IMPROVING DISASTER HEALTH OUTCOMES AND RESILIENCE THROUGH RAPID RESEARCH IMPLICATIONS FOR PUBLIC HEALTH POLICY AND PRACTICE

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Table of Contents

Editorial: Improving disaster health outcomes and resilience through rapid research: Implications for public health policy and practice

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Editorial on the Research Topic
Improving disaster health outcomes and resilience through rapid research: Implications for public health policy and practice

Rapid research during and following a disaster

The need for researchers to respond to disasters becomes more vital as natural disasters, outbreaks, and pandemics become more frequent and severe across the globe, with devastating, extensive, and prolonged effects on some people's physical and mental health, social and personal relationships, and welfare (1–3). The increasing frequency and severity of natural disasters is exacerbating their cascading and compounding effects. Disaster research helps us to better understand population needs in terms of coping, stress, resiliency, the ability of organizations to deliver urgent services and supports, and the immediate and long-term effects of disasters on the health and wellbeing of residents, communities' and first responders. The findings from disaster research also demonstrate important lessons that can inform current and future policy decisions related to disaster or emergency mitigation, prevention, recovery, and community resiliency. Governments and healthcare organizations across the globe have relied on rapid research efforts to quickly understand the immediate health and social effects from disasters, and to inform prevention, mitigation, and recovery strategies (4–6). Examples of government-funded rapid research include the Ebola, SARS, and Zika Virus outbreaks, major natural disasters including the 2016 Horse River Wildfire in Alberta, Canada and the 2019-2020 bushfires

in Australia, and more recently the global COVID-19 pandemic. The current COVID-19 pandemic has seen the scientific community rapidly conduct research to improve our understanding of the virus and its wider societal impacts, and to provide the evidence-base for governments to make decisions (4). Enabling rapid research during and after a disaster allows for the real-time collection and analysis of data essential to an effective evidence-informed response.

Gaillard and Gomez coined the term "research gold rush" to describe the post-disaster rush to identify and understand the immediate effects after high profile disasters (7). Although responses to disaster events typically use the best available science for quickly gathering information to support rapid delivery of services and interventions to communities and populations affected, additional research, done during and after the response itself, is often essential to address pressing knowledge gaps presented by disasters (such as longer-term effects on a population and health system responsiveness to address urgent population health needs) and to ensure that they are addressed by the time another similar disaster happens (8, 9).

In this Research Topic titled, *Improving Disaster Health Outcomes and Resilience through Rapid Research: Implications for Public Health Policy and Practice*, scholars explore research conducted from rapid funding opportunities to address urgent disasters across geographical settings; examine how to integrate rapid research into existing disaster and emergency response structures; identify critical research needs and priorities; identify obstacles and barriers to conducting disaster research; examine health, mental health, social and environmental effects across diverse population groups and first responders; explore ethical and sensitive approaches to conducting disaster research with vulnerable communities; implement and report findings from rapid interventions; explore innovative methods and approaches for both rapid and longer-term research; and support evidence-informed policy decisions for government, private and non-profit sectors post-disaster.

McFarlane and Norris define disasters as "a potentially traumatic event that is collectively experienced, has an acute onset, is time-delimited… [and] may be attributed to natural, technological, or human causes" (10). This Research Topic was launched in Summer 2020 with an explicit aim to advance knowledge and scholarship on the health, social and environmental consequences of natural disasters. We were especially focused on rapid and effective interventions to support affected populations, and on identifying best practices for conducting community-based or scientific research on disaster-related health effects. The guest editors of this Research Topic came together with a shared commitment to promoting ethical and sensitive approaches to research and meaningful outcomes in a post-disaster environment. While this Research Topic focused solely on research related to natural disasters, it offers important insights and lessons for academics, government, non-profit and health system leaders conducting rapid research during public health crises, such as a pandemic.

Conducting responsive and ethical disaster research

The realities of research on disaster or emergency crises are different from other types of empirical academic research, especially in populations suffering greatly. Health and social science researchers in the affected areas are often untrained in disaster research; the community, people, and services to be studied are often in disarray; and participants in the affected areas may be overwhelmed by the high number of research investigations or needs assessments that occur to examine impacts to residents and the environment (11). The issue of over-research is widely acknowledged by researchers generally, but has received little attention in disaster-related health studies (12). Furthermore, the immediate attention paid by researchers to examine the effects of a disaster on a population may interfere with the time required for people to heal or recover from the disaster.

Researcher sensitivity to the vulnerability of the populations affected is also critical. For instance, research participants may be at risk of re-traumatization and/or physical harm from talking about their experience Pazderka, Brown, Agyapong et al.. Also, inadequate recruitment strategies may cause additional burden or stress on participants, such as feelings of being used for research purposes. Being aware of the challenges, obstacles, and difficulties associated with this area of inquiry prior to conducting research after a disaster, and building in contingencies to deal with any additional burden or distress for participants, may facilitate sensitive approaches to research and more productive and beneficial research efforts.

Recent events have also illustrated gaps in planning for, and rapidly executing, scientific research in the context of a crisis. Although timely research of populations affected by disasters has been identified as a priority for disaster preparedness, response, and recovery; several important ethical issues prior to the onset of disasters need to be addressed, such as minimizing risks, promoting benefits to participants, and attending to systemic inequities some population groups experience with access to health services (13). Oulahen, Vogel and Gouett-Hanna emphasize building on existing local expertise by engaging and co-producing knowledge with the people and communities affected by a disaster (6). Establishing strong research relationships grounded in trust and reciprocity can stand in contrast to the urgency and timeliness of rapid research responses (6).

In this Research Topic, we consider some of these ethical issues by drawing on insights gained from rapid research during or immediately following natural disasters. For instance, the article by Fitzpatrick et al. described that many services and programs that were delivered following the 2016 Horse River wildfire in Alberta were limited in scope and resources and did not account for pre-existing inequities in access to health and mental health services among Indigenous residents

and communities, which were heightened after the wildfire. Thériault et al. qualitatively examined the experiences of evacuees during the 2016 Horse River wildfire evacuation and highlighted the importance of tailoring recovery responses to the needs of evacuees, providing support over a longer period of time, and building on local expertise.

Furthermore, important information on the health, social and environmental effects from a disaster that needs to be collected during and immediately following these disasters is often missed because of barriers and obstacles to gathering such data, such as length of time taken by institutional ethics review boards (14), lack of knowledge around how best to integrate research into government response and recovery frameworks, and limited time, funding and resources to study longer-term health and mental effects post-disaster of affected populations. Several articles in this Research Topic highlight how mental health effects among adults, children, and youth persist for several years following a disaster Belleville et al., Brown et al.. For instance, Brown et al. found that mental health effects persisted in youth for years following Alberta's Horse River wildfire and highlighted the need for multi-year mental health support programs for youth in post-disaster situations. Yang et al. showed delayed-onset post-traumatic stress disorder (PTSD) symptoms continue to affect earthquake survivors from Wenchun Earthquake in China 10-years later. Moreover, Thériault et al. argue that few studies adopt a longitudinal lens to examine the evolution of the consequences of disasters. Rodney et al. designed a survey to be deployed quickly to capture a broad snapshot of a population's health in response to a bushfire smoke event in Australia. While the survey allowed the researchers to capture experiences from a broad cross-section of the population, they noted a limitation with this method was the ability to capture complex information such as mental health problems and post-traumatic stress, requiring a more detailed examination of social and economic factors and over a longer period. However, the survey provided, as planned, an important baseline for ongoing research on the long-term effects of exposure to bushfires and bushfire smoke.

Mental health impacts post-disaster among vulnerable populations

As described above, several articles published in the Research Topic examined increased rates of mental health problems, PTSD, among vulnerable and high-risk population groups. Hyde et al. recruited a cohort of mothers who were pregnant or post-partum during Alberta's Horse River wildfire and found that these women experienced clinically significant PTSD Hyde et al.. Brown et al. reported on results of a survey among school-aged children and adolescents following the same wildfire event and observed higher levels of mental health distress among

older students, in females compared to male students, and in transgender and gender-non-conforming individuals Brown et al.. Within this same population group, Pazderka, Brown, Agyapong et al. examined the effects of collective trauma and found that youth who experienced prior trauma had higher rates of mental ill-health post-disaster. Moreover, findings from these studies emphasize the importance of addressing the social determinants of health as protective factors for mental health during a disaster. Also, underserved populations such as Indigenous communities are especially vulnerable to experiencing poor mental health because of pre-existing structural and systemic inequities that existed prior to the disaster Fitzpatrick et al.

Future directions

To facilitate rapid, responsive, and relevant disaster research, we need rapid-learning research systems that integrate researchers, funders, health and social systems, frontline workers, and community partners asking relevant research questions, using innovative research designs and methods, and leveraging rich, longitudinal data across a range of population groups and communities affected. These systems need to be established prior to a disaster and be ready for rapid mobilization. Disasters are important in the policy process because they can open windows of opportunity for elevating issues onto the government agenda (15, 16). It is therefore important to generate rapid, real-time evidence to catalyze opportunities for policy change and effective responses, supported by lessons learned from the disaster event (17).

Author contributions

SM lead the submission for the Research Topic in Frontiers, provided oversight on editorial process for article submissions, and lead the writing of the editorial. IW and AWHC participated as the assigned editor for articles submitted to the Research Topic and reviewed drafts of the editorial. All authors contributed to the editorial and approved the submitted version.

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to bring disaster health researchers together to conceptualize the main goals and focus of the Research Topic.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Psychological Symptoms Among Evacuees From the 2016 Fort McMurray Wildfires: A Population-Based Survey One Year Later

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Background: The 2016 wildfires in Fort McMurray (Alberta, Canada) led to a massive displacement of 88,000 people and destroyed 2,400 homes. Although no direct human fatality resulted, many individuals feared for their lives or those of their loved ones.

Objectives: (1) To estimate the prevalence of post-traumatic stress, major depressive, insomnia, generalized anxiety, and substance use disorders in the adult population of Fort McMurray 1 year after the evacuation; (2) To identify pre-, peri-, and post-disaster correlates of mental health disorders.

Methods: A phone survey using random digit sampling was used to survey evacuees. A total of 1,510 evacuees (response rate = 40.2%, 55.5% women, mean age = 44.11, SD = 12.69) were interviewed between May 9th and July 28th, 2017. Five validated scales were administered: the PTSD Symptoms Checklist (PCL-5), the Insomnia Severity Index (ISI), the depression and anxiety subscales of the Patient Health Questionnaire (PHQ-9, GAD-7), and the CAGE Substance Abuse Screening Tool.

