Prevalence and Predictors of Sleep and Trauma Symptoms in Wildfire Survivors

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A B S T R A C T

Objective: This study aimed to establish the prevalence and to identify predictors of insomnia, nightmares and post-traumatic stress disorder (PTSD) in wildfire survivors.
Method: A total of 126 (23 males, 102 females, and 1 nonbinary individual, Mage = 52 years, SD = 14.4) wildfire survivors from Australia, Canada and the USA took part in an online survey. Participants completed a demographic questionnaire and self-report measures including: The Insomnia Severity Index (ISI), PTSD Checklist for DSM-5 (PCL-5), and Disturbing Dream and Nightmare Severity Index (DDNSI).
Results: Results showed that 49.2% of the sample reported clinical insomnia on the ISI, 28.7% reported nightmares on the DDNSI, and 77.88% reported PTSD symptoms on the PCL-5. Fear for life of others (*Pearson's r* = .40, .21, .31), and the impact of smoke (*Pearson's r*, .47, .25,.41) significantly correlated with insomnia, nightmares and PTSD symptoms, respectively. Hierarchical regression showed that smoke was a significant predictor of insomnia (β = .17, p <.05, *95% CI*, 0.15 – 1.49), and insomnia predicted both of PTSD (β = .27, p <.05, *95% CI*, 0.26 – 1.05), and nightmares (β = .19, p = .04, *95% CI*, 1.01 – 1.45) scores.
Conclusion: Insomnia, nightmares and PTSD are highly prevalent in wildfire survivors. Smoke, one of the trauma-related factors, was found to be as a significant predictor of insomnia; and insomnia was a significant predictor of both PTSD and nightmares. Future longitudinal studies are needed to establish which disorder emerges first as a result of smoke.

1. Introduction

Climate change has set the stage for increased frequency and severity of various natural disasters including floods and fires. Particularly, the rise in global temperature and resulting droughts has contributed to the increase in wildfires, leading to a global crisis [1]. Wildfires have been predicted to increase by 57% by the end of this century [2], as they are now impacting many parts of the world that were previously immune to their destructive nature, including parts of Russia, the Amazon and even the Arctic region [1,3]. Parts of Australia, Canada and the United States of America (USA), are prone to wildfires and climate change has further increased their vulnerability [4–7].

Repercussions of wildfires

The repercussions of wildfires extend from financial losses, to human hardship with loss of life and injury, and psychological traumatisation of survivors [7]. Many survivors report difficulties initiating sleep, maintaining sleep, waking up too early in the morning with inability to return to sleep, which are typical symptoms of insomnia [8,9]. Some survivors report regularly experiencing highly stressful, well remembered dreams

that result in awakening from sleep and difficulty returning to sleep which is consistent with nightmare disorder [8,10]. Survivors may also report constant re-living of the traumatic event, hyperarousal, negative affect symptoms, and avoidance of remembering the traumatic event. This cluster of symptoms is referred to as post-traumatic stress disorder (PTSD) [8]. The co-occurrence of insomnia, nightmares, and PTSD potentially complicate psychological treatment, leading to increased depression, anxiety, stress, reduced daily functioning, and poor quality of life. Studies show that the presence of sleep disturbances in those who experience trauma, exacerbates and maintains PTSD, and hinders recovery [11–14].

The relationship between sleep disturbances and PTSD symptoms

The literature is inconclusive on whether sleep disturbances lead to the development of PTSD or whether PTSD leads to sleep disturbances. Whilst some researchers suggest a bi-directional relationship between the two [11,15], experimental animal designs, current theoretical models, and intervention studies suggest that sleep disturbances possibly precede the development of PTSD [12,16–22]. Historically, insomnia and nightmares occurring in the context of PTSD disorder, have always been

viewed as symptoms of PTSD disorder rather than independent entities [8,23]. However, with the advances in the field of sleep and trauma, it has been noted that sleep disturbances often precede PTSD and thus should be treated in parallel with trauma symptoms [12,16].

Prevalence of sleep disturbances in wildfire survivors

In a systematic review of wildfire studies, Isaac et al. [10] reported that the prevalence of insomnia ranged between 63.0–72.5%, and nightmares ranged between 33.3–46.5% in wildfire survivors. Even though, Isaac et al.'s study was the first systematic review to assess prevalence of sleep disturbances in wildfire survivors, their review only located five studies, with two studies reporting prevalence of sleep disorders in clinical and paediatric wildfire survivors. There is limited data available on the prevalence of sleep disorders in wildfire survivors and studies have utilised different methodologies to assess prevalence in this population [10]. Examining the prevalence of sleep difficulties in wildfire survivors may provide information to assist government agencies and policy makers to provide appropriate services for wildfire survivors to prevent the development of long-term mental health conditions that complicate treatment and recovery [10].

The impact of smoke

The impact of smoke during and after wildfires is one of the variables that has been studied [3,24]. Most studies of wildfire smoke have focused on examining the impact of smoke on respiratory health, with little attention given to its impact on mental health [25]. Smoke from wildfires can travel thousands of kilometres affecting not only those in close proximity but also those who are far away [26]. Smoke is also known to negatively affect sleep and is associated with insomnia and nightmares [25]. The UN Environment programme suggests that smoke from wildfires negatively affects the health of hundreds of thousands of people and is responsible for 33,000 deaths annually [3].

Other wildfire trauma-related variables

Other wildfire trauma-related outcomes include fear for life, loss of loved ones to fires, loss of property, and imminence of death during the fires [27,28]. Bryant and colleagues [24] found that communities highly affected by the 2009 Black Saturday fires in Australia (in terms of lives lost and property destruction) were significantly more likely to report more major life stressors, fearing for their lives, and having lost someone in the fires in comparison to medium and low impacted communities. Furthermore, significantly higher rates of PTSD were observed in highly affected communities (15.6%) in comparison with communities where affects were medium (7.2%), or low (1%) (*95% CI*: 2.61–8.00). Gender, death of loved ones, low education, fear for life, loss of property, and subsequent major life stressors were all significant predictors of PTSD resulting from bushfires [24].

To et al. reviewed 63 studies and found that witnessing of wildfires, fear for personal and others' life and safety, loss of a loved one, lack of support from family and friends following the fires, and subsequent ongoing trauma increased the risk of developing PTSD following wildfires [7]. Other studies reported that some of the factors that predicted PTSD symptoms in those affected by bushfires were, being female, prior mental health conditions, prior traumatic experiences, lower education, being evacuated, and feeling very distressed during the fire disaster [24,29]. One study by Psarros and colleagues found that scores on imminence of death significantly predicted insomnia scores following wildfires [28]. The studies by To et al. [7], Bryant et al. [24], and Parslow et al. [29] focused mainly on the influence of wildfire trauma-related variables on the development of and/or the severity of PTSD. It is not well understood whether the relationship between wildfire trauma-related factors and the severity of PTSD is simply a direct relationship or whether it is mediated by sleep difficulties such as insomnia and nightmares [11].

In summary, there are limited empirical data in relation to the prevalence of sleep disorders in wildfire survivors [10]. Gaining such knowledge will provide an understanding of resources and interventions needed to aid wildfire survivors [30]. Better understanding of sleep disturbances and trauma symptoms may indicate how early those symptoms emerge following the fires, thus allowing for better and timely interventions to prevent the development of more severe mental health issues. The available studies have mainly explored the influence of wildfire trauma-related factors on PTSD, but have not examined the influence of trauma-related factors on sleep difficulties including insomnia and nightmares. While, the effect of smoke has been researched in terms of its impact on respiratory health [25], its influence on mental health, including sleep, has been overlooked. Exploring and understanding how different trauma-related and post-trauma related variables affect insomnia, nightmares and PTSD can clarify the contribution of each variable on each health condition following the experience of wildfires [25].

2. Aims of the study

The aims of this study were to explore the prevalence of sleep and trauma symptoms in wildfire survivors and to identify wildfire trauma-related variables that predict the development of sleep and trauma symptoms. It was hypothesised that: the prevalence of insomnia, nightmares and trauma symptoms in wildfire survivors would be significantly higher than that reported in a representative sample of college students; wildfire survivors who have experienced more severe trauma-related factors such as greater losses (e.g., personal injury, loss of property, people, and animals), experienced more imminence of death, were more severely impacted by smoke, and experienced more fear for the loss of lives (e.g., fear for loss of own life and life of others) would exhibit more severe insomnia, nightmares, and PTSD symptoms than those experiencing fewer trauma-related factors; and the number of losses, the impact of smoke on health, and fear for loss of lives due to the experience of wildfires, would significantly predict scores for insomnia, nightmares, and PTSD symptoms.

3. Method

3.1. Participants

One hundred and twenty-six wildfire survivors from Australia, Canada and USA completed an online survey. The sample comprised 23 males (18.3%), 102 females (81%), and one nonbinary (0.8%). Participants' ages ranged from 20 to 92 years (*M* age = 52 years, *SD* = 14.4). Table 1 shows the characteristics of the sample (*N* =126).

3.2. Measures

Demographic questionnaire: Participants were asked to provide information about age, sex, employment, education, marital status, country of residence, country of birth, experience with fires, evacuation experience, COVID-19 impact on mental health and sleep, medical history, history of mental health diagnosis prior to the experience of fires, and fear related to fires.

Additional trauma questionnaire [31]: Eight items were obtained and adapted, to our survey, from the PCL-5 with Life Event Check List Criterion A (PCL-5 with LEC-5 and Criterion A) for the purpose of collecting data on additional trauma incurred following the fires including, transport accidents, accidents at work, personal assaults, serious illness, sudden loss of a loved one, disruption to accommodations, disruption to work, and disruption to relationships [31]. Participants were required to respond with a yes or a no to each item.

The Insomnia Severity Index Scale (ISI)[32]: The ISI is a 7-item, self-reportscale measuring severity of insomnia. The scale has a good internal consistency with a Cronbach's alpha ranging from $\alpha = .87$ to $\alpha = .92$ [33]. In the present study Cronbach's alpha was .92, and a cut off score of 14 was used to discriminate between mild and severe symptoms [34].

Generalized Anxiety Disorder Questionnaire (GAD-7) [35]: The GAD-7 is a 7-item, self-report scale that has a good internal consistency with a Cronbach's alpha ranging from $\alpha = .82$ to $\alpha = .93$ at pre and post-treatment [36]. In the present study Cronbach's alpha was .95, and

Table 1

Demographic Characteristics of the Sample.

Demographic Variables	(n)%
Country of Residence	
Australia	44(34.9%)
Canada	27(21.4%)
USA	55(43.7%)
Education (n = 125)	
Primary school	1(0.8%)
High school	23(18.4%)
Certificate/diploma	42(33.6%)
Bachelor degree	37(29.6%)
Postgraduate degree	22(17.6%)
Income (n = 123)	
$0 income	1(0.8)
$1 to $20,799 per year	21(17.1%)
$20,800 to $41,599 per year	25(20.3%)
$41,600 to $77,999 per year	31(25.2%)
$78,000 to 155,999 per year	34(27.6%)
$156,000 or more per year	11(8.9%)
Employment (n = 125)	
Student	2(1.6%)
Employed	69(55.2%)
Unemployed	11(8.8%)
Looking for work	5(4.0%)
Retired	38(30.4%)
Marital Status (n = 126)	
Single	24(19%)
Separated/divorced	13(10.3%)
Widowed	7(5.6%)
Married	82(65.1%)

Table 2

Means, Standard Deviations, Frequencies and Percentages of Sleep, Trauma Symptoms, Sleep Quality, Anxiety and Depression.

Variables	M(SD)	n(%)
DDNSI (n = 87)	8.57(7.25)	62(71.3%) No nightmares 25(28.7%) Nightmare disorders
ISI (N =126)	13.78(7.05)	25(19.8%) No clinical insomnia 39(31%) subthreshold insomnia 46(36.5%) clinical moderate insomnia 16(12.7%) clinical severe insomnia
PCL-5 (n = 104)	46.42(17.02)	23(22.12%) some symptoms of PTSD 31(29.81%) moderate-moderately high severity 50(48.07%) high severity of PTSD symptoms
PSQI (n = 116)	9.54(4.34)	22(19%) good sleep quality 94(81%) poor sleep quality
GAD-7 (n = 110)	9.89(6.88)	30(27.3%) minimal anxiety 28(25.5%) mild anxiety 16(14.5%) moderate anxiety 36(22.7%) severe anxiety
PHQ-9 (n = 124)	10.79(6.72)	28(22.2%) minimal depression 33(26.2%) mild depression 26(20.6%) moderate depression 24(19%) moderately-severe depression 15(11.9%) severe depression.

book, Instagram, Reddit, LinkedIn, online community noticeboards, local newspapers, and wildfire interest group sites.

3.4. Data Analysis

Descriptive analyses, frequencies, percentages and means and standard deviations were used to summarize the demographic variables and to assess the prevalence of insomnia, nightmares and PTSD symptoms. Inferential statistics were utilised to examine the relationships and differences between study variables. All dependent variables were normally distributed except the DDNSI which was positively skewed.

Prior to conducting multiple regression analyses to examine which variables predicted insomnia, nightmares and trauma symptoms, statistical analyses of normality, homoscedasticity, and linearity for multiple regression were conducted. Multiple linear hierarchical regression and logistic regression analyses were used to assess predictions of insomnia, trauma and nightmare symptoms.

4. Results

4.1. Prevalence of sleep and trauma symptoms

Frequencies for the DDNSI, ISI, PCL-5, PSQI, GAD-7, PHQ-9, were calculated to assess the prevalence of anxiety, depression, insomnia, sleep quality, nightmare and trauma symptoms. Table 2 shows means, standard deviations and percentages for the independent variables (N= 126).

Almost half of the sample self-reported clinically moderate (36.5%) and severe (12.7%) insomnia symptoms, over half of the sample reported moderate (29.81%) to high (48.07%) severity of PTSD symptoms (indexed using the PCL-5), and nearly 29% of wildfire survivors self-reported nightmare symptoms (DDNSI).

Of the 81 participants (77.88%) who met a PTSD provisional diagnosis (assessed by the PCL-5), 52 (69.3%) met criteria for clinical insomnia symptoms (assessed by the ISI), and 21 (28%) also met criteria for nightmare disorders (assessed by the DDNSI).

a cut-off score of 10 was used to discriminate between mild and severe symptoms [35].

The Patient Health Questionnaire (PHQ-9) [37]: The scale consists of nine items assessing depression symptoms. In the present study Cronbach's alpha for the PHQ-9 was .91, and a cut-off score of 10 was used to discriminate between mild and severe symptoms [37].

Pittsburgh Sleep Quality Index (PSQI) [38]: The PSQI is a 19-item questionnaire with an additional five questions rated by a bed partner. The PSQI has a good test-retest reliability with $r = .87$ [39]. In the present study, Cronbach's alpha was .81, and a cut off score of 5 was used to discriminate between mild and severe symptoms [39].

PTSD Checklist for DSM-5 Scale (PCL-5) [40]: The PCL-5 Checklist – Civilian Version (PCL-5) consists of 17 self-report items that screen for the presence of PTSD symptoms over the last month. The PCL-5 also provides provisional diagnosis of PTSD. The PCL-5 has good psychometric properties with an internal consistency of ($\alpha = .94$), convergent validity of ($r = .74 - .85$), and test-retest reliability of ($r = .82$) [41]. In the present study Cronbach's alpha was.95, and a cut-off score of 33 was used to discriminate between mild and severe symptoms [42].

Disturbing Dream and Nightmare Severity Index (DDNSI) [43]: This scale is a five item self-report instrument which assesses severity and frequency of disturbing nightmares and dreams. The DDNSI has demonstrated a good internal consistency (Cronbach's alpha $\alpha = .93$) [44]. In the present study a cut-off score of 10 was used to discriminate between the presence and absence of nightmares [45].

3.3. Procedure

Following approval from (Federation University Human Research Ethics Committee , approval number: A21-124) advertisements about the study including a URL link were posted from October 2021 to March 2022. Participants were eligible to complete the survey if they were survivors of wildfires (within the last 10 years), 18+ years old, and fluent in English. Participants were recruited via social media sites such as Face-

Table 3

Correlation Between Demographic Variables and Wildfire Trauma Variables with the Dependent Variables.

Variables	DDNSI ($n = 87$)	GAD7 ($n = 110$)	ISI ($n = 126$)	PCL-5 ($n = 104$)	PHQ9 ($n = 124$)	PSQI ($n = 116$)
Age	-.09	.31**	-.131	-.27**	-.23*	-.10
Income	-.10	-.16	-.28**	-.21*	-.24**	-.30**
Additional trauma	.32**	.40**	.37**	.55**	.31**	.40**
COVID-19/sleep	.01	.36**	.31**	.26**	.27**	.126
COVID-19/MH	.11	.48**	.36**	.40**	.37**	.19*
Number of losses	.11	.22*	.17	.22*	.16	.30*
Imminence of death	.07	.44**	.29*	.33*	.26*	.23*
Smoke impact	.25*	.33**	.47**	.41**	.31**	.43**
Fear for personal life	.19	.38**	.40**	.37**	.38**	.30*
Fear for life of others	.21*	.32*	.40**	.31*	.32**	.28*
Fear for loss of property	.11	.29*	.30*	.26*	.17	.23*

Note. *< .05; **< .01; ***< .001.

4.2 Comparison between the study sample and college participants

To examine whether sleep and trauma symptoms were higher in the present study to those reported in a representative college sample ($N = 583$) [46], a single sample *t-test* was used and showed that the ISI mean score in the present sample ($M = 13.78$, $SD = 7.05$) was significantly higher than that reported in Nadorff et al.'s study ($M = 8.84$, $SD = 4.69$), $t = 7.87$, $p < .001$ (95% CI, 3.70 - 6.18). A single sample *t-test* also showed that the mean for DDNSI in the present sample was significantly higher ($M = 8.57$, $SD = 7.25$) than that reported in Nadorff et al.'s study ($M = 3.78$, $SD = 4.96$), $t = 6.17$, $p < .001$ (*95% CI*, 3.25 - 6.34). Similarly, the mean score for the PCL-5 ($M = 46.42$, $SD = 17.02$) was significantly higher to that reported in Nadorff et al.'s sample ($M = 34.30$, $SD = 11.81$), t = 7.27, $p < .001$ (*95% CI*, 8.81-15.43) [46].

4.3 Relationship between wildfire trauma-related variables and sleep and trauma symptoms

Pearson's correlations were calculated between the ISI, GAD-7, PCL-5, PSQI, and PHQ-9; and Spearman's *rho* correlations for the DDNSI with other variables to examine if wildfire survivors who have experienced greater losses, greater danger of imminent death, more impact of smoke, and more fear for the loss of lives showed more severe symptoms of insomnia, nightmares and trauma. Table 3 shows a correlation matrix of the dependent variables with demographic and trauma variables following fires.

Table 3 shows that additional trauma, smoke impact and fear for life of others were correlated positively with all of insomnia, nightmares and PTSD symptoms. COVID-19 impact on sleep and mental health correlated positively with insomnia and PTSD. The other trauma-related variables including number of losses, imminence of death, fear for personal life and fear for loss of property also correlated positively with PTSD and/or insomnia with a small to large magnitude.

4.4 Predictors of sleep and trauma symptoms

To determine which wildfire related variables predicted insomnia, nightmares, and trauma symptoms (ISI, DDNSI, and PCL-5), multiple hierarchal regression and logistic regression analyses were conducted. To examine the unique contribution of imminence of death, fear for own life and the life of others, and smoke caused by wildfires in the explanation of insomnia symptoms, a hierarchical multiple regression analysis was performed. The dependent variable in the model was insomnia score, and independent variables that explain wildfire trauma were entered in five steps. In Step 1, sex and income were controlled for. This model significantly predicted insomnia symptoms contributing 11.4% to the variance, $F (2,100) = 6.42$, $p = .002$. In Step 2, COVID-19 impact on mental health, contributed an extra 11.3% to the model $F (1, 99) = 14.46$, $p < .001$, $R^2 = .227$. Additional trauma after the fires was entered in Step 3, which contributed 4.8% of variance to the model $F (1,98) = 6.54$, $p = .012$, $R^2 = .275$. In Step 4, depression scores, anxiety, and trauma symptoms were entered (PHQ-9, GAD-7, PCL-5). The four variables in Step 4 contributed 41% of the variance of insomnia scores, $F (3,95) = 41.12$, $p < .001$, $R^2 = .685$. In the final step, imminence of death, fear for own life and the life of others, and smoke impact were entered which contributed a further 4.1% to the overall model, $F (3,92) = 4.63$, $p = .005$, $R^2 = .726$. Table 4 shows the coefficients for the variables entered in the hierarchical regression.

A hierarchical multiple regression analysis was conducted to examine which variables (i.e., number of losses, fear for life, and smoke caused by wildfires) predicted trauma symptoms as measured by the PCL-5 scale. The PCL-5 was entered as a dependent variable in the regression analysis. In Step 1, sex and income were entered. This model significantly predicted trauma symptoms contributing 10.3% of the variance, $F (2,100) = 5.77$, $p = .004$. In Step 2, COVID-19 impact on mental health, added an extra 13.4% to the model $F (1, 99) = 17.40$, $p < .001$, $R^2 = .237$. Additional trauma after the fires was entered in Step 3, which contributed 15.8% of variance to the model, $F (1,98) = 25.65$, $p < .001$, $R^2 = .396$. In Step 4, depression, anxiety, and insomnia scores (PHQ-9, GAD-7, ISI) were entered. The four variables in Step 4 contributed a further 40.6% of the variance to trauma scores, $F (3,95) = 64.90$, $p < .001$, $R^2 = .802$. In Step 5, number of losses, fear for life, and smoke impact were entered. The model was not significant, with trauma of fires adding only .02% to the overall model, $F (3,92) = 0.32$, $p = .811$, $R^2 = .804$ (see Table 4).

A logistic regression was conducted to examine which variables predicted nightmare symptoms as measured by the DDNSI (categorised as nightmare *vs.* no nightmare symptoms). Only variables that correlated with the DDNSI were considered. The independent variables were entered in the following order: Step 1/sex, Step 2/additional trauma, Step 3/anxiety, trauma, depression and insomnia symptoms, and Step 4/smoke impact and fear for life. The analysis showed that model 3 significantly predicted nightmare symptoms, $\chi 2 (5, N = 76) = 20.43$, $p = .001$, with insomnia being the only significant predictor in the model ($\beta = .19$. $p = .017$). The addition of smoke impact and fear for life variables to the final model, did not contribute significantly to nightmare symptoms. However, the model remained significant $\chi 2 (7, N = 75) = 20.46$, $p = .005$, with insomnia being the only significant contributor to the model ($\beta = .16$. $p = .03$) (see Table 5 for coefficient values).

5. Discussion

The aims of the study were to explore the prevalence of sleep and trauma symptoms and to identify which wildfire trauma-related variables predicted the development of sleep and trauma symptoms in wildfire survivors. In the current study and in support of the first hypothesis, results showed high rates of insomnia, nightmares and trauma symptoms in wildfire survivors; and the reported rates were found to be significantly higher than that reported in a sample of college students (all

Table 4

Summary of Hierarchical Regression Analyses of Variables Predicting Insomnia, and Trauma Symptoms.

Variables	β	t	SE	R²	95% CI
Insomnia model				.114	
Step 1	.19	1.95	1.66		[-0.05 – 6.52]
Sex	-.27	-2.44*	.62		[-2.55 – -0.46]
Income					
Step 2				.227	
Sex	.13	1.45	1.58		[-0.85 – 5.41]
Income	-.28	-3.13*	.50		[-2.53 – -0.57]
COVID-19/MH	.34	3.80**	.42		[0.61–2.56]
Step 3				.275	
Sex	.10	1.10	1.55		[-1.36 – 4.78]
Income	-.25	-2.81*	.49		[-2.33 – - 0.40]
COVID-19/MH	.27	3.00*	.43		[0.43 – 2.12]
Additional Trauma	.24	2.56*	.42		[0.24 –1.90]
Step 4				.685	
Sex	.03	.50	1.06		[-1.58 – 2.64]
Income	-.10	-1.69	.34		[-1.23 – 0.10]
COVID-19/MH	.05	.67	.31		[-0.41 – 0.83]
Additional Trauma	-.02	-.30	.33		[-0.74 – 0.55]
PCL-5	.44	3.59*	.05		[0.08 –0.28]
PHQ-9	.39	3.67**	.11		[0.20 – 0.63]
GAD-7	-.00	-.03	.10		[-0.21 –0.20]
Step 5				.726	
Sex	-.03	-.52	1.11		[-2.79 –1.63]
Income	-.08	-1.31	.33		[-1.10 –0.23]
COVID-19/MH	-.03	-.39	.32		[-0.76 –0.51]
Additional Trauma	-.02	-.22	.32		[-0.69 –0.55]
PCL-5	.39	3.29*	.05		[0.06 – 0.26]
PHQ9	.38	3.70*	.11		[0.19 – 0.62]
GAD-7	-.00	-.02	.10		[-0.20 –0.20]
Number of losses	-.04	-.66	.27		[-0.72 –0.36]
Smoke impact	.17	2.42*	.34		[0.15 – 1.49]
Fear for loss of life	.10	1.42	.21		[-0.12 –0.70]
PTSD model					
Step 1	.25	2.58*	4.02	.103	[2.41 – 18.38]
Sex	-.19	-2.01*	1.28		[-5.12 – -0.04]
Income					
Step 2				.237	
Sex	.19	2.09*	3.78		[0.38 – 15.37]
Income	-.20	-2.27*	1.19		[-5.05 – -0.34]
COVID-19/MH	.37	4.17**	1.00		[2.19 – 6.17]
Step 3				.396	
Sex	.13	1.58	3.42		[-1.39 –12.17]
Income	-.14	-1.78	1.07		[-4.03 – 0.23]
COVID-19/MH	.25	3.00*	.94		[0.95 – 4.67]
Additional Trauma	.43	5.06**	.92		[2.84 – 6.50]
Step 4				.802	
Sex	.08	1.81	2.00		[-0.36 – 7.60]
Income	.03	.54	.65		[- 0.94 – 1.64]
COVID-19/MH	-.03	-.49	.60		[-1.48 – 0.90]
Additional Trauma	.24	4.64**	.56		[1.49 – 3.73]
ISI	.27	3.59*	.18		[0.30 – 1.03]
PHQ-9	.32	3.36*	.21		[0.39 – 1.24]
GAD-7	.26	3.36*	.19		[0.26 – 1.00]
Step 5				.804	
Sex	.07	1.38	2.22		[-1.34 – 7.47]
Income	.03	.56	.68		[-0.96 – 1.72]
COVID-19/MH	-.03	-.48	.65		[-1.59 – 0.97]
Additional Trauma	.24	4.62**	.57		[1.50 – 3.78]
ISI	.27	3.29*	.20		[0.26 – 1.05]
PHQ9	.33	3.81**	.22		[0.40 – 1.26]
GAD-7	.26	3.31*	.19		[0.25 – 1.01]
Number of losses	.02	.41	.55		[-0.86 – 1.31]
Smoke impact	.04	.66	.70		[-0.94 – 1.86]
Fear for loss of life	-.05	-.79	.42		[-1.16 – 0.50]

Note. *< .05; **< .01; ***< .001; SE = standard error; CI = confidence intervals.

$p < .001$ [46]. Although, a college sample is not representative of the general public, the study by Nadorff and colleagues was the only study that provided prevalence on insomnia, nightmares and PTSD symptoms using the same scales that were utilised in the present study [46].

Prevalence of insomnia in the present sample was higher than that reported by Belleville and colleagues one year following the 2016 Fort McMurray wildfire, with insomnia prevalence reported to be ($N = 1,510$,

28.5%) [9]. This is perhaps reflective of the fact that the time elapsed since the fires determines prevalence rate of insomnia which may fluctuate over time following trauma. This hypothesis was not tested in the present study; however, it is an important observation and it should be investigated further.

While nightmares were highly prevalent in the present study, the prevalence was lower than that reported by Krakow and colleagues

Table 5

Summary of Logistic Regression Analysis of Variables Predicting Nightmare Symptoms.

Variables	β	SE	Wald	P	95% CI
Nightmare model					
Step 1	.43	.72	0.36	.551	[0.37 – 6.30]
Sex					
Step 2					
Sex	.22	.75	0.09	.77	[0.29 – 5.43]
Additional trauma	.20	.16	1.66	.198	[0.90 – 1.66]
Step 3					
Sex	-.22	.89	0.06	.805	[0.14 – 4.59]
Additional trauma	- .06	.21	0.08	.781	[0.63 – 1.42]
PCL-5	.02	.04	0.41	.522	[0.95 – 1.10]
PHQ-9	.01	.08	0.02	.886	[0.86 – 1.19]
GAD-7	-.03	.08	0.12	.73	[0.84 – 1.14]
ISI	.19	.08	5.70	**.017**	[1.04 – 1.42]
Step 4					
Sex	-.23	.92	0.06	.801	[0.13 – 4.80]
Additional	-.07	.22	0.09	.760	[0.62 – 1.43]
Trauma	.02	.04	0.40	.527	[0.95 – 1.10]
PCL-5	.01	.08	0.01	.892	[0.85 – 1.19]
PHQ-9	-.03	.08	0.13	.716	[0.83 – 1.14]
GAD-7	.19	.09	4.35	**.037**	[1.01 – 1.45]
ISI	.00	.32	0.00	.990	[0.53 – 1.82]
Smoke impact	.04	.18	0.04	.845	[0.73 – 1.48]
Fear for loss of life					

Note. Wald = Chi-Squared test; SE = standard error; CI = confidence intervals.

as measured by the DDNSI (33%, $N = 78$) six to ten months following the 2000 Cerro Grande Fire [30]. Notably, Krakow et al.'s study included wildfire survivors seeking treatment for sleep disturbances, perhaps explaining the discrepancy in rates between the two studies [30]Nevertheless, there is limited research available on prevalence of nightmares in wildfire survivors and they are always measured in the context of PTSD rather than as an independent entity [23].

In relation to PTSD symptom, the findings were consistent with findings from Belleville and colleagues three months following the 2016 Fort McMurray fires, with 60% ($N = 379$) of their sample reporting symptoms of PTSD, measured by the PCL-5 [47].

Furthermore, in the present study, the prevalence of insomnia and nightmares were high in those presenting with PTSD symptoms (69.3% and 28%, respectively). The higher reported rates are consistent with other studies of wildfire survivors which found insomnia and nightmares to be statistically higher ($p < .005$) among survivors with PTSD than those without PTSD symptoms [28].

5.1 Relationship between additional acquired trauma following wildfires, insomnia, nightmares and PTSD

In the present study, those who acquired other types of traumas following the trauma of wildfires, had more insomnia, nightmares, experienced more PTSD symptoms, and reported poorer sleep quality than those without additional trauma. Previous research found that wildfire survivors' PTSD symptoms intensified 6-8 months following the trauma, which may not only be linked to fluctuation in PTSD symptoms across time, but can also be a result of other acquired traumas following the trauma of wildfires [48,49]. Other findings from a study comparing high affected with low affected communities by the 2009 Black Saturday bushfires found that the trauma related to difficulties associated with housing and employment following bushfires impacted the mental health of survivors [24]. It is worth highlighting that property loss following the fires is likely to cause relocation, difficulties in rebuilding and settling down, difficulties with insurance companies, and perhaps income difficulties which can ultimately contribute to poorer mental health, including sleep disturbances [50,51].

5.2 The impact of COVID-19

The findings in relation to COVID-19 impact on sleep and mental health found that those who scored higher on the impact of COVID-19 on sleep and mental health reported more insomnia, more PTSD symptoms and poorer sleep quality, than those who reported less impact.

The impact of COVID-19 has been undeniably severe on both sleep and mental health. The present findings add to the reported literature by suggesting a possible link between COVID-19 and PTSD. Previous research suggested that 30.2% ($N = 381$) patients who presented to emergency rooms with COVID-19 and recovered in a post-acute care experienced PTSD symptoms [52]. The COVID-19 pandemic adds another layer of trauma to survivors who have endured complex and multiple traumas, which complicates the presentation and treatment of wildfire survivors. For example, Agyapong et al. assessed the impact of cumulative trauma in Canadians who experienced multiple traumatic events since the 2016 Fort McMurray fires including the 2020 floods, and the COVID-19 pandemic [53]. Those who experienced wildfires, flooding, and the COVID-19, ($N = 47$) were 11 times more likely to report PTSD symptoms compared to respondents who experienced COVID-19 trauma only ($N = 19$). This finding also adds to the aforementioned results about the negative impact of subsequent trauma acquired following the fires, whereby cumulative trauma can compromise resilience leading to the development of psychopathology [7].

5.3 Relationship between wildfire trauma-related variables, insomnia, nightmares and PTSD

In support of hypothesis 2, the present study found that wildfire survivors with higher losses including those who feared for their life and safety, feared for the life of others, those who feared for the loss of property, and those who felt death was imminent scored higher on insomnia, nightmares, PTSD symptoms, and reported poorer sleep quality. Previous findings confirmed that both adults and children who experienced fires directly were more likely to report worse sleep quality than those who were indirectly affected [10,51,54]. Recent research of the impact of wildfires on mental health, found that trauma-related factors such as witnessing of the fires burning properties, losing loved ones, fearing for the loss of lives, imminence of death, and lack of support from family

and friends increased the risk of developing PTSD and insomnia symptoms following the fires [7,28,55].

5.4 Smoke Impact

The present study also revealed that those who were affected more severely by smoke resulted from wildfires scored higher on insomnia, nightmares, PTSD, and had poorer sleep quality. The Sleep Foundation report indicated that regardless of the location, around 58% of people surveyed stated that smoke resulted from the fires has affected their sleep [56]. Smoke travels to the nervous system affecting neurotransmitters which affect sleep cycles. Furthermore, inflammation in the brain caused by smoke, affects breathing, causes nasal congestion and sinus inflammation leading to airway obstruction which in turn leads to sleep disturbances [57]. To the best of our knowledge, only one study examined the impact of smoke on sleep. Rodney et al. examined the impact of direct exposure to smoke resulted from the 2019-2020 Summer wildfire in Australia in a sample of ($N = 2,084$), and found that nearly 50% of the sample reported sleep difficulties, with 37.2% reporting disrupted or poor sleep [25]. The impact of smoke seen on sleep can provide evidence on how PTSD symptoms may develop when sleep is affected. Rumination about wildfire trauma due to lack of sleep provides the platform for rehearsal of negative cognition and emotions leading to the contents of the trauma played in a way of nightmares [22]. Frequency of nightmares related to the actual trauma leads to further hyperarousal and sleep latency which can eventually lead to the development of psychopathology such as PTSD [22,58].

5.5 Predictors of insomnia, PTSD, and nightmares

The third hypothesis which stated that the number of losses, the impact of smoke on health, and fear for loss of lives due to the experience of wildfire, would predict scores on insomnia, nightmares and trauma symptoms was partially supported. For the insomnia model, while depression, anxiety, and PTSD symptoms contributed 41% to the overall model, smoke predicted insomnia by contributing 4.1% to the model. As highlighted above, the negative impact of smoke on the nervous system, the nasal congestion and sinus inflammation can lead to difficulties in initiation and/or maintenance of sleep leading to insomnia [25,57].

In relation to the PTSD model, insomnia significantly predicted PTSD symptoms. Prior research found that insomnia predicts the development of PTSD in both the general public and veterans [19,21]. The present findings are contradictory to what previous research has reported in relation to the association between trauma-related variables and PTSD symptoms [24,27,28].

The nightmare model showed that only insomnia significantly predicted the development of nightmares. In a longitudinal study, Miller and colleagues collected 468 morning reports of 31 veterans revealing that elevated respiratory event index and lower sleep periods respiratory sinus arrhythmia predicted nightmares. Sleep disordered breathing is a factor in nightmares [59]. It is possible that the negative impact of smoke which predicted insomnia can in turn lead to nightmares.

Taken the three models together, smoke from wildfires predicted insomnia. This is a novel finding and one that should be investigated further. The results from the models also showed that a bidirectional relationship between insomnia and PTSD may exist [15]. However, time in relation to fire occurrence, which the study did not take into account, can mask the true direction in the relationship between sleep disturbances and PTSD symptoms. The model also found that insomnia predicts nightmares. Rodent models provide support to the present findings. For example, Taranissi et al. explored the role of sleep disturbance in the development of PTSD in rodents using a "predator odour trauma" model. The mice were exposed to predator odour (soiled cat litter) for 90 minutes [20]. On day five of the experiment, when the mice were exposed to objective remainders of the odour, they displayed hyperarousal and sleep disruption which resulted in flashbacks in comparison to controls [20]. In consideration of the study's findings, it seems the constant

exposure to smoke can act as a reminder of the fire trauma which can disturb sleep leading to insomnia. The presence of insomnia then leads to the development of worry, avoidance of anxiety-related trauma, and increase in suppression of intrusive memories related to trauma [19]. The persistence of insomnia can interfere with processing of traumatic experiences causing further intrusive memories of the trauma and leading to nightmares and ultimately PTSD [22]. The impact of smoke (olfactory memory) is perhaps more strongly engraved in the brain more than verbal or visual memories of the trauma [60,61].

Conclusion

Insomnia, nightmares and PTSD symptoms were highly prevalent in wildfire survivors. Trauma-related variables such as number of losses, fear for loss of lives, imminence of death and additional acquired trauma following the fires were related to more severe insomnia, nightmares and PTSD symptoms. Finally, smoke from wildfire emerged as the most significant trauma-related predictor of insomnia, which, in turn predicted the development of both PTSD and nightmares symptoms.

Implications

Insomnia and nightmares can emerge in the acute phase of wildfire trauma as the impact of smoke is felt immediately during and after the trauma of wildfires. This theory in consideration, and given how COVID-19 pandemic changed the way health care is received and provided to consumers [62], early intervention in treating sleep disorders is essential. Furthermore, awareness about the impact of wildfire on sleep should become part of preparing vulnerable communities for the fire seasons. Furthermore, given the shortage of well-trained counsellors/psychologists, in the treatment of sleep disorder, particularly in regional and remote locations, digital therapies for sleep difficulties and trauma should be considered and promoted. There is also a need to provide and test the usefulness and effectiveness of digital treatment modalities for sleep difficulties in vulnerable communities that may not get access to face-to-face health care in a timely manner. Digital self-paced interventions are likely to benefit thousands of wildfire survivors. They can also meet the needs of the individual by increasing self-governance, increasing personal responsibility towards therapy, and by providing more privacy [63]. This will reduce both the burden of sleep disturbances and the subsequent development of serious psychopathology in communities affected by wildfires [11,12].

Limitations

The study would have been more informative if time of wildfire occurrence was measured relative to trauma and sleep disturbances symptoms. This would have provided more information about the timeline of the occurrence of sleep disturbances and trauma symptoms. Furthermore, an assessment of acquired trauma prior to wildfire trauma, would have provided more information to partial out the contribution of trauma caused solely by wildfire.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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