognitive and psychological health. As fire seasons become increasingly demanding, it is vital to

understand the current state of physical and mental health of those in the fire service and to continue to try to mitigate the occupational exposures of the profession.

4.3. Potential Mechanisms

While experiencing or witnessing a traumatic event can be a significant contributor to developing a psychological condition such as PTSD or depression, other exposures may additionally increase risk for a mental health problem. Recently, the investigation of air pollution and its contributions to mental health conditions such as depression and anxiety disorders has been increasingly more relevant due to the current state of climate change and global air pollution. During wildfire events, smoke carries SO_2 and $\text{PM}_{2.5}$ into the environment and air, exposing the firefighters not just on the ground but in the surrounding areas [42]. In a meta-analysis of studies that looked at air pollution and its effects on depression, researchers found that an increase in the long-term exposure of particulate matter, $\text{PM}_{2.5}$, was associated with an increased risk of depression [43]. Another study evaluated the relationship between emergency department visits due to suicide attempts and meteorological and air pollution and found that increased levels of SO_2 were linked to increased incidents of suicide attempts [42,44]. There are multiple studies that reported the increased suicide risk during times of intense heat [45]. For example, the prevalence of suicide by ‘violent means’ was found to increase during days of higher temperatures [44]. This is significant to consider when investigating the exposures of wildfire events and mental health outcomes as it demonstrates that firefighters are put at physical and psychological risk through a combination of occupational and environmental exposures.

Along with air pollution and severe heat, studies have shown that wildfires release heavy metals and other chemicals such as aluminum, sulfate, potassium, iron, zinc, lead, and copper into the air [46]. Higher exposures to heavy metals and metalloids like lead, arsenic, and cadmium have been shown to be associated with increased risks of mental disorders. For example, one study surveying the presence of heavy metals in soil in Spain found that as likely exposures of heavy metals increased, measured via topsoil, the adults in the surrounding areas were at a higher risk of developing psychological disorders [47]. To fully grasp the risks to the psychological health of firefighters who respond to wildfires, it is important that future research considers the cumulative effects of the many different exposures that firefighters face during their careers.

4.4. Gaps in Disaster Research: Limitations and Strengths

There were multiple limitations to the studies included in this review. Most of the limitations can be attributed to the unpredictable nature of disaster research and the limited time the researchers had to gather certain data regarding baseline mental health prior to the wildfire events. While all the studies gathered demographic information of their population, there lacked prior data regarding the prevalence of mental ill health and potentially relevant adverse life experiences within their respective cohorts. Adverse life experiences and previous mental health symptoms and conditions are necessary to understand how wildfires may exacerbate current symptoms and conditions or if they have greater contributions to the onset of psychological conditions. One study in this review utilized the Childhood Experience of Care and Abuse Questionnaire and screened for previous mental health diagnoses [9]. The same data from the study were utilized to further understand the relationship between childhood care and abuse and the prevalence of mental health conditions in this cohort [48]. In the study, they found that every participant who reported experiencing sexual abuse met the criteria for at least one psychological condition.

Another limitation, as reported by the studies, is the lack of generalizability of the results based on geographical region and the uniqueness of each disaster. This could also include cultural differences within the cohorts with regard to the understanding of mental health and the stigma surrounding the discussion of mental ill health. Furthermore, six of the studies were published in the late 1980s [21–26]. In comparison to today, the

experiences of firefighters responding to wildfire suppression efforts, their understanding of psychological conditions, and the measures of diagnosing psychological conditions from forty years ago could be drastically different.

One of the greatest limitations to these studies was the lack of statistical comparison to a control or other significant population. Only one of the studies examined data on other first responders, such as police officers, who experienced the same event [19]. Without comparing the mental health outcomes of various populations after an extreme disaster, disaster research will continue to lack significant information regarding the variation in mental health outcomes amongst first responders.

The process of recruiting victims of major disasters can raise ethical concerns surrounding compensation for participation in the study. In aligning with ethical standards of disaster research, it is recommended that participants are not compensated through monetary means [49,50]. One of the studies disclosed if the participants received compensation for their participation, although some offered alternatives to compensation. In the studies included in this review, two mentioned being associated with groups providing direct care at the time of the incident, such as psychiatrists [17,18], and one mentioned providing information on mental health resources both during the study and after it concluded [9].