Results: One year after the wildfires, 38% had a probable diagnosis of either post-traumatic stress, major depressive, insomnia, generalized anxiety, or substance use disorder, or a combination of these. Insomnia disorder was the most common, with an estimated prevalence of 28.5%. Post-traumatic stress, major depressive and generalized anxiety disorders were almost equally prevalent, with ~15% each. The estimated prevalence of substance use disorder was 7.9%. For all five mental health disorders, having a mental health condition prior to the fires was a significant risk factor, as well as having experienced financial stress or strain due to the economic decline already present in Fort McMurray. Five post-disaster consequences were significant predictors of four of the five disorders: decrease in work, decrease in social life, poorer current health status, increase in drug and alcohol use, and higher level of stress experienced since the fires.

Conclusion: One year after the fires, more than one third of the evacuees had clinically significant psychological symptoms, including those of insomnia, post-traumatic stress, depression, anxiety, and substance use. This study helped identify individuals more at risk for mental health issues after a natural disaster and could guide post-disaster psychosocial support strategies.

INTRODUCTION

In a natural disaster, physical injuries and material losses go alongside emotional distress, psychosocial problems as well as mental health disorders which can linger years after the event. The mental health consequences of natural disasters are increasingly recognized, although they remain difficult to assess and to address. Systematic reviews indicate that up to 40% of individuals exposed to a natural disaster will develop stress-related or adjustment disorders such as post-traumatic stress disorder (PTSD), major depression, substance use disorders (SUD), insomnia, or complicated bereavement (1, 2). A general consensus in the disaster-related literature is that mental health issues should be an integral part of the medical and emergency response (2). Monitoring the long-term consequences of disasters on mental health and providing ongoing psychosocial support and specialized mental health care to individuals and communities has been identified as a critical gap by a panel of disaster management experts convened by the World Health Organization in 2018 to identify key emergency and disaster research needs (3).

In North America, wildfires causing damage and evacuations in urban areas have been increasing in the past 30 years, a trend that is thought to continue due to climate change (4). The long-term mental health impacts of wildfires have received relatively limited attention to date. After the 2003 California fires, one study showed that two-thirds of participants had reported having feared for their own life or for the life of a loved one; 3 months after the fires, one quarter of respondents met the criteria for PTSD, and one third met the criteria for major depression (5). One study noted a significant increase in anxiolytic drug consumption after a wave of wildfires in Spain (6). Compared to a control group, persons exposed to wildfires in Greece were observed to have significantly higher somatization, depression and anxiety symptoms, and higher levels of paranoia, hostility, and phobic anxiety (7, 8). Three to 4 years after the Victorian Black Saturday bushfires in Australia (2009), 16–22% of individuals in communities affected by the fires were still found to meet the criteria for PTSD and 13% suffered from major depression (9), indicating that mental health effects are still measurable several years after the event. These studies report precious epidemiological data, but are less informative of the predictors of the development of mental disorders.

In May 2016, a major wildfire affected the Fort McMurray area in Alberta, Canada, destroying 2,400 homes and businesses (10). Approximately 88,000 persons were evacuated. Although there were no deaths directly linked to the wildfire, two persons lost their lives in an accident during the evacuation, and many individuals had to face potential threat to their life or that of their loves ones, for example, by evacuating on roads with fire on both sides, seeing houses on fire or collapsing. A significant number of people were separated from loved ones or experienced important issues with communicating with family members during the evacuation (Thériault, Belleville, Ouellet, and Morin, submitted). Many families were relocated for several months and incurred significant material losses and financial stress.

Three to 5 months after the Fort McMurray fires (July-September 2016), our team collected data on a sample of 379 evacuees with an online questionnaire and conducted standardized psychodiagnostic interviews (in-person or by phone) with a subsample of 55 individuals (11). Although this was a convenience sample, 62.5% were found to have clinically significant symptoms of post-traumatic stress disorder (PTSD) as measured by the PTSD Symptoms Checklist (PCL-5). Among those who completed the psychodiagnostic interview, 29.1% met the criteria for PTSD, 25.5% for major depression, and 43.6% for an insomnia disorder. Another team evaluated 486 residents 6 months after the fires and found that 13% suffered from probable PTSD (15% in females vs. 9% in males) and 20% suffered from probable Generalized Anxiety Disorder (GAD) (12). Taken together, these results indicate rates of mental health issues in the first few months after the disaster that were significantly higher than in the general population.

According to Bonanno (13, 14), reactions to traumatic events are quite heterogeneous and evolve differently across individuals: while many initially experience intense psychological reactions which subside more or less rapidly, other individuals are resilient throughout the aftermath, others still may experience delayed reactions or gradual recovery and some can unfortunately develop chronic mental health issues. Predicting who will develop more serious and pervasive mental health issues requiring clinical attention or psychosocial support is important to increase the preparedness of communities in dealing with the long-term mental health consequences of wildfires and other natural disasters. The level of exposure to the disaster itself and the consequences of the disaster (peri and post-disaster factors) are known to be linked to psychological outcomes. Six months following the Fort McMurray fires, Agyapong et al. (12) found that having witnessed houses being destroyed by the fire,

being relocated, and having little support from the family or government were linked to the presence of symptoms of GAD and/or PTSD. Having experienced physical or mental health issues prior to the disaster also increased the risk for mental health issues post-disaster (12, 15). Importantly, the consequences of a natural disaster are often superimposed onto ongoing problems or chronic issues affecting the community (and as such add stress on the individuals), for example, economic uncertainty, psychosocial problems, and difficulties with access to health services, which can interact with post-disaster individual impacts such as job stress, or job relocation (16). In sum, individual and collective psychosocial factors are known to contribute to psychological adaptation after disasters (17).

In a recent review including 40 disasters having occurred between 1982 and 2017, Lowe and colleagues (18) identified several recurring predictors of post-disaster mental health issues: female gender, being at a socioeconomic disadvantage, high exposure during the disaster (e.g., seeing damage or injury first-hand), and having more limited psychosocial resources (18). This review was however limited to PTSD and depression symptoms. Several other mental health outcomes need to be examined including anxiety, insomnia and substance use. Furthermore, it remains unclear which factors are common to the emergence of difference types of psychopathology. It is essential to obtain a clearer picture of the various types of psychological problems that emerge and to identify the predictors of mental health issues, especially potentially modifiable factors which could be intervened upon. Indeed, identifying individuals at greater risk of developing mental health disorders in the long-term after a disaster could help communities better organize psychosocial support or interventions to foster resilience. Such knowledge could be precious in a preventive perspective as wildfires will continue to affect communities in the future. The present study thus aimed to evaluate multiple mental health issues after a disaster and to examine a large spectrum of potential predictors, including pre-, peri, and post-traumatic factors. The specific objectives of this study were (1) to document the presence of probable mental health disorders in the adult population of Fort McMurray 1 year after the evacuation, namely PTSD, major depression, insomnia, GAD and substance misuse and; (2) to identify pre- peri and post-disaster sociodemographic, health and disaster-related factors accounting for symptom severity.

METHOD

Participants and Procedure

To participate in this study, respondents had to be aged 18 or older, be fluent in English, be physically or mentally able to complete the interview and be a current or former Fort McMurray resident who had been evacuated from their home during the 2016 fires. A professional interview firm (BIP Research) drew a random sample of 10,000 home phone numbers and 10,000 mobile phone numbers in Fort McMurray, using the ASDE Sampling Software (ASDE Inc.). Forty-five interviewers worked on the project, supervised by two BIP

supervisors as well as the PI (GB), a psychologist specialized in PTSD and a co-PI (MCO), also a certified psychologist. To ensure validity and standardization of the calls, 15% of interview hours were reviewed by a supervisor (315 h). A total of 12,318 numbers were called between May 9th and July 28th, 2017. The response rate was 40.2% and average length of interview was 26.4 min (**Table 1**). The institutional review board of Université Laval approved the research protocol, and participants provided informed consent.

Measures

We developed questions to assess the respondents' socio-demographic characteristics (age, gender, ethnicity, membership in a First Nation, marital status, level of education, work status before the fires, and number of persons depending on the respondent such as children or persons with restricted mobility). Variables describing the status of participants before the fires included: health status (on a 5-point scale ranging from poor to excellent), presence of a serious physical (such as diabetes, heart problems, or cancer), and mental health problems (such as depression, anxiety, or alcohol or drug abuse), and whether the respondent was experiencing financial strain or stress due to the economic turndown in Fort McMurray. Eight questions assessed participants' experience of the fires and evacuation (peri-traumatic variables): we assessed the subjective level of fear experienced during the evacuation (on a 0–10 scale), and whether the respondent was on duty as a first responder. Level of exposure to the traumatic event was assessed by six yes/no questions asking whether the respondent smelled smoke or fire, saw buildings or surroundings on fire, feared for the safety of a loved one, saw explosions or buildings collapsing, feared for their own safety, or was separated from a loved one. Consequences of the fires (or post-traumatic variables) included the subjective level of material loss or damage and the subjective level of stress experienced since the fires (on a 0–10 scale), the number of days evacuated, whether they suffered loss or damages to their household content, their house or apartment, sentimental possessions, car or truck, pets, or other things, changes in work status, whether they returned to live in the same home, activity decrease in work, in sports and leisure, or in social life, current health status (on a 5-point scale ranging from poor to excellent), whether they were having problems with finances and money or with insurance claims, and whether they had increased their alcohol and/or drug use. Descriptive data are presented in **Table 2**.

We used five validated self-report questionnaires to estimate the prevalence of post-traumatic stress, major depressive, insomnia, generalized anxiety and substance use disorders. The *PTSD Checklist for DSM-5* (PCL-5) (19) is a self-reported questionnaire that assesses post-traumatic symptoms in the last month. It includes 20 items rated on a 5-point Likert scale. Total severity scores range from 0 to 80, with a higher score indicating greater severity. A cutoff score of 33 discriminates between people with or without PTSD and was used to indicate probable PTSD. The *Insomnia Severity Index* (ISI) (20) is a self-reported questionnaire that assesses insomnia symptoms in the last month. It includes seven items scored on a 5-point Likert scale assessing

TABLE 1 | Data collection.

