Chronic Mental Health Impacts of Climate Change Extremes: A Case Study of the Largest Californian Wild Fire

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Abstract

Background. Weather-related disasters such as droughts and fires as accelerated by climate change have led to substantial growth in interest in impacted health outcomes. While physical health outcomes have been studied in this context, our understanding of climate change impacted mental health is at its infancy. This study focuses on the mental health impacts of the largest Californian wildfire to-date, the Camp Fire of 2018.

Methods. We investigated a sample of 780 Californian residents with different degrees of disaster exposure, and measured mental health using clinically valid scales for post-traumatic stress disorder (PTSD), major depressive disorder (MDD), and generalized anxiety disorder (GAD); data were collected six months post-exposure to understand sustained chronic impacts. Data were modeled using multiple-regression analyses. Additionally, we included vulnerability and resilience factors in hierarchical regression analyses.

Results. Our primary finding is that direct exposure to large scale fires significantly increased the risk for all three mental health disorders, PTSD, MDD and GAD. Indirect exposure, for those who witnessed but did not personally experience the fires, increased the risk for MDD and GAD. Inclusion of vulnerability and resilience factors led to significantly improved prediction of all mental health outcomes. Low socio-economic status, childhood trauma and sleep disturbances were identified as vulnerability factors, while self-reported resilience had a positive effect on mental health. Mindfulness was associated with lower MDD and GAD symptom scores.

Conclusion. Overall, our study demonstrates that climate-related extremes such as fires severely impact long-term mental wellbeing. Additionally, pre-existing adverse life events, resilient personality traits and lifestyle factors play an important role in the development of psychopathology after such disasters. Unchecked climate changes of magnitude projected for the latter half of this century risk severely impacting the mental wellbeing of the global population.

Significance Statement

Environmental disasters are being accelerated by climate change and risk grave impact on human health. In a case study of the Camp Fire, the largest Californian wildfire to-date, we show that mental health was significantly impacted by fire exposure, including heightened prevalence of post-traumatic stress disorder, major depression and generalized anxiety disorders. We identified low socio-economic status, prior childhood trauma and sleep disturbances as vulnerability factors, and self-reported resilience as a positive mental health factor. Other lifestyle factors such as mindfulness, physical exercise and emotional support were protective factors especially in the case of depression. Our findings call for better understanding of mental health impacts of future climate changes, and for urgently developing remedial measures to cope with these impacts.

1. Introduction

Natural disasters, such as floods, cyclones and droughts, are predicted to increase as a consequence of climate change (1). The annual western forest-fire area in the US increased by ~ 1000% from 1984 to 2017 (2), and since the 1970s to 2018, particularly California has witnessed an eight-fold increase in the areal extent of fires (3, 4). During the same period the state has warmed by 1.4ºC (about 50% greater than global warming estimates) largely due to anthropogenic sources (2). In 2017–2018 alone, there have been approximately 16,000 wildfires reported in this state, with 2 million acres of land burned, resulting in 13.7 billion USD in costs of damages, and ~ 250 reported injuries, 25% of which have resulted in death (5, 6). Climate experts unanimously agree that climate change has had a definitive role to play in these disasters. These weather extremes combined with the large acres of dead tree fuel in California have resulted in frequent and large fires that are unfortunately predicted to escalate further in future years.

Climate change driven weather extremes, such as the California wildfires, are being associated with huge costs to human health (7). It is projected that the US population exposed to such climate extremes will nearly double by 2050, affecting nearly 25% of all humans in the US each year (8). Public health scientists and clinicians are continuing to study the critical impact of climate change related air pollutants on cardiovascular and respiratory health. There are certainly acute and chronic climate change-related health effects on the body that need to be better understood and mitigated in the future (9–12). Yet, the impact of climate change on mental health is far less acknowledged and discussed (13–15), even though prior studies stress the mental health consequences of environmental disasters (16–19). The two most common adverse mental health outcomes of natural disasters are depression and post-traumatic stress disorder (PTSD) (17). While research provides evidence for a cumulative impact of exposure to disasters (20, 21), most studies report data from the aftermath of a single disaster, and most of those again classified as natural disasters, and not climate-change driven extreme environmental events. Prior studies of wildfires provide evidence for mental health sequelae, particularly for PTSD symptoms in California residents in the immediate aftermath of the 1991 firestorm (22); symptoms were shown to substantially decreased over time (23). PTSD symptoms were also found in firefighters one-month after the occurrence of wildfires in Greece (24). To our knowledge, no research to date has addressed long-term differential mental health outcomes, i.e. PTSD, depression and anxiety symptoms in civilians exposed to climate-change accelerated wildfires.

A causal pathways framework suggests direct effects of climate change on mental health through exposure to traumatic stressors, as well as indirect effects mediated by impacted physical health, the physical environment or community wellbeing (25, 26). Prior research suggests that an adverse impact of environmental disasters is dependent on the degree of disaster exposure. In those studies, degree of exposure was defined objectively (e.g., as geographical distance of residence from the epicenter of the disaster) (27, 28) or subjectively (e.g., as degree of household damage) (27). It has also been shown that PTSD symptoms occur in relation to fire exposure particularly in highly exposed individuals, who experienced loss of residency or injuries (22). However, it remains an open question whether different degrees of physical and mental exposure differentially impact PTSD, depression and anxiety.

It has also been argued that the impact of fire expose on mental health is highly moderated by pre-existing vulnerabilities (29). One factor that has been found to influence the impact of stressful life events on mental health is past experience of childhood adversities. Previous research has shown that past-year stressful life events are associated with increase in current-year risk of mental disorders particularly in adults with adverse childhood experiences (30). Adversity in the form of child abuse and/or neglect is a transdiagnostic factor that increases risk for several mental disorders (31). A potential mechanism is stress sensitization (i.e., lower tolerance to stress due to adversities experienced early in life).

In addition to vulnerability factors it is important to identify survivors of serious environmental disasters who have the capacity to mitigate adverse outcomes. Particularly relevant in this context is the notion of resilience (i.e., the ability to recover quickly and adapt well in the face of adversities). Yet, only few studies to date have investigated dimensions of personal resilience in climate adaptation (23, 32). One personal resiliency characteristic that has been suggested as a pathway towards achieving sustainable climate adaptation is mindfulness (i.e., a non-judgmental attentiveness to the present moment) (33). Psychological resilience can also be conceptualized from a social-ecological angle. Particularly social support has consistently been highlighted as an indicator of resilience (32). Besides, specific lifestyle factors may strengthen resilience in developmental psychopathology. While sleep is known to play a crucial role in various mental disorders, recent research increasingly suggests that the relationship between sleep disturbances and symptom severity is bi-directional (34, 35). Altered sleep not only temporally precedes the onset of psychopathology, but may also serve as risk or resilience factor (36, 37). The role of physical exercise in preventing stress-related

psychopathology is supported by its effects on several neurobiological factors that affect individual resilience, including attenuation of stress responses and increased release of endorphins (38).

In the current study, we aim to understand the mental health sequelae of serious climate change related events, specifically, California's largest wildfire to-date - the 2018 Camp Fire. In addition to mental health impacts, we assess several factors that may serve as risk or resilience factors, so that ultimately we may have some insight whether or not an environmental disaster will incapacitate an individual towards rebuilding their displaced lives.

2. Materials And Methods

2.1. Sample

The study included 780 (mean age 26.56 ± 13.21; age range 18–84 years) California residents sampled in Spring 2019, six-months after the 2018 Camp Fire. Participants were recruited at three sites in California, one in San Diego, and two in Chico. While San Diego is at a distance of approximately 600 miles from the center of the Camp Fire, Chico is one of the cities whose residents were most affected, within 10–15 miles of the center of the Camp Fire. The samples recruited from Chico were either students in the department of psychology at the California State University (CSU) (sample n = 417) or individuals enrolled in the CSU Basic Needs program that provided disaster relief and community-based support directly to Camp Fire victims (sample n = 110) (39). The sample from San Diego was recruited at the University of California San Diego (UCSD, sample n = 253). The response rate of invited study participants from the CSU Basic Needs program was 37%; response rates could not be determined for CSU Psychology and UCSD samples as there was no determinable upper limit to the number of individuals who may have seen the recruitment advertisement. Based on these recruitment sites in relation to the Camp Fire, we refer to these groups as "primary proximity and help seeking" (those in the Basic Needs program), "primary proximity" (CSU students not in the Basic Needs program), "secondary proximity" (those at San Diego).

The study was approved by the institutional review boards (IRB) of the University of California San Diego and California State University at Chico. All study participants provided written informed consent. A sample comparison regarding demographic variables from the three recruitment sites is shown in Table 1.

Table 1
Sample demographics across all study sites

		Primary proximity help seeking M ± SD n (%)	Primary proximity M ± SD n (%)	Secondary proximity M ± SD n (%)	χ^2	*p*
Age		27.35 ± 9.74	21.60 ± 3.42	34.40 ± 19.41	107.20	< .001
Sex	Male	28 (25.5)	85 (20.4)	102 (40.3)	31.62	< .001
	Female	82 (74.5)	332 (79.6)	151 (59.7)		
Ethnicity	Caucasian	77 (70.0)	238 (57.1)	130 (51.4)	104.50	< .001
	African American	3 (2.7)	16 (3.8)	3 (1.2)		
	Asian	7 (6.4)	19 (4.6)	72 (28.5)		
	mixed/other	13 (11.8)	64 (15.3)	30 (11.9)		
	n/a	10 (9.1)	80 (19.2)	18 (7.1)		
SES		1.75 ± .68	2.11 ± .74	2.27 ± .72	40.03	< .001

Note. n/a = unknown or not reported, SES = socio-economic status (range 0–9). χ^2 = Chi-Square statistics derived from non-parametric group comparisons.

2.2. Measures

All study participants reported on the following measures at six-months after the 2018 Camp Fire. This time of assessment is considered suitable in signifying chronic mental health outcomes (40). The Research Electronic Data Capture (REDCap) tool was used for survey administration.

Demographics. Assessed demographic variables included age, sex, race (Caucasian, African American, Pacific Islander, Asian, American Indian or mixed), years of education and socio-economic status (SES). Due to low prevalence of individuals with American Indian or Pacific Islander origin (< 1%), we extended the racial category “mixed” to “mixed/other”. SES composite scores were assessed using the family affluence scale; this scale measures family wealth based on family ownership of objects of value (e.g., car/computer) and produces a composite score ranging

from 0 (low affluence) to 9 (high affluence) (41). Demographic predictors that have previously been associated with effects of environmental disasters on mental health include sex and SES (17).

Life events. We evaluated life events related to fire and to childhood adversity. For the former, we used the Life Events Checklist (LEC-5; (42)) from the Diagnostic and Statistical Manual of Mental Disorders (DSM-5), which assesses potentially traumatic events that might have happened at any time in life. It inquires the exposure to events on a 5-point nominal scale (happened to me = 1, witnessed it = 2, learned about it = 3, part of my job = 4, not sure = 5, does not apply = 0). The events cover a vast variety, yet we focused on an item assessing exposure to fire. Positive responses can be given to multiple levels of exposure, if applicable. Note that LEC-5 “witnessed it” responses on fire exposure pertain to real life events and do not include exposure to pictures or videos of the fire in the media. Note that we did not explicitly inquire about exposure to the 2018 Camp Fire as the CSU IRB objected to inclusion of such a direct question given its potential to lead to further traumatic stress.

Additionally, experiences of child maltreatment during the first 18 years of life were assessed using the 28-items brief screening version of the Childhood Trauma Questionnaire (CTQ; (43)). The CTQ is a self-administered retrospective inventory consisting of five categories of child neglect and abuse. Each category entails five items that are rated on a 5-point Likert scale ranging from “never true” (= 1) to “very often true” (= 5).

Mental health outcomes. All mental health scales for PTSD, depression and anxiety were assessed in self-report. PTSD symptom severity was measured using the PTSD-Checklist (PCL-5 (44)). The PCL-5 consists of 20 questions that cover experience of PTSD symptoms such as memories, dreams, avoidance of certain external or internal stimuli etc. Responses are given on a 5-point Likert scale asking how much one was bothered by these experiences from “not at all (= 0)” to “extremely (= 4)”. To assess major depressive disorder (MDD), we used the Patient Health Questionnaire (PHQ-9; (45)), a diagnostic instrument that scores each of the 9 DSM-5 criteria for MDD on a 4-point Likert scale assessing frequency of symptoms from “not at all” (= 0) to “nearly every day” (= 3). To assess Generalized Anxiety Disorder (GAD), we used the 7-item brief scale GAD-7 (46). Frequency of anxiety symptoms is scored on a 4-point Likert scale from “not at all” (= 0) to “nearly every day” (= 3).

Resilience factors. We assessed subjective resilience and resilient lifestyle factors, specifically, (I) sleep quality, (II) exercise, (III) mindfulness and (IV) emotional support.

The Brief Resilience Scale (BRS; (47)) measures resilience as the capacity to bounce back after tough times, with 6 items on a 5-point Likert scale, half of them inverted from “strongly disagree” (= 1) to “strongly agree” (= 5).

(I) Sleep quality was assessed with regards to sleep disturbances, using the short form of the Patient-Reported Outcomes Measurement Information System (PROMIS) - Sleep Disturbance scale (48). It consists of 8 items that assess sleep disturbances (e.g. “my sleep was restless”) in the past week on a 5-point Likert scale ranging from “not at all” (= 1) to “very much” (= 5).

(II) To investigate physical exercise, we use three questions of the Godin Leisure-Time Exercise Questionnaire (49). Participants are asked how many times on average during a typical 7-day period, they do strenuous, moderate or mild exercise for more than 15 minutes.

(III) The disposition of being mindful, which can be conceptualized as open and receptive awareness, was measured with the Mindful Attention Awareness Scale (MAAS; original scale by (50), implemented in the version described by (51)). The MAAS entails 14 items such as “I could be experiencing some emotion and not be conscious of it until sometime later.” that are inversely scored on a 6-point Likert scale from “almost always” (= 1) to “almost never” (= 6).

(IV) Due to its well documented impact on mental and physical health, we additionally measure emotional support from social relationships using the respective subscale from the NIH Toolbox on Social Relationships (SR) (52). The sum of 8 items on a 5-point Likert scale from “never” (= 0) to “always” (= 4) represents the presence and frequency of social support in the participants’ lives.

2.3. Data Analysis

Exposure to wildfires across participant subgroups.

We compared the participant subgroups recruited from the three sites in their self-reported degree of exposure to the wildfires. For this, we used the “fire or explosion” life event of the LEC-5 and computed chi-square tests for all five qualitatively different forms of exposure between the three participant pools. As the study sample was recruited from different locations in California, this analysis step is included to confirm that study participants in closer proximity to the outbreak of the fires were indeed more directly exposed.

Mental health outcomes of wildfires.

To study mental health outcomes of the wildfires, we computed separate multiple regressions for each mental health outcome. Group membership (directly exposed, indirectly exposed, not exposed) together with demographic variables age, sex, ethnicity and SES were modeled as predictors. Due to non-parametric score distributions in the mental health outcomes, we performed bootstrapping using 1000 bootstrap samples. We report two statistical measures of model fit. The F-test for overall model significance indicates whether the regression model fits the data, and R^2 indicates the percentage of explained variance of the outcome.

Using hierarchical multiple regression analyses, factors of vulnerability and resilience (i.e., childhood trauma, resilience, sleep quality, exercise, mindfulness and emotional support) were modeled as additional predictors. This approach allowed to test whether vulnerability and resilience factors add value to the prediction of mental health outcomes, as indicated by a significant increase in R^2 by means of model extension.

3. Results

3.1. Exposure to wildfires across participant subgroups

We confirmed significant differences between participant subgroups in their self-reported exposure to fire. While participants with secondary proximity to the Camp Fire mainly reported learning about the fires, $\chi^2 = 11.27$, $p = .004$, participants with primary proximity either witnessed the fires, $\chi^2 = 40.13$, $p < .001$, or were personally affected by the fires, $\chi^2 = 107.22$, $p < .001$ (i.e., primary proximity and help seeking subgroup) (Fig. 1). Additionally, for a very small percentage of participants (1.6% of secondary proximity; 1.4% of primary proximity; 1.8% of primary proximity and help seeking), exposure to fires were part of their work. Less than 1% of participants in each group were not sure how to classify their exposure to the wildfires.

3.2. Mental health outcomes of exposure to wildfires

In the following analyses, we refer to individual positive responses on “LEC-5: happened to me” as “directly exposed”, positive responses on “LEC-5: witnessed it” as “indirectly exposed”, and positive responses on “LEC-5: learned about it” as “not exposed”. Results of the bootstrapped multiple regression for mental health impacts (i.e., PTSD/ depression/

anxiety) as predicted by sample demographics and fire exposure (directly/ indirectly/ not exposed) is presented in Table 2.

Post-Traumatic Stress Disorder. The multiple regression model to explain variance in PTSD PCL-5 scores (mean 8.01 ± 16.39, score range 0–78) by demographic variables showed overall significance, $F = 3.03$, $p = .001$, $R^2 = .14$. Scores on the PCL-5 were significantly higher in directly exposed individuals (Fig. 2A). Besides, lower SES and Asian and mixed/other ethnic background was associated with higher PCL-5 scores.

Major Depressive Disorder. The multiple regression model to explain PHQ-9 scores (mean 6.90 ± 5.93; score range 0–27) was significant, $F = 8.07$, $p < .001$, $R^2 = .11$. In this model, individuals that were directly and indirectly exposed to fires showed significantly higher scores on the PHQ-9 (Fig. 2B). Besides, younger age, lower SES, Caucasian and mixed/other ethnic background was associated with higher MDD symptom severity.

General Anxiety Disorder. The regression model with GAD-7 scores as mental health outcome (mean 7.29 ± 5.61; score range 0–21) was significant, $F = 12.40$, $p < .001$, $R^2 = .16$. Both directly and indirectly fire exposed individuals reported higher symptom severity on the GAD-7 (Fig. 2C). Again, younger age, lower SES, and mixed/other ethnic background, and additionally male sex was related to higher scores on this measure.

Table 2
Mental health prediction by demographics and fire exposure

	PTSD				**MDD**				**GAD**			
			CI				*CI*				*CI*	
	β	f^2	LL	UL	*β*	f^2	LL	UL	*β*	f^2	LL	UL
Age	.03	.00	− .17	.28	− .08**	.03	− .10	− .05	− .10**	.07	− .13	− .08
Sex (male)	2.36	.00	-3.25	8.41	.35	.00	− .51	1.27	1.12*	.01	.29	1.98
Caucasian	5.63	.01	− .53	12.77	1.62*	.01	.29	2.89	.95	.00	− .21	2.10
African	15.76	.02	-2.60	34.46	1.29	.00	-2.05	4.84	.30	.00	-4.03	4.59
Asian	10.39*	.02	.68	20.01	.05	.00	-1.56	1.58	-1.41	.00	-2.81	− .00
mixed/other	12.49*	.03	3.43	21.99	2.83**	.02	1.23	4.59	2.02*	.01	.51	3.66
SES	-4.92*	.04	-8.83	-1.25	− .89*	.01	-1.55	− .24	− .88*	.01	-1.40	− .30
Not exposed	-4.56	.01	-9.79	1.17	− .33	.00	-1.16	.58	− .46	.00	-1.27	.45
Indirectly exposed	3.17	.01	-2.38	8.72	1.52*	.01	.58	2.39	1.25*	.01	.42	2.07
Directly exposed	10.11*	.06	4.43	15.59	1.80*	.02	.59	2.99	1.42*	.01	.36	2.51

Note. PTSD = Post-Traumatic Stress Disorder, MDD = Major Depressive Disorder, GAD = General Anxiety Disorder, *β* = regression weight, f^2 = effect size (.02 small, .15 medium, .35 large), CI = 95% confidence interval, LL = lower limit, UL = upper limit. Significance level * $\alpha < .05$, ** $\alpha \leq .001$

3.2. Influence of vulnerability and resilience factors

Post-Traumatic Stress Disorder. The hierarchical regression analyses to predict PTSD PCL-5 scores showed significantly improved model fit when including vulnerability and resilience factors, R^2 change = .35, $p < .001$. PCL-5 scores were positively associated with childhood trauma (CTQ) scores and negatively associated with resilience (BRS) scores. Out of the resilient lifestyle factors, only sleep quality was found to predict PCL-5 scores, with higher sleep disturbance (PROMIS) scores related to higher symptom severity (Table 3).

Major Depressive Disorder. Similarly, for MDD symptoms measured on the PHQ-9, the regression model including vulnerability and resilience factors in addition to demographics and fire exposure, was significantly improved, R^2 change = .43, $p < .001$. Higher childhood trauma scores and higher sleep disturbance scores, as well as lower resilience scores, lower exercise scores and lower mindfulness scores were related to higher PHQ-9 scores (Table 3).

Generalized Anxiety Disorder. Adding vulnerability and resilience factors as predictors of anxiety symptoms on the GAD-7, led to an increased model fit, R^2 change = .32, $p < .001$. There were significant positive associations with childhood trauma and sleep disturbance scores, and negative associations with resilience and mindfulness scores (Table 3).

Table 3
Mental health prediction by vulnerability and resilience factors

	PTSD				**MDD**				**GAD**			
			CI				*CI*				*CI*	
	β	f^2	LL	UL	*β*	f^2	LL	UL	*β*	f^2	LL	UL
Childhood Trauma	9.86**	.22	6.46	13.12	2.17**	.13	1.50	2.88	1.33**	.03	.70	1.92
Resilience	-1.26**	.16	-1.77	− .83	− .27**	.14	− .34	− .20	− .30**	.12	− .37	− .23
Sleep Disturbances	.56*	.05	.11	1.03	.28**	.23	.23	.34	.17**	.05	.12	.23
Exercise	− .03	.01	− .06	.04	− .01*	.02	− .01	− .00	− .00	.01	− .01	.00
Mindfulness	− .96	.01	-3.81	1.68	-1.58**	.16	-1.96	-1.20	-1.61**	.12	-1.99	-1.21
Emotional Support	.01	.00	− .02	.03	.00	.04	− .00	.01	.00	.01	.00	.01

Note. PTSD = Post-Traumatic Stress Disorder, MDD = Major Depressive Disorder, GAD = General Anxiety Disorder, *β* = regression weight, f^2 = effect size (.02 small, .15 medium, .35 large), CI = 95% confidence interval, LL = lower limit, UL = upper limit. Significance level * $\alpha < .05$, ** $\alpha \leq .001$

Discussion

The current study investigates mental health outcomes of a significant environmental disaster, the largest California wildfire in history. Our analyses include three groups of participants that were identified by local proximity as well as help seeking behavior post-fire. Previous research suggests an association of mental health outcomes after disasters, and the degree of exposure as measured in distance to the disaster, degree of household damage or physical injury (22, 27, 28). Here, in the context of fires, we confirmed that our cohort were directly exposed (i.e., to whom the fire happened to), indirectly exposed (i.e., who have witnessed the fire) and not exposed (i.e., who have learned about the fire) as per their self-reported fire exposure. With regard to mental health outcomes, significantly higher symptom

scores on all mental health outcomes of PTSD, MDD and GAD were found in directly exposed individuals. Additionally, indirectly exposed individuals had higher levels of MDD and GAD symptom severity than not exposed individuals. While previous research suggests similar short- and long-term impacts of direct and indirect exposure on mental health (53, 54), our results suggests that PTSD symptoms are particularly associated with a direct exposure to the fires, while risk of MDD/GAD mood disorders is additionally elevated by indirect exposure.

PTSD, MDD and anxiety disorders can all be conceptualized as stress-related disorders, for which environmental stressors and individual (biological and psychological) stress responses are central to pathogenesis. In line with this, not only the experience of wildfires, but also childhood trauma (i.e., child abuse and neglect) was consistently found to increase risk of all of these symptoms. This may be particularly relevant in the study samples from Chico, as over 70% of the population are reportedly affected by childhood adversities (55). Our findings thus support the notion that adverse childhood experiences may serve as a vulnerability factor for mental health sequelae in adulthood (31). On a similar note, lower socio-economic status was also identified as a consistent predictor of PTSD, MDD and GAD symptoms.

We further included measures of resilience and resilient lifestyle in our study. Several factors, including personal, social, economic, institutional, infrastructure, and community resources, may contribute to resilience and adaptation to environmental disaster, and can be used as indicators thereof. Our study focuses on personal resilience as the ability to bounce back after stressful life events, as well as sleep quality, physical exercise, mindfulness and emotional support, which are all contributors to resilience. As hypothesized, we consistently found self-reported resilience to be inversely associated with PTSD, MDD and GAD symptom severity. Besides, lower levels of sleep disturbances were related to lower scores on all clinical symptom scales; these results highlight the relevance of sleep in mental health, although our analyses cannot disentangle whether sleep disturbances were symptomatic of the mental disorders or a risk factor to their development (35).

Additionally, mood disorders (MDD and GAD) were negatively associated with mindfulness. It has been argued that mindfulness may support a fundamental shift in the way we think about and act on local and global ecological crises (56), and thus plays a role in developing psychological resilience. Recent evidence shows that mindfulness correlates with responses to severe climate events, recovery, and proactive climate adaptation (57). As much as trait mindfulness is considered to relate to greater psychological adjustment following exposure to trauma in general, we did not find an effect of mindfulness on PTSD symptoms. Similarly, a study in Tsunami disaster survivors didn’t find a positive effect of trait mindfulness on PTSD symptoms, indicating that mindfulness may not be a protective factor against posttraumatic stress in trauma-exposed individuals (58). Apart from mindfulness, physical exercise and emotional support were found to affect only MDD symptom severity in a positive manner, and didn’t have an effect on levels of PTSD and GAD.

Our primary finding is that climate related extremes such as fires severely impact mental wellbeing. With respect to fire disasters, mental health outcomes in civilians are dependent on the degree of fire exposure, pre-existing vulnerabilities due to low socio-economic status and childhood adversities, trait resilience and quality of sleep. Mindfulness can serve as a protective factor for depression and anxiety, and also exercise shows a buffering effect in the case of depression. This implies that bolstering skills in resilience can be an effective tool in urgently needed disaster relief efforts and programs (59). The ways in which we respond to climate change accelerated environmental disasters pose a complex global sustainability challenge. Proactive climate adaptation requires a set of resilient personality traits and lifestyle factors that preserve mental health and facilitate a much-required cultural shift towards sustainability.

These findings have important implications for societal adaptation to future climate changes. The planet has already warmed by 1^0C, since the early twentieth century. In the absence of mitigation steps to bend carbon emissions, the

warming is projected to increase four-fold to 4^0C, exposing almost 80% of the world population to extremes such as heat waves. Our findings call for a major new focus on evaluating the mental health effects of climate extremes and for developing remedial measures to cope with them at-scale.

Declarations

- **Ethics approval and consent to participate.** All study participants provided written informed consent to participate. The study was approved by the institutional review boards of the University of California San Diego (IRB#180140) and California State University at Chico (IRB#22838).
- **Consent for publication.** Not applicable.
- **Availability of data and materials.** The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.
- **Competing interests.** The authors declare that they have no competing interests.
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- **Authors' contributions.** SS and JM designed the study. MK, MCW and GG collected the data. SS, MK, MCW and GG analyzed and interpreted the results of the data. SS, VR and JM wrote the manuscript. All authors read and approved the final manuscript.
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Figures

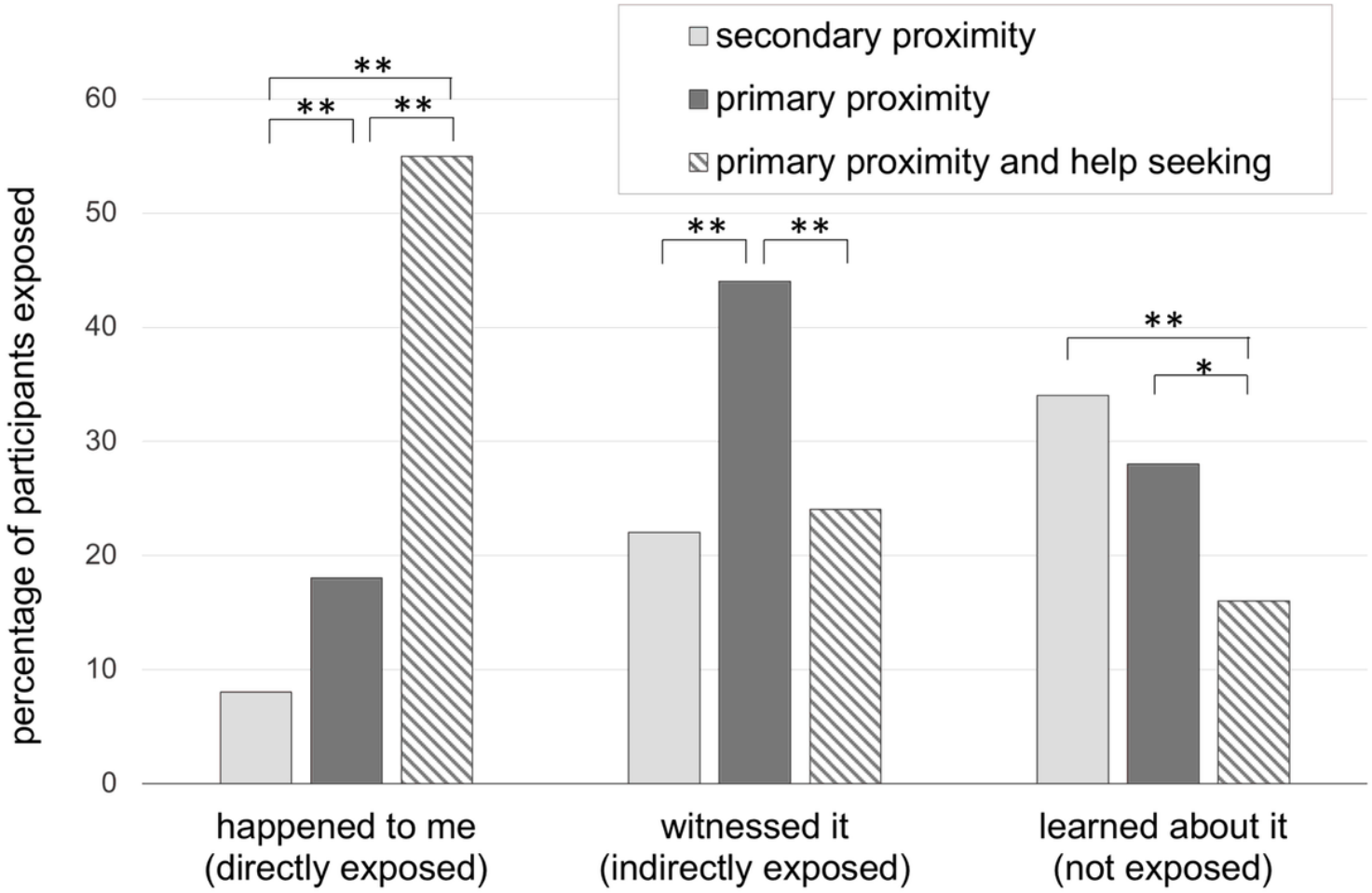

Figure 1

Exposure to fires in individuals in primary proximity to the 2018 California Camp Fire with or without help seeking behavior and in secondary proximity to the wildfire. Group differences with significance level * α < .05, ** α ≤ .001

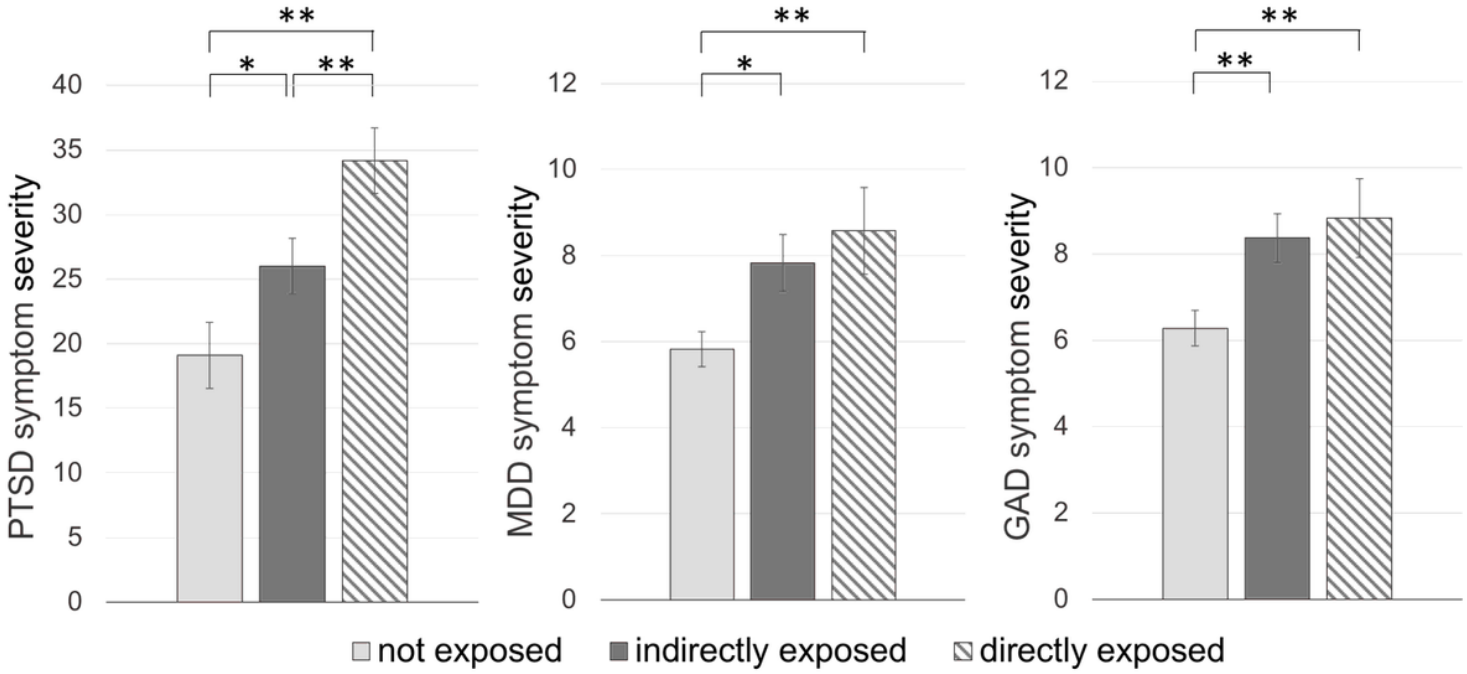

Figure 2

Mental health outcomes in individuals with different degrees of fire exposure. Means and standard errors are plotted. Group membership was determined by highest level of exposure. Sample size of groups were near equivalent; “not exposed” n = 138, “indirectly exposed” n = 223, and “directly exposed” n = 156. Significance level * α < .05, ** α ≤ .001 of Mann-Whitney U statistics. PTSD: post-traumatic stress disorder; MDD: major depressive disorder; GAD: generalized anxiety disorder.