There were also limitations in the synthesis of included studies, as there was considerable heterogeneity in how mental health data were collected and reported. For example, the procedures for understanding the prevalence of mental illness and symptoms within these cohorts varied due to the diagnostic standards of the time the disaster took place and the different psychological health data that each study tried to report. While nearly every study that identified clinical diagnosis conducted their own interviews, one study relied on the self-reported data of diagnoses from the participants [15]. This may contribute to an underreporting of psychological conditions within that cohort and thus this review.

This review has strengths to also consider. In all but one of the studies that assessed for psychological disorders, the assessment of psychological disorders was conducted through both structured and unstructured interviews that assessed for the different experiences of the firefighters during the wildfires and after the wildfires. Another strength to consider is that the studies were conducted as soon as one month after the wildfire event [14,17,18]. Psychological conditions and their symptoms can wane over time, so understanding the immediate psychological experiences of the participants is important. Six of the studies included in this review were longitudinal studies, following participants as soon as 4 months after the disaster and as long as 84 months after the disaster [21–26]. Understanding how the symptoms related to their exposures can change over time is significant in predicting how significant wildfire events may affect other aspects of the participants' lives and even their work. Moreover, research like this is necessary for advancing the field of disaster research and its intersections with psychological health.

5. Conclusions

The data gathered from this review suggest that there is a high prevalence of PTSD and psychological symptoms in firefighters who respond to wildfire events, both during the event and months to years after the wildfire. As the prevalence and intensity of wildfires is predicted to increase due to the changing climate, it is important that fire services prepare their workers for both the greater psychological and physical demands of their work. Further, clinicians working with those in the fire service should be aware of past and current risk factors for developing a mental health disorder, especially after experiencing a wildfire event.

Additionally, this review found that there are gaps in disaster research regarding first responder health and wellness. First responder physical and mental health should be a priority for occupational and disaster research. Additional areas of research include first responder risk perception with regard to environmental and occupational exposures and stressors, the current state of psychological and physical health in the fire service, and the impacts of poor psychological and physical health of workers in the fire service on

the workforce. Understanding how the unstable climate will affect the daily activities and practices of first responders as well as its potential to have significant impacts on the workforce must be a focus for future research. The fire service is a diverse workforce that includes many different occupations and is composed of both men and women, as well as volunteer and career personnel, and additional research should address the risk levels of psychological ill health amongst different groups in the service. For disaster workers like those in the fire service, their occupation provides a unique opportunity for valuable occupation- and climate-related research. As natural disasters become increasingly more prevalent and extreme, it will be imperative for researchers to consider how the evolving landscape of disasters will challenge them to maintain and raise their standards of ethical research. The findings of this review further uphold the need to address the mental health needs of workers in the fire service and highlight the critical lack of data on the physical and psychological impacts of climate-related events like wildfires on firefighters.

Author Contributions: Conceptualization, I.B. and J.L.; methodology, I.B. and J.L.; writing—original draft preparation, I.B. and O.M.H.; writing—review and editing, I.B., O.M.H. and J.L.; supervision, O.M.H. and J.L. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by the National Institutes of Environmental Health Sciences R25-ES021649 and T32ES007062; The National Institute of Child Health and Human Development R01HD087485; and the University of Pennsylvania Center of Excellence in Environmental Toxicology P30-ES013508.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: No new data were created or analyzed in this study. Data sharing is not applicable to this article.

Acknowledgments: This work was supported by the University of Pennsylvania Center of Excellence in Environmental Toxicology (CEET), STEER research program.

Conflicts of Interest: The authors declare no conflicts of interest.

Appendix A

Appendix A includes a search strategy string.

(MAINSUBJECT.EXACT("Fire Fighters") OR "fire fight*" OR firefight*) AND (MAINSUBJECT.EXACT("Psychological Stress") OR MAINSUBJECT.EXACT("Stress Management") OR MAINSUBJECT.EXACT("Perceived Stress") OR MAINSUBJECT.EXACT("Stress and Trauma Related Disorders") OR MAINSUBJECT.EXACT("Posttraumatic Stress Disorder") OR MAINSUBJECT.EXACT("Social Stress") OR MAINSUBJECT.EXACT("Posttraumatic Stress") OR MAINSUBJECT.EXACT("Acute Stress Disorder") OR MAINSUBJECT.EXACT("Chronic Stress") OR MAINSUBJECT.EXACT("Stress") OR MAINSUBJECT.EXACT("Acute Stress") OR MAINSUBJECT.EXACT("Stress and Coping Measures") OR MAINSUBJECT.EXACT("Stress Reactions")).

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