Collection dates: May 9th to July 28th 2017
Interview mean duration: 26 min
Total phone numbers: 12,318

	Frequency	Total
A. Invalid phone numbers		**6,237**
Out of service	5,738	
Non-residential	316	
Fax/Modem	183	
B. Exclusion		**1,739**
Language	98	
Unable to complete the interview (Age/Disease/Incapacity)	95	
Duplicate (cellular /wired)	115	
Has not been evacuated	1,221	
<18 years old	59	
Out of sector	151	
C. Undetermined admissibility		**1,530**
No answer/Voice mail[a]	571	
Refusal before assessment of admissibility	959	
D. Admissible respondents without complete interviews		**1,302**
Prolonged absence	0	
Incomplete interview	17	
Appointment after the end of data collection	40	
Refusal after confirmation of admissibility	1,245	
E. Complete interviews		**1,510**
Response rate[b,c]	$\frac{E}{C^*(A.R.)+D+E} = \frac{1,510}{3,757} = 0.402$	

[a]*A phone number is categorized as "no answer" if it has always been unanswered throughout the data collection. For example, an incomplete interview for which there was subsequently no answer at the time of the second appointment is categorized as "incomplete interview" and not as "no answer".*
[b]*Computed according to the Canadian Marketing Research and Intelligence Association norms (https://mria-arim.ca/).*
[c]*Admissibility Rate (A.R.)* $= \frac{D+E}{B+D+E} = \frac{2812}{4551} = 0.62.$

sleep difficulties related to falling asleep, maintaining sleep and early morning awakenings, satisfaction with sleep, interference of problems with daily functioning, the perceptibility of the difficulties associated with sleep problems as well as the level of distress related to the sleep problems. Total severity scores range from 0 to 28, with a higher score indicating greater severity. A cutoff score of 10 is optimal to detect insomnia in a community sample (21) and was used to indicate probable insomnia disorder. The *Patient Health Questionnaire Depression Scale* (PHQ-9) (22) is a self-reported questionnaire that assesses depressive symptoms in the last 2 weeks. It includes nine items on a 4-point Likert scale (from 0 = Not at all to 3 = Nearly every day). Total

TABLE 2 | Sample characteristics.

Sociodemographic characteristics		
	M	SD
Age	44.11	12.69
	n	%
Gender		
Female	838	55.50
Male	672	44.50
Other/Prefer not to say	0	0
Ethnicity		
White	1,116	73.9
Asian or Pacific Islander	159	10.5
Black or African American	65	4.3
Native American or American Indian	57	3.8
Hispanic or Latino	38	2.5
Metis	27	1.8
Other or Prefer not to say	48	3.2
Member in a First Nation	93	6.2
Marital Status		
Married or domestic partnership	1,105	73.2
Single, separated, divorced or widowed	399	26.4
Level of Education		
Primary	36	2.4
Secondary	403	26.7
Post-secondary without bachelor degree	597	39.5
Bachelor	342	22.6
Master	113	7.5
Doctoral	15	1.0
Work Status (before the fires)		
Full or part time work	1,159	76.8
Homemaker	109	7.2
Retired	87	5.8
Unemployed/out of work/welfare	87	5.7
Student	38	2.5
Sick leave/invalidity	29	1.9
Number of persons depending on the respondent (e.g., children, persons with restricted mobility)		
None	611	40.5
1	276	18.3
2	303	20.1
3	174	11.5
4 – 9	139	9.2
Status before the fires (pre-traumatic)		
	n	%
Health Status		
Excellent	447	29.6
Very good	410	27.2
Good	531	35.2
Fair	88	5.8
Poor	34	2.3
Physical health problem	148	9.8
Mental health problem	177	11.7
Financial strain or stress due to economic turndown	346	22.9

(Continued)

TABLE 2 | Continued

Experience of the fires (peri-traumatic)		
	M	SD
Subjective level of fear (0–10)	6.51	2.88
	n	%
Level of exposure		
Smelled smoke or fire	1,456	96.4
Saw buildings or surroundings in fire	1,220	80.8
Feared for the safety of a loved one	1,070	70.9
Saw explosions or buildings collapsing	390	25.8
Feared for their own safety	856	56.7
Separated from a loved one	762	50.5
On duty as first responder	67	4.4

Consequences of the fires (post-traumatic)		
	M	SD
Subjective level of material loss or damages (0–10)	2.70	3.28
Subjective level of stress since the fires (0–10)	5.64	3.06
Number of days evacuated[a]	Mean: 46.57 Median: 35 Mode: 30 Range: 0–420	38.89
	n	%
Loss or damages		
Household content	698	46.2
House or apartment	427	28.3
Sentimental possessions	210	13.9
Car or truck	183	12.1
Pets	66	4.4
Other[b]	188	12.5
Work status change	252	16.7
Returned to live in the same home	1,264	83.7
Activity decrease		
Work	461	30.5
Sports and leisure	516	34.2
Social life	596	39.5
Health status (current)		
Excellent	336	22.3
Very good	375	24.8
Good	526	34.8
Fair	209	13.8
Poor	64	4.2
Problems with finances or money	427	28.3
Problems with insurance claims	401	26.6
Alcohol/drug use increase	145	9.6

[a]51 (3.4%) respondents had not returned home yet at the time of the survey.
[b]Including, in descending order of representativity: Backyard equipment, Lost everything, Recreational vehicles, Rental property, Food, and Clothes.

severity scores range from 0 to 27, with a higher score indicating greater severity. A cutoff score of 10 has been documented as optimal to detect probable Major Depressive Disorder (MDD). The *Patient Health Questionnaire Generalized Anxiety Disorder Scale* (GAD-7) is a 7-item self-reported scale used to identify probable cases of GAD and assess anxiety symptom severity in clinical practice and research (23). It includes seven items rated on a 4-point Likert scale (from 0 = Not at all to 3 = Nearly every day). Total severity scores range from 0 to 21, with a higher score indicating greater severity. A cutoff score of 10 is optimal to screen for GAD in clinical settings (23) and was used to indicate probable GAD. The *CAGE* (Cut down, Annoyed, Guilty, and Eye-opener) (24) is a short 4-item self-reported screening tool to assess substance misuse. Items are answered by no (0) or yes (1). Scores range from 0 to 4, a higher score being an indication of alcohol problems. A total score of two or greater is considered clinically significant.

Data Analysis

Descriptive statistics were used to describe the study variables. Means and standard deviations (SD) were reported for continuous variables. Frequencies and proportions were reported for categorical variables. The proportions of respondents meeting the cut-off scores as described in the previous section on the various measures were reported to estimate the rates of probable mental disorders in the sample. Generalized linear models (GLM) were used to determine the factors associated with symptom severity (PCL-5, PHQ-9, ISI, GAD-7, and CAGE total scores). Univariate GLM models were first used to determine the factors associated with the outcome variables. Collinearity was checked for the factors, and if the factors were correlated, only one of the factors was used in the model. Standard model building strategies were used to determine the most parsimonious model. Variables significant at $p < 0.10$ level were entered into the multivariate model. The final model for each of the outcome variables was based on statistical significance, with the exception of age, gender, ethnicity, and membership in a First Nation, which were included in all multivariate models regardless of univariate statistical significance. A p-value < 0.05 was used to indicate statistical significance. Bonferroni and Holm-Bonferroni (25) corrections were also computed to provide the p-values adjusted for multiple testing for each symptom severity. SPSS version 25 (IBM Corp. Released 2017. IBM SPSS Statistics for Windows, Version 25.0. Armonk, NY: IBM Corp.) was used for all statistical analyses.

RESULTS

Prevalence of Mental Health Disorders

Figure 1 presents the prevalence of probable mental health disorders in the sample. PTSD, MDD and GAD were almost equally represented, with an estimated prevalence of ~15% each. Insomnia disorder was the most common probable diagnosis with a prevalence of 28.5%, while the prevalence of probable SUD was 7.9%.

More than one third of the sample (37.7%) had at least one probable diagnosis, and 20% had more than one (**Figure 2**). Among individuals with probable PTSD, 87.1% presented with at least one other probable diagnosis. Among individuals with probable MDD or GAD, this figure increased to 94.3 and 94.0%, respectively. The proportion of individuals with at least one other probable diagnosis was 61.7% among individuals with

FIGURE 1 | Prevalence estimates of post-traumatic stress, major depressive, insomnia, generalized anxiety, and substance use disorders.

FIGURE 2 | Estimated number of probable diagnoses per person.
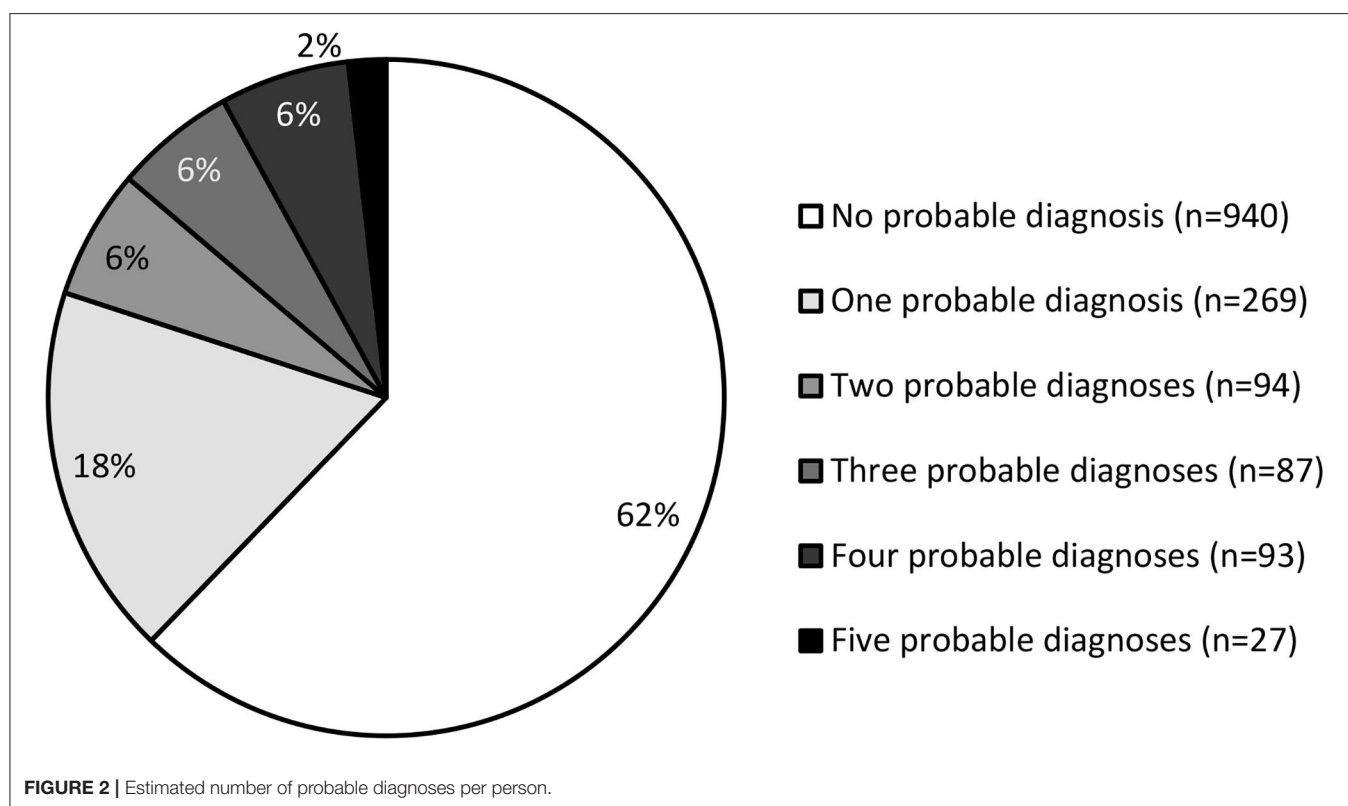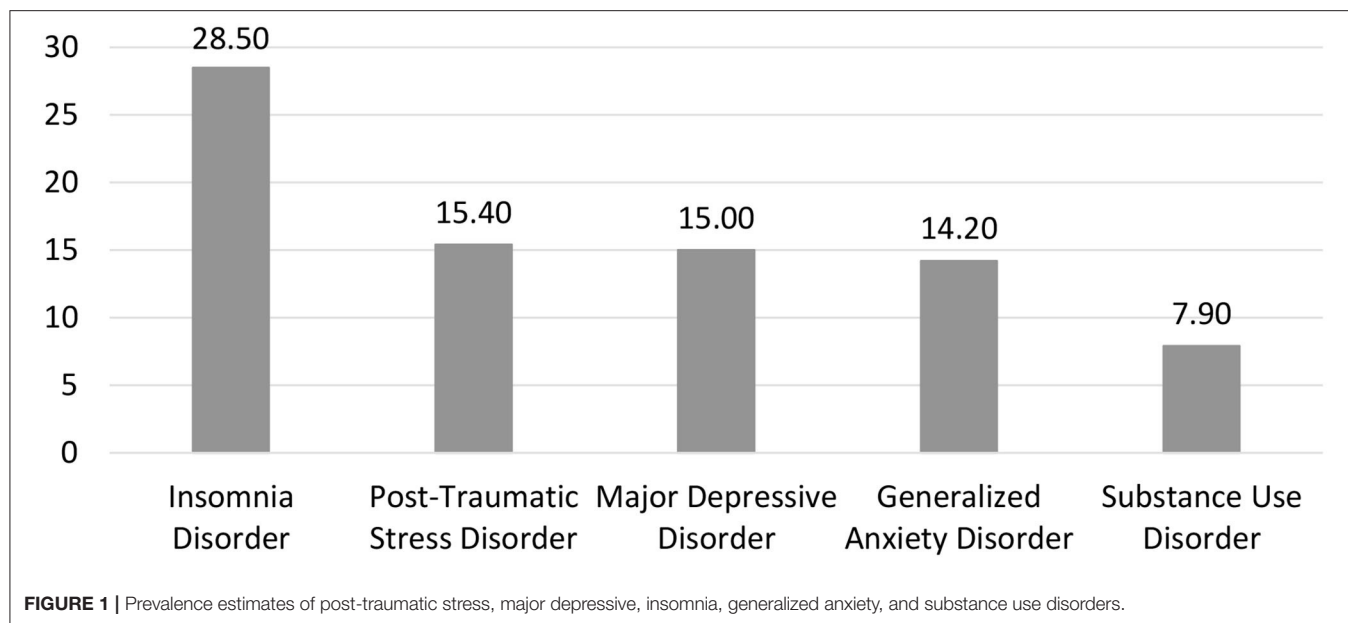
probable Insomnia Disorder, and 60.0% among individuals with probable SUD.

Correlates of Mental Health Disorders

Variables associated with univariate or multivariate effects on post-traumatic stress, depressive, insomnia, and anxiety symptom severity, as well as increased risk of drug or

alcohol dependency are listed in **Tables 3**–**7**, respectively, and summarized in **Table 8**. For all five mental health disorder symptom severity, having a mental health condition prior to the fires was a significant risk factor, as well as having experienced financial stress or strain due to the economic decline already present in Fort McMurray. After applying Bonferroni and Holm-Bonferroni corrections for multiple testing, the

TABLE 3 | Association between sample characteristics and PTSD symptom severity (PCL-5).

Characteristic	Univariate analysis		Multivariate analysis	
	B (95% CI)	*p*-value	B (95% CI)	*p*-value
Age	0.02 (-0.04 – 0.08)	0.476	0.03 (-0.01 – 0.08)	0.156
Female gender	4.45 (2.89 – 6.01)	<0.0001	0.43 (-0.75 – 1.61)	0.479
Ethnicity: White	3.52 (1.75 – 5.29)	<0.0001	0.27 (-1.04 – 1.58)	0.690
Membership in a First Nation	6.12 (2.89 – 9.35)	<0.0001	1.08 (-1.21 – 3.37)	0.356
Mental health problem	10.43 (8.05 – 12.80)	<0.0001	3.94 (2.21 – 5.66)	<0.0001
Financial strain or stress	8.44 (6.63 – 10.25)	<0.0001	1.54 (0.17 – 2.91)	0.028
Level of fear	2.52 (2.28 – 2.76)	<0.0001	0.69 (0.44 – 0.94)	<0.0001
Feared for the safety of a loved one	11.03 (9.40 – 12.66)	<0.0001	1.73 (0.40 – 3.06)	0.011
Saw explosions or buildings collapsed	8.88 (7.16 – 10.61)	<0.0001	3.34 (2.07 – 4.61)	<0.0001
Level of stress	3.10 (2.90 – 3.31)	<0.0001	1.43 (1.19 – 1.67)	<0.0001
Decrease in work	11.25 (9.65 – 12.85)	<0.0001	2.84 (1.56 – 4.12)	<0.0001
Decrease in social life	14.74 (13.33 – 16.16)	<0.0001	5.47 (4.21 – 6.73)	<0.0001
Health status (compared to Excellent)				
Poor	27.53 (23.95 – 31.10)	<0.0001	12.59 (9.57 – 15.61)	<0.0001
Fair	21.72 (19.41 – 24.03)	<0.0001	12.47 (9.53 – 15.42)	<0.0001
Good	9.37 (7.54 – 11.20)	<0.0001	11.24 (8.43 – 14.05)	<0.0001
Very good	3.89 (1.92 – 5.86)	<0.0001	3.94 (0.96 – 6.91)	0.009
Problems with finances or money	13.81 (12.22 – 15.40)	<0.0001	1.91 (0.47 – 3.34)	0.009
Problems with insurance	8.59 (6.88 – 10.31)	<0.0001	1.04 (-0.24 – 2.31)	0.111

Variables associated with more severe PCL-5 symptoms in univariate analyses: greater number of persons depending on the respondent, single, divorced or widowed (compared to married or partnership), poorer health status before the fires, saw buildings or surroundings on fire, feared for their own safety, separated from a loved one, greater level of material loss, damage to household content, to house, to sentimental possessions, to cars or trucks, to pets, other damage, work status change, did not return to live in same home, decrease in sports and leisure, increase in alcohol or drug use, greater number of days evacuated.

Variables without univariate or multivariate effect: level of education, work status, physical health problem, smelled smoke or fire, on duty as first responder, work status change.

Bonferroni p-value = 0.003; Holm-Bonferroni p-value = 0.008.

predictive value of prior mental health condition remained statistically significant. Financial stress remained significant only for anxiety after applying the Bonferroni correction. With the Holm-Bonferroni correction, financial stress was predictive of insomnia, anxiety and risk of drug and alcohol dependence. Five post-disaster consequences were significant predictors of four of the five disorder symptom severity: a higher level of stress experienced in the year following the fires, decrease in work, decrease in social life, poorer current health status, and increase in drug and alcohol use. All predictors remained significant after applying corrections for multiple testing, except for decrease in social life, which was no longer a significant predictor of depressive and insomnia symptoms.

The variables with predictive power in three of the five models included one sociodemographic characteristic, i.e., being single, separated, or divorced (for models explaining the severity of depressive and insomnia symptoms and the risk of drug or alcohol dependency), and one variable describing the peri-traumatic experience, i.e., having seen explosions or buildings collapse during evacuation (for models explaining the severity of post-traumatic stress, depressive and insomnia symptoms). After applying corrections for multiple testing, marital status remained a significant predictor of depressive symptoms only, and having seen explosions remained a significant predictor of post-traumatic stress and insomnia symptoms.

Socio-demographic characteristics mostly made significant contributions in the multivariate model explaining the risk of drug or alcohol dependency. Interestingly, female gender, a predictor of more severe symptoms in four univariate models, was no longer a significant predictor in multivariate models; on the contrary, female gender had a protective effect in models explaining the severity of anxiety symptoms (no longer apparent after corrections for multiple testing) and the risk of drug or alcohol dependency. Identifying as White was a multivariate predictor of more severe anxiety (no longer apparent after corrections for multiple testing) and depressive symptoms. Membership in a First Nation was associated with more severe symptoms in all five univariate models, but no effect was demonstrated in the multivariate models.

DISCUSSION

This study aimed to estimate the prevalence of post-traumatic stress, major depressive, insomnia, generalized anxiety and substance use disorders in the adult population of Fort McMurray in a sample of 1,510 evacuees surveyed 1 year after the fires. Insomnia disorder was the most common probable diagnosis, with a prevalence of 28.5%. PTSD, MDD, and GAD were almost equally represented, with an estimated prevalence of

TABLE 4 | Association between sample characteristics and depression symptom severity (PHQ-9).

Characteristic	Univariate analysis		Multivariate analysis	
	B (95% CI)	p-value	B (95% CI)	p-value
Age	0.003 (−0.019 – 0.025)	0.791	0.01 (−0.01 – 0.03)	0.184
Female gender	0.91 (0.35 – 1.47)	0.001	0.02 (−0.42 – 0.45)	0.933
Ethnicity: White	0.15 (−0.48 – 0.79)	0.635	0.80 (0.29 – 1.31)	0.002
Membership in a First Nation	1.88 (0.73 – 3.02)	0.001	0.27 (−0.61 – 1.15)	0.543
Single, separated, divorced or widowed	1.59 (0.96 – 2.22)	<0.0001	0.81 (0.32 – 1.30)	0.001
Mental health problem	5.19 (4.36 – 6.01)	<0.0001	2.98 (2.31 – 3.65)	<0.0001
Financial strain or stress	2.92 (2.28 – 3.57)	<0.0001	0.72 (0.19 – 1.25)	0.008
Saw explosions or buildings collapsed	2.35 (1.73 – 2.98)	<0.0001	0.67 (0.19 – 1.16)	0.007
Level of stress	0.88 (0.80 – 0.96)	<0.0001	0.40 (0.32 – 0.49)	<0.0001
Number of days evacuated	0.02 (0.01 – 0.03)	<0.0001	0.006 (0.001 – 0.012)	0.027
Decrease in work	3.64 (3.06 – 4.21)	<0.0001	1.01 (0.51 – 1.51)	<0.0001
Decrease in sports and leisure	4.14 (3.59 – 4.69)	<0.0001	0.87 (0.33 – 1.40)	0.001
Decrease in social life	4.22 (3.69 – 4.75)	<0.0001	0.72 (0.20 – 1.25)	0.007
Health status (compared to Excellent)				
Poor	11.35 (10.09 – 12.60)	<0.0001	6.62 (5.45 – 7.79)	<0.0001
Fair	7.50 (6.68 – 10.09)	<0.0001	3.73 (2.95 – 4.51)	<0.0001
Good	3.36 (2.72 – 4.00)	<0.0001	0.87 (0.27 – 1.47)	0.004
Very good	1.48 (0.78 – 2.17)	<0.0001	0.44 (−0.17 – 1.05)	0.153
Problems with finances or money	4.40 (3.82 – 4.98)	<0.0001	0.77 (0.22 – 1.33)	0.007
Increase in alcohol or drug use	4.74 (3.83 – 5.66)	<0.0001	2.13 (1.40 – 2.87)	<0.0001

Variables associated with more severe PHQ-9 symptoms in univariate analyses: greater number of persons depending on the respondent, poorer health status before the fires, greater level of fear, saw buildings or surroundings on fire, feared for the safety of a loved one, feared for their own safety, separated from a loved one, greater level of material loss, damage to household content, to house, to sentimental possessions, to cars or trucks, to pets, other damage, work status change, did not return to live in same home, problems with insurance. Variables without univariate or multivariate effect: level of education, work status, physical health problem, smelled smoke or fire, on duty as first responder.
Bonferroni p-value = 0.0026; Holm-Bonferroni p-value = 0.006.

~15% each. The prevalence of probable SUD was 7.9%. All in all, more than one third of the sample (37.7%) had at least one probable diagnosis.

These figures are similar to those reported 6 months after the fires by Agyapong and his colleagues who observed 12.8% PTSD (26) and 19.8% GAD (12) in a smaller and less representative sample of the general adult population in Fort McMurray. The same team evaluated the mental health impacts in several specific Fort McMurray population subgroups 18 months after the fires. In a sample of 3,070 adolescents (grade 7–12), they found 46% of all adolescent students met the criteria for at least one diagnosis 18 months after the disaster (PTSD, depression, GAD or substance misuse (27). In school staff, prevalence rates for probable PTSD were 10.2%, 18.3% for major depression, and 15.7 % for GAD (26). In college students, PTSD affected 11%, major depression 23.4% and GAD 18.7% (28). In primary care patients this time, these researchers rates similar to ours with 13.6% suffering from probable PTSD, and 18% from GAD, but they observed slightly higher prevalence of major depression with 24.8 % in these patients (29).

Our results are also in line with prevalence rates of PTSD (16–22%) and depression (13%) documented 3–4 years after the 2009 bushfires in Australia (9). Taken together, our findings indicate much higher rates of psychopathology among evacuees from forest fires than among the general Canadian population. As a reference, 12-month prevalence rates in Canada for persons 15 and older were of ~4.7% for major depression, 2.6% for GAD, and 4.4% for substance use disorders in 2012 (30). The 1-month prevalence rate for PTSD in Canada was estimated at 2.4% by van Ameringer et al., in 2008 (31). Our study goes further by including insomnia as an important outcome. The vast majority of studies assessing the mental health impacts of fires have focused only on PTSD and depression (32). In a review of 160 studies examining the impacts of disasters reviewed by Norris and collaborators (33), only 10 measured sleep. There is however more and more evidence that persistent sleep problems are among the most frequent reactions after a traumatic event (11, 34–37).

The second objective of the present study was to identify pre-, peri-, and post-traumatic correlates of different mental health disorders. Two pre-existing conditions, that is the presence of a mental health condition and financial problems, were significant predictors of all five types of psychopathology. Not surprisingly, having a mental health condition prior to the fires was a significant predictor in all five models. In non-disaster settings, it is well-known that having a history of mental issues strongly predicts future episodes of psychopathology (38, 39). This seems to be even more true in the context of disasters. As such, particular attention should be given to individuals who are

TABLE 5 | Association between sample characteristics and Insomnia Symptom Severity (ISI).

Characteristic	Univariate analysis		Multivariate analysis	
	B (95% CI)	*p*-value	B (95% CI)	*p*-value
Age	0.01 (−0.02 – 0.04)	0.401	0.02 (−0.00 – 0.04)	0.098
Female gender	1.22 (0.57 – 1.88)	<0.0001	0.18 (−0.39 – 0.74)	0.538
Ethnicity: White	0.33 (−0.42 – 1.08)	0.388	0.42 (−0.24 – 1.08)	0.210
Membership in a First Nation	1.74 (0.38 – 3.09)	0.012	−0.36 (−1.48 – 0.81)	0.566
Single, separated, divorces of widowed	1.29 (0.55 – 2.04)	0.001	0.70 (0.07 – 1.34)	0.030
Mental health problem	4.54 (3.55 – 5.54)	<0.0001	2.26 (1.38 – 3.13)	<0.0001
Financial strain or stress	3.05 (2.28 – 3.81)	<0.0001	0.98 (0.31 – 1.65)	0.004
Saw explosions or buildings collapsed	2.88 (2.14 – 3.61)	<0.0001	1.06 (0.43 – 1.69)	0.001
Separated from a loved one	2.21 (1.56 – 2.86)	<0.0001	0.86 (0.31 – 1.40)	0.002
Level of stress	1.00 (0.91 – 1.10)	<0.0001	0.49 (0.38 – 0.59)	<0.0001
Number of days evacuated	0.023 (0.014 – 0.031)	<0.0001	0.007 (0.000 – 0.014)	0.059
Decrease in work	3.83 (3.15 – 4.52)	<0.0001	1.16 (0.53 – 1.79)	<0.0001
Decrease in sports and leisure	4.66 (4.01 – 5.31)	<0.0001	1.06 (0.36 – 1.75)	0.003
Decrease in social life	4.65 (4.02 – 5.28)	<0.0001	0.84 (0.16 – 1.52)	0.015
Health status (compared to Excellent)				
Poor	11.51 (9.96 – 13.06)	<0.0001	5.91 (4.39 – 7.42)	<0.0001
Fair	8.12 (7.12 – 9.12)	<0.0001	3.93 (2.92 – 4.94)	<0.0001
Good	4.18 (3.39 – 4.98)	<0.0001	1.38 (0.16 – 2.16)	<0.0001
Very good	2.50 (1.64 – 3.35)	<0.0001	1.23 (0.44 – 2.02)	0.002
Increase in alcohol or drug use	5.01 (3.92 – 6.09)	<0.0001	2.52 (1.56 – 3.47)	<0.0001

Variable associated with more severe ISI symptoms in univariate analyses: greater number of persons depending on the respondent, poorer health status before the fires, physical health problem, greater level of fear, smelled smoke or fire, saw buildings or surroundings on fire, feared for the safety of a loved one, feared for their own safety, greater level of material loss, damage to household content, to house, to sentimental possessions, to cars or trucks, to pets, other damage, work status change, did not return to live in same home, problems with finances or money, problems with insurance.
Variable without univariate or multivariate effect: level of education, work status, on duty as first responder.
Bonferroni p-value = 0.0026; Holm-Bonferroni p-value = 0.007.

already known to have experienced mental health issues in the past, because their condition can be reactivated or exacerbated. Milligan and McGuinness (40) advocate for early identification of persons suffering from mental illness by first responders in order to ensure that proper referrals are made and appropriate follow-ups are put into place to minimize high-risk behaviors (e.g., suicidal ideation). Furthermore, these authors underscore that individuals with a psychiatric history are in need of specific efforts to stabilize their social environment and ensure they achieve a sense of community. They also suggest that health professionals already involved with these patients can play a pivotal role to help them prepare for the consequences of the disaster. However, one important issue in a disaster such as the one seen in Fort McMurray is that health professionals themselves may have significant needs for psychosocial support as they are part of the affected community (L. Serrano, FuseSocial, personal communication, May 2017).

Having experienced financial stress or strain due to the economic decline already present in Fort McMurray before the fires was another pre-existing condition predicting all five types of psychopathology, although this effect was less resistant to statistical corrections for multiple testing. Several studies have documented that the financial consequences of disasters have an impact on mental health (32): already being in a situation

of financial precariousness before facing a disaster also seems important to consider. Before the fires, the Fort McMurray region was already experiencing an economic downturn due to the recession in the Canadian oil sands regions, which was already affecting the use of mental health services (41). The negative impact of economic hardship on mental health (42) and sleep (43) has been documented. The present results go further by suggesting that the financial difficulties present before the fires are crucial in the development of mental health problems, even more so than the direct damage and losses associated with the fires. Future research could investigate whether financial assistance programs contribute reduce the impact of disasters on mental health.

Five post-disaster consequences were significant predictors of four of the five disorders, most often post-traumatic stress, depression, insomnia and anxiety. Decrease in work, decrease in social life, poorer current health status, increase in drug and alcohol use, and the level of stress experienced since the fires were all associated with more severe symptoms, and most of these effects were robust to statistical adjustment for multiple testing. Thus, the results point to the importance of paying particular attention to the level of burden that affects individuals in the year following a natural disaster, whether it be stress, physical health hassles or withdrawal from professional or recreational activities.

TABLE 6 | Association between sample characteristics and anxiety symptom severity (GAD-7).

Characteristic	Univariate analysis		Multivariate analysis	
	B (95% CI)	p-value	B (95% CI)	p-value
Age	−0.01 (−0.03 – 0.01)	0.232	−0.01 (−0.03 – 0.01)	0.176
Female gender	0.86 (0.33 – 1.38)	0.001	−0.47 (−0.90 −−0.04)	0.032
Ethnicity: White	0.39 (−0.21 – 0.98)	0.203	0.62 (0.13 – 1.10)	0.013
Membership in a First Nation	1.77 (0.69 – 2.84)	0.001	0.11 (−0.73 – 0.96)	0.796
Mental health problem	4.09 (3.30 – 4.88)	<0.0001	2.15 (1.51 – 2.80)	<0.0001
Financial strain or stress	2.75 (2.14 – 3.35)	<0.0001	0.81 (0.31 – 1.30)	0.001
Level of fear	0.66 (0.58 – 0.75)	<0.0001	0.16 (0.08 – 0.25)	<0.0001
Level of stress	0.88 (0.81 – 0.95)	<0.0001	0.40 (0.31 – 0.49)	<0.0001
Number of days evacuated	0.020 (0.013 – 0.026)	<0.0001	0.005 (−0.001 – 0.010)	0.075
Damage to house or apartment	2.79 (2.23 – 3.35)	<0.0001	0.76 (0.27 – 1.24)	0.002
Decrease in work	3.38 (2.84 – 3.92)	<0.0001	0.94 (0.47 – 1.40)	<0.0001
Decrease in social life	4.08 (3.59 – 4.58)	<0.0001	1.19 (0.73 – 1.66)	<0.0001
Health status (compared to Excellent)				
Poor	9.29 (8.08 – 10.49)	<0.0001	5.27 (4.15 – 6.38)	<0.0001
Fair	6.97 (6.19 – 7.75)	<0.0001	3.51 (2.76 – 4.25)	<0.0001
Good	3.03 (2.41 – 3.65)	<0.0001	0.62 (0.05 – 1.19)	0.033
Very good	1.25 (0.59 – 1.92)	<0.0001	0.16 (−0.42 – 0.74)	0.588
Problems with insurance	2.73 (2.16 – 3.31)	<0.0001	0.52 (0.04 – 1.00)	0.033
Increase in alcohol or drug use	4.43 (3.58 – 5.29)	<0.0001	1.99 (1.29 – 2.69)	<0.0001

Variables associated with more severe GAD-7 symptoms in univariate analyses: greater number of persons depending on the respondent, single, divorced or widowed (compared to married or partnership), poorer health status before the fires, saw buildings or surroundings on fire, feared for the safety of a loved one, saw explosions or buildings collapsed, feared for their own safety, separated from a loved one, greater level of material loss, damage to household content, to sentimental possessions, to cars or trucks, to pets, other damage, work status change, did not return to live in same home, decrease in sports and leisure, problems with finances or money.
Variables without univariate or multivariate effect: level of education, work status, physical health problem, smelled smoke or fire, on duty as first responder.
Bonferroni p-value = 0.0028; Holm-Bonferroni p-value = 0.006.

TABLE 7 | Association between sample characteristics and increased risk of alcohol or drug dependency (CAGE).

Characteristic	Univariate analysis		Multivariate analysis	
	B (95% CI)	p-value	B (95% CI)	p-value
Age	−0.006 (−0.011 – 0.002)	0.007	−0.004 (−0.008 – 0.000)	0.028
Female gender	−0.28 (−0.39 – 0.17)	<0.0001	−0.26 (−0.36 – 0.17)	<0.0001
Ethnicity: White	0.07 (−0.08 – 0.22)	0.342	0.11 (−0.02 – 0.24)	0.091
Membership in a First Nation	0.36 (0.13 – 0.58)	0.002	0.18 (−0.2 – 0.38)	0.073
Single, separated, divorces of widowed	0.31 (0.19 – 0.44)	<0.0001	0.13 (0.02 – 0.24)	0.021
Full time or part time work	0.15 (0.01 – 0.29)	0.037	0.14 (0.02 – 0.26)	0.021
Health status before the fires (compared to Excellent)				
Poor	0.76 (0.31 – 1.22)	0.001	0.47 (0.09 – 0.86)	0.016
Fair	0.24 (−0.01 – 0.49)	0.064	0.18 (−0.04 – 0.40)	0.109
Good	0.08 (−0.07 – 0.22)	0.290	−0.02 (−0.14 – 0.10)	0.777
Very good	0.04 (−0.11 – 0.19)	0.594	−0.02 (−0.14 – 0.11)	0.782
Mental health problem	0.46 (0.29 – 0.63)	<0.0001	0.33 (0.18 – 0.48)	<0.0001
Financial strain or stress	0.24 (0.10 – 0.38)	0.001	0.17 (0.05 – 0.29)	0.005
Increase in alcohol or drug use	1.33 (1.19 – 1.47)	<0.0001	1.26 (1.12 – 1.39)	<0.0001

Variables associated with higher CAGE score in univariate analyses: lower level of education, greater level of material loss, damage to sentimental possessions, work status change, greater level of stress, decrease in work, in social life, in sports and leisure, poorer current health status, problems with finances or money, problems with insurance.
Variables without univariate or multivariate effect: number of persons depending on the respondent, physical health problem, level of fear, smelled smoke or fire, saw buildings or surroundings on fire, feared for the safety of a loved one, saw explosions or buildings collapsed, feared for their own safety, separated from a loved one, on duty as first responder, damage to house or apartment, to household content, to cars or trucks, to pets, other damage, return to live in same home, number of days evacuated.
Bonferroni p-value = 0.004; Holm-Bonferroni p-value = 0.006.

TABLE 8 | Summary of regression models.

Predictors associated with more severe symptoms or higher risk in multivariate models	Predicted variables				
	PTSD	Depression	Insomnia	Anxiety	Drug/Alcohol
Sociodemographic characteristics					
Age					X*
Male gender				X*	X
Ethnicity: White		X		X*	
Membership in a First Nation					
Single, separated, divorced or widowed		X	X*		X*
Level of education					
Full time or part time work					X*
Number of persons depending on the respondent					
Status before the fires (pre-traumatic)					
Poorer health status (before the fires)					X*
Physical health problem					
Mental health problem	X	X	X	X	X
Financial strain or stress due to economic turndown	X*	X*	X†	X	X†
Experience of the fires (peri-traumatic)					
Subjective level of fear	X			X	
Smelled smoke or fire					
Saw buildings or surroundings on fire					
Feared for the safety of a loved one	X*				
Saw explosions or buildings collapsing	X	X*	X		
Feared for their own safety					
Separated from a loved one			X		
On duty as first responder					
Consequences of the fires (post-traumatic)					
Subjective level of material loss or damages					
Subjective level of stress since the fires	X	X	X	X	
Number of days evacuated		X*			
Loss or damages: household content					
Loss or damages: house or apartment				X	
Loss or damages: sentimental possessions					
Loss or damages: car or truck					
Loss or damages: pets					
Loss or damages: other					
Work status change					
Returned to live in the same home					
Decrease in work	X	X	X	X	
Decrease in sports and leisure		X	X†		
Decrease in social life	X	X*	X*	X	
Poorer health status (current)	X	X	X	X	
Problems with finances or money	X*	X*			
Problems with insurance claims				X*	
Increase in alcohol or drug use		X	X	X	X

Unadjusted statistical significance p < 0.05.
*No longer significant when adjusted for multiple testing (Bonferroni and Holm-Bonferroni).
†Significant when adjusted with Holm-Bonferroni correction, not with Bonferroni correction.

In fact, in the present study, the level of stress experienced in the year following the fires was found a significant predictor in four psychopathologies vs. two for the level of fear experienced during the event *per se*. This was perhaps because the intensity and the nature of threat to oneself or loved ones could have been considered lower than in other disasters. Indeed, the city

of Fort McMurray is surrounded by wilderness, and the city's population is accustomed to the annual presence of forest fires in its vicinities, either wildfires or prescribed burn[1]. In 2016, the wildfires first appeared under control but unexpectedly and rapidly reached the populated areas because of high winds (44). Only an hour after the evacuation was announced, the fire reached the city and blocked one of its two main routes out (45). Another aspect of this event is that although the entire city (~88,000 people) was urgently evacuated, there were no deaths directly related to the fires (although two people died in a car accident while evacuating). In disasters involving more property damage than casualties, post-disaster stress level may be a more important predictor of symptom severity.

The cross-sectional design prevented any conclusion on the causal relationships between significant predictors of the models and the outcomes. It was not possible to determine whether the consequences of fires triggered the symptoms or whether the symptoms led to more severe consequences. For example, did a higher level of perceived stress increase the risk of developing GAD or could it be that the intolerance of uncertainty characterizing people suffering from GAD led to an inflated perception of stress? Another example lies in decreased activity levels and depression which could influence each other bidirectionally and even constitute a vicious cycle. Longitudinal studies with assessments at varying time points post-disaster would be needed to clarify the causal relationships between predictors and mental health outcomes. It would also be important for future studies to distinguish pre-existing conditions from direct psychological consequences of the traumatic event.

It is interesting to note in our sample that female gender, although predicting more severe symptoms in four univariate models, was no longer a significant predictor in the multivariate models. Similarly, First Nations membership was associated with more severe symptoms in all five univariate models, but no effect was demonstrated in the multivariate models. These results contrast with those of other studies that showed that socio-demographic characteristics, particularly female gender, was a predictor of mental health problems such as post-traumatic stress (46), anxiety (47), depression (48), and insomnia (49). Female gender was commonly found a predictor of mental health problems after a disaster (18). When multivariate models are used, however, these sociodemographic characteristics seem to have less predictive power, possibly due to shared variance with other variables.

Our findings suggest the need to provide victims of a natural disaster with effective support and stress management strategies after the more acute phase of the disaster. Multiple clinical practice guidelines, meta-reviews and meta-analyses indicate that psychotherapy, particularly cognitive-behavior therapy (CBT), is an effective and cost-efficient treatment option for PTSD, generalized anxiety, depression, substance misuse, and insomnia. Access to psychotherapy, however is an important preoccupation, especially in the aftermath of a disaster, and there is still limited research indicating how therapy protocols for

various mental health issues should be adapted to populations having experienced different types of disasters or other mass traumatic events. Although there are empirically supported treatments for a variety of mental health issues, modalities to increase access to larger numbers of people are still under researched. For example, the potential of online evidence-based interventions could be harnessed, if at all possible to implement, in the longer term after a disaster. This however requires important resources and expertise.

Even if effective treatments are developed for individuals, however, only part of the problem would be solved. Larger-scale social and psychosocial intervention programs are also needed to increase the resilience and preparedness of communities at higher risk of disasters. It is probably reasonable to propose that programs targeting some of the predictors identified in the present study, those which are modifiable at least, could have a positive impact on mental health outcomes: teaching effective stress management techniques, allowing individuals a healthy processing of the fear they experienced during the event, alleviating financial burden, providing opportunities and strategies to return to productive and social activities, providing guidance to healthier consumption of drugs and alcohol, ensuring optimal physical health follow-ups. Furthermore, social and health care systems could identify individuals known to be more vulnerable and who would be in need of closer monitoring in the event of a disaster. Even more important, specific plans could be devised for post-disaster large scale mental health screening and trajectories for accessing mental health support or services. This position echoes that of Rebmann and colleagues who already suggested in 2008 that preventive measures should be put into place to establish plans for accessing mental health *before* a disaster occurs (50). This seems particularly advisable in urban areas where wildfires could be expected to continue to occur or in other communities known to be more at risk for other types of disasters (e.g., flooding). There is still much work to be done in this area however since a systematic review by Roudini et al. in 2017 (51) indicated that very few studies yet have documented community mental health preparedness for disasters or tools that persons or communities could use to prepare themselves for a disaster. These authors suggest that with the increasing numbers of countries facing disasters, local governments and mental health agencies should strive to develop operational plans to intervene, for example by informing different individuals about normal reactions to a disaster and about their potential roles and responsibilities during and after a disaster. The development and evaluation of formal programs which could be implemented at regional or even national levels will need much future work and could focus on educating the public and specific responders or stakeholders on how to best prepare and react in the event of a disaster and in the following years. There is a need to use the growing scientific evidence to support strong advocacy to adopt policies that will build and support community resilience. The present COVID-19 crisis may in fact help us in this regard, since governments are presently rapidly mobilizing themselves to increase access to basic mental health information, self-help tools, crisis helplines,

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[1] Alberta Wildfire. Available online at: https://wildfire.alberta.ca/.

and are identifying resources able to deliver mental health services (52–54).

The results of this study must be interpreted in light of certain limitations. The main one is that sensitive data were collected by interviewers without clinical experience over the phone. Although a portion of the interviews were reviewed by psychologists specializing in the assessment of mental disorders who gave feedback to the interview firm manager, the large number of interviews conducted in a short period of time required a large number of interviewers with a variety of experience level. However, the interview questions and their order were standardized. Also, because the measures were self-reported and targeted potentially sensitive subjects, a social desirability bias cannot be ruled out. Self-reported questionnaires may also overestimate the prevalence of mental health problems when compared to diagnostic interviews, especially in non-clinical populations (55). Last, the cross-sectional design prevented any conclusion on the causal relationships between significant predictors of the models and the outcomes. Despite these limitations, the study built on and extended previous findings by relying on a large randomly selected representative sample. This method made it possible to reach people who had not yet returned to their homes after the disaster (3.4% of the sample), a population that is very difficult to trace in the study of disaster consequences. Finally, the study looked at five mental health outcomes, all of which were assessed using validated instruments.

In conclusion, 1 year after the fires, more than a third of the evacuees showed clinically significant psychological symptoms, including insomnia, post-traumatic stress disorder, depression, anxiety, and substance abuse. This study identified those most at risk for mental health problems after exposure to a natural disaster and could guide the development of psychosocial support strategies after a disaster and increase preparedness for more vulnerable individuals. These results indicate that attention must be paid to the psychiatric past, financial situation and consequences following the traumatic event.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by Comité D'éthique de la Recherche de l'Université Laval. The patients/participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

GB, M-CO, SuG, CM, SB, StG, NB, TC, and FM contributed to the conception and the design of this study. GB, M-CO, JL, and SuG participated in the acquisition of data, analysis, and interpretation of data. GB, M-CO, and JL drafted and revised the article. All authors participated sufficiently in this research to warrant authorship, in agreement with the content of the manuscript, reviewed the article critically, and approved the final version.

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The Role of Social Determinants in Mental Health and Resilience After Disasters: Implications for Public Health Policy and Practice

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In this general literature review, we will explore the impacts and contribution of social determinants to mental health and resiliency following both natural and man-made disasters. Natural disasters, such as wildfires, earthquakes, tsunamis, and hurricanes, as well as man-made disasters, such as civil wars, have been known to inflict significant damage to the mental health of the victims. In this paper, we mainly explore some most studied vulnerability and protective social determinant factors such as gender, age, ethnicity, socials support and socioeconomic status for the mental health and resiliency in survivors of such disasters. Several other possible factors such as previous trauma, childhood abuse, family psychiatric history, and subsequent life stress that were explored by some studies were also discussed. We conducted a literature search in major scientific databases, using keywords such as: mental health, social determinants, disasters, wildfires, earthquakes, terrorist attacks, and resilience. We discuss the implications for public health policy and practice.

Keywords: mental health, resilience, disaster, social determinant, public health policy

INTRODUCTION

According to the World Health Organization (WHO), mental health is defined as the successful performance of an individual's mental capabilities. Mental health is a state of well-being in which each person realizes their potential, can manage the changes and everyday stresses of life, can work efficiently and productively, and is capable to contribute to his or her own community (1). Mental health includes emotional, psychological, and social well-being. It is also essential to recognize that the absence of a mental disorder does not indicate sound mental health (2, 3).

There has been increased recognition that social and economic circumstances affect people's mental health, and that natural and man-made disasters can also impact the resiliency of one's mental health. Social determinants include the condition in which people were born, live, and work; their age; ethnic status, and so on. They include factors such as social-economic status, educational attainment, neighborhood, and physical environment, employment, social support networks, as well as access to health care (4), which are in turn determined by a wider amount of forces, such as macroeconomics, environment, and politics (5).

As large-scale events, disasters are often unexpected (6, 7). They disrupt the normal conditions of existence, can cause death, trauma, and the destruction of property that can exceed the affected communities' capacity to adjustment (8). Each year, disasters affect millions of people worldwide. Averagely, at least one disaster happens each day around the world, and because of climate change

and the growing population density, the frequency and impact of disasters keep staying at a high level (9). In 2017, over 11,000 people died or disappeared due to disasters, while millions were left homeless. In 2018, more than 13,500 people lost their lives or went missing from disasters, with damages totaling $165 billion of economic losses (10). In 2019, 11,000 people around the world perished or were missing in natural and human-made disasters (11).

Studies usually classify disasters into three different types: natural disaster, such as earthquake; man-made non-intentional technological disaster, such as the nuclear accident at Chernobyl; man-made intentional acts, for example, the mass violence and terrorism as seen on September 11, 2001 World Trade Center (WTC) attacks (7, 12). Although the area remains controversial to study, some research indicates that man-made disasters and mass violence incidents tend to create greater mental and psychological impacts on survivors than natural disasters (7, 13). However, considering the wider picture of human health, it might be more critical and useful to focus on the traumatic event's characteristics, instead of the cause, since different types of disasters can have many similarities in terms of impact and outcome. Moreover, like the events in Fukushima, Japan, 2011 demonstrate, some disasters can consist of both natural and technological disaster, meaning some disasters can be multi-type (9). Accordingly, in this review paper, we go beyond categorizing disasters by cause and instead highlight the aspects of the disaster experience that can be associated with the psychological and mental health problems of these events.

The psychological consequences of natural and man-made disasters have been studied intensively in the past 20 years (14), with research also exploring the mental health impacts on victims of disasters, such as Hurricane Katrina in 2005, Hurricane Sandy in 2012, the Fukushima nuclear disaster in 2011, and the terror attack on the World Trade Center in 2001 (15). Studies of traumatic events often indicate that among people who have been directly affected by disasters and events of mass violence, a majority of do not develop psychopathological issue and cope well in the aftermath of disaster (16, 17). The capacity to continue functioning after encountering a disaster is common and characteristic of normal coping and adaptation mechanisms, with the phenomenon becoming known as "resilience" (18). The American Psychological Association (APA) defined resilience as the "process of adapting well in the face of adversity, trauma, tragedy, threats or even significant sources of stress" (19). However, not everyone can function well and demonstrate resilience after a traumatic event, with some survivors experiencing psychological impairments, while a small number of these develop more serious forms of mental disorder (7) such as major depression, generalized anxiety, and post-traumatic stress disorder (PTSD). These extreme outcomes may last for extended periods following the disaster and may even be present for the rest of their lives (15).

STUDY AIMS

The growing recognition of mental health issues highlights the need to develop an understanding of what makes some people more vulnerable to be negatively impacted by disasters.

A significant amount of study has led to the recognition of a series of social, physical, and economic factors referred to as the potential causes of mental health issues after disaster. In this paper, we review the current state of the field of disaster-related mental health research, with the aim of exploring the vulnerability and protective social determinant factors which impact on the mental health and resiliency in survivors of disasters. To achieve this aim, we will conduct a general literature search in major scientific databases using keywords such as: mental health, social determinants, disasters, wildfires, earthquakes, terrorist attacks, and resilience, whilst also describing challenges and limitations to our current methodologies, thus allowing for suggestions about the direction of future research.

METHODOLOGY

This general review aims to explore the impacts and contributions of social determinants to mental health and resiliency following both natural and man-made disasters. The review was conducted through a general search of the literature on Google Scholar, PubMed, PsycINFO, SpringerLink, Taylor & Francis Online, BioMed Central, and ScienceDirect. Search terms included social determinants (e.g., gender, age, ethnicity, social supports, socioeconomic status, etc.) mental health (e.g., PTSD, depression, anxiety, resilience, etc.) and disasters (e.g., floods, earthquakes, terrorist attacks). We began the review with an examination of the definitions, origins, and types of disaster to deepen and clarify the understanding of the main concepts. We summarized the key findings in literature on the social determinants and protective factors for mental health following disasters in a tabular form. We then discussed the vulnerability and protective social determinant factors such as gender, age, ethnicity, social support, and socioeconomic status for the mental health and resiliency in survivors of such disasters by reference to existing literature. We also discussed several other possible social determinants that were studied by some researches. Thereafter, we provided a conceptual framework for the relationship between social determinants and the resiliency of mental health problems in the post-disaster period as well as discuss the policy implications. In the end, we concluded the review by examining some areas related to this field that may benefit most from future research and provided a commentary on the possible research topic for future study.

RESULTS

Table 1 summarize key literature on social determinants and protective factors for mental health following disasters.

Discussion

Exposure to disasters has been related to various mental health outcomes (7). As summarized in **Table 1**, many social determinants have been used to deduce what kind of people are more liable to suffer from the adverse effects of traumatic events and thus more vulnerable to mental health issues (15). The following section discusses the vulnerability factors and protective social determinant factors for mental health and

TABLE 1 | Summary of studies on key social determinants and protective factors for mental health following disasters.

References	Study Aims	Methods	Main Findings
Agyapong et al. (27, 91)	To assess likely prevalence of PTSD in residents of Fort McMurray 6 months after a wildfire and to determine the predictors of likely PTSD in the respondents.	A quantitative cross-sectional survey was used to collect data through self-administered paper-based questionnaires to determine likely PTSD.	• Support from family/friends following wildfires may be protective against likely PTSD, • A prior diagnosis of an anxiety disorder significantly increased risk for developing PTSD
Agyapong et al. (26)	This study describes the changes in the stress, anxiety, and depression levels of subscribers to the Text4Hope program after 6 weeks of exposure to daily supportive SMS text messages.	Self-administered web-based questionnaires were used to assess the demographic and clinical characteristics of subscribers. Perceived stress, anxiety, and depression were measured with PSS-10, GAD-7 scale, and PHQ-9 scale at baseline and 6th week time points. Moderate or high perceived stress were assessed using cutoff scores.	• At the 6-week time point, there were statistically significant reductions in mean scores on the PSS-10 and GAD-7 scales but not on the PHQ-9 scale. • There were statistically significant reductions in the prevalence rates of moderate or high stress and likely generalized anxiety disorder but not likely major depressive disorder for the group that completed both the baseline and 6-week assessments. The largest reductions in mean scores and prevalence rates were for anxiety (18.7 and 13.5%, respectively).
Agyapong et al. (139, 140)	This study describes the changes in the stress, anxiety, and depression levels of subscribers to the Text4Hope program after 3rd month of exposure to daily supportive SMS text messages.	Self-administered web-based questionnaires were used to assess the demographic and clinical characteristics of subscribers. Perceived stress, anxiety, and depression were measured with PSS-10, GAD-7 scale, and PHQ-9 scale at baseline and 3rd month time points. Moderate or high perceived stress were assessed using cutoff scores.	• After 3 months of using Text4Hope, subscribers' self-reports revealed significant ($p < 0.001$) mean score reductions compared with baseline on: the GAD-7 by 22.7%, PHQ-9 by 10.3%, and PSS-10 scores by 5.7%. • Reductions in inferred prevalence rates for moderate to high symptoms were also observed, with anxiety demonstrating the largest reduction (15.7%).
Brewin et al. (29)	To investigate the risk factors for posttraumatic stress disorder in trauma-exposed adults.	Meta-analyses were conducted on 14 separate risk factors for PTSD, and the moderating effects of various sample and study characteristics, including civilian/military status, were examined.	• Gender, age at trauma, and race predicted PTSD in some populations. • Education, previous trauma, and general childhood adversity predicted PTSD consistently. • Psychiatric history, reported childhood abuse, and family psychiatric history that had more uniform predictive effects
Chan et al. (88)	To examine the contribution of pre- and post-disaster social support to short- and long-term mental health after Hurricanes Katrina	This is a three-wave longitudinal study, 492 residents in the region affected by Hurricane Katrina reported levels of perceived social support and symptoms of psychological distress prior to the storm (Wave 1). One year after Hurricane Katrina (Wave 2), they reported levels of exposure, perceived social support, and symptoms of psychological distress and posttraumatic stress. The latter three variables were assessed again 4 years after the hurricane (Wave 3).	• Pre-Katrina support predicts psychological outcomes by reducing hurricane exposure. • Post-Katrina social support predicts later psychological distress but not posttraumatic stress. • Four years after Katrina, perceived social support remains lower than baseline.
Cherry et al. (59)	To examine the effects of Hurricanes Katrina and Rita on cognitive and psychosocial functioning in adults 6–14 months after the storms.	Participants were recruited from the Louisiana Healthy Aging Study (LHAS). Most were assessed during the immediate impact period and retested for this study.	• Middle-aged adults reported more storm-related stressors and greater levels of stress than the two older groups at both waves of testing.
Dai et al. (95)	To measure the prevalence rate of PTSD at follow-up and identify predictors of recovery from the PTSD diagnosis in 2000.	PTSD at follow-up was reassessed using the PTSD Checklist-Civilian version. Information on demographics, trauma-related stressors, and coping style were collected through face-to-face interviews. Logistic regression was used for data analyses.	• Individuals who had lost relatives, suffered from bodily injury, had a low level of social support, or had a negative coping style were less likely to recover from PTSD.

(Continued)

TABLE 1 | Continued

References	Study Aims	Methods	Main Findings
Galea et al. (13)	To comprehensively and systematically assessing the epidemiologic evidence about PTSD after disasters.	This is a systematic review. It limited this review to studies conducted between 1980, when PTSD was first codified as a disorder in the DSM, DSM-III, and 2003.	• Most studies have focused on adults who were direct victims of the disaster. • Women has consistently been shown to be more likely to get PTSD after disasters. • A history of prior traumas has been associated with PTSD onset across multiple studies, as has low social support and having poor relationships with family members and coworkers.
Green et al. (52)	To investigate how age, gender and parental functioning effects PTSD symptoms on Children after disaster.	179 children aged 2–15 who were exposed to the Buffalo Creek dam collapse in 1972 were rated for PTSD symptoms 2 years after the disaster. Age and gender effects and the impact of the level of exposure and parental functioning were examined according to a conceptual model addressing factors contributing to adaptation to a traumatic event.	• Fewer PTSD symptoms were found in the youngest age group. • Higher symptom levels for girls than boys. • Life threat, gender, parental psychopathology, and an irritable and/or depressed family atmosphere all contributed to the prediction of PTSD symptomatology in the children.
Hall et al. (96)	To evaluate if baseline psychological distress symptoms and changes in these symptoms were associated with changes in social resources 5 months later among treatment-seeking torture survivors residing in Kurdistan, Iraq.	This longitudinal study used the Hopkins Symptom Checklist-25, Harvard Trauma Questionnaire, and a traumatic grief measure to collect information; Locally derived scales were used to measure perceived social support related measures. Multinomial logistic regression models assessed the association between symptoms and loss or gain in social resources.	• Higher mental health symptoms have a correlation with decreased social support. • The decline of social contact was associated with increased anxiety and PTSD symptoms. • Gaining social contact was related to decreasing depression and PTSD symptoms
Irmansyah et al. (31)	To exploring the effect on mental health of direct exposure to the tsunami.	Questionnaire was collected information from 783 people aged 15 years in tsunami-affected areas of Aceh and Nias. Group comparisons, contrasting responses Internally Displaced Persons and non-IDPs, were by chi-square for frequency data and t-tests for ordinal or continuous data. Hierarchical multiple linear regression analyses were performed to examine the relative contributions to psychopathology of demographic variables and measures of exposure, impact and resilience.	• High rates of psychopathology were recorded in the overall sample, particularly in those who experienced more substantial post-disaster changes in life circumstances. • Higher Self-Reporting Questionnaire scores were observed among women, those with lower education, those with diminished resilience beliefs, those experiencing high scores on disaster impact, those experiencing direct exposures to the disaster
Johnson et al. (98)	This study is a longitudinal course of psychiatric sequelae of a mass shooting incident at a courthouse.	Participants were interviewed 6–8 weeks after the incident and followed up 1 year and 3 years later. DIS/DS was used to collected data. Chi-square analyses, McNemar tests, T-tests and Multiple regression analysis were applied to do data analysis.	• Pre-existing psychopathology was a strong indicator of those at risk for a post disaster disorder
Kessler et al. (67)	To get a comprehensive understanding about the PTSD on the general population through National Comorbidity Survey.	Modified versions of the DSM-III-R PTSD module from the Diagnostic Interview Schedule and of the Composite International Diagnostic Interview were administered to a representative national sample of 5,877 persons aged 15–54 years in the part II subsample of the National Comorbidity Survey.	• The estimated lifetime prevalence of PTSD is 7.8%. • Prevalence is elevated among women and the previously married. • The traumas most commonly associated with PTSD are combat exposure and witnessing among men and rape and sexual molestation among women. • More than one third of people with an index episode of PTSD fail to recover even after many years.

(Continued)

TABLE 1 | Continued

References	Study Aims	Methods	Main Findings
Neria et al. (6)	To systematically assess the evidence about PTSD following exposure to disasters.	A systematic search was performed. Eligible studies for this review included reports based on the DSM criteria of PTSD symptoms. The timeframe for inclusion of reports in this review is from 1980 and February 2007 when the literature search for this examination was terminated.	• Post-disaster PTSD is associated with a range of correlates including sociodemographic and background factors, event exposure characteristics, social support factors and personality traits.
North et al. (30)	To understand the coping, functioning and adjustment of rescue workers after the Oklahoma City Bombing.	The participants were the 181 firefighters who served first as rescue workers. Pre and post disaster psychiatric diagnoses were assessed with the DIS for DSM-III-R. The Disaster Supplement 9 elicited additional information in open-ended questions. Chi-square tests, Fisher's exact tests and Wilcoxon tests were performed for data analysis.	• Functional impairment was uncommon (15%) in firefighters without PTSD but common (83%) in those with this diagnosis • The only aspect of interpersonal functioning manifesting significant problems after the bombing was marital disruption. • Among these firefighters nearly 50% rates of lifetime and 25% rates of current alcohol use disorder
Orui et al. (43)	To determine whether the tsunami disaster following the Great East Japan Earthquake has influenced the national suicide rates.	The time-series analysis and the Poisson distribution test were used to compare suicide rates in the tsunami disaster-stricken areas to national averages	• In tsunami disaster-stricken areas, male suicide rates were significantly lower than the national average at the beginning and started to increase after 2 years. But not for female.
Perilla et al. (62)	To investigate how natural disasters affect the mental health of people with different ethnicity	404 residents of southern Florida were interviewed 6 months after Hurricane Andrew. The sample was composed of equal numbers of Hispanics, non-Hispanic blacks, and Caucasians. 30-item Revised Civilian Mississippi Scale were used to assess posttraumatic stress.	• Ethnic groups differed strongly in the prevalence of PTSD • Caucasian disaster victims showed the lowest rate (15%), Spanish-preferring Latinos showed the highest rate (38%), and African Americans showed a rate (23%) between these two extremes.
Rafiey et al. (58)	To compare positive mental health between elderly and young earthquake survivors.	Data of the 324 earthquake survivors were obtained from a population-based cross-sectional survey conducted in Iran, 2015. The long-term effect of earthquake was assessed using the Mental Health Continuum-Short Form questionnaire. A one-way multivariate analysis of covariance (MANCOVA) using SPSS (version 22) was used in data analysis.	• Elderly earthquake survivors showing a higher level of positive mental health compared with their younger counterparts in the wake of natural disasters suggest that advancing per se does not contribute to increasing vulnerability.
Sasaki et al. (86)	To examine whether pre-disaster social support functions can mitigate post-disaster depressive symptoms among older survivors of the 2011 Great East Japan earthquake and tsunami.	This study was a part of the Japan Gerontological Evaluation Study, which began in 2010 as a nationwide, population-based, prospective cohort study investigating the predictors of physical and psychological health in community-dwelling Japanese older adults. In the present longitudinal study, the study used panel data from two waves of the JAGES survey.	• Participants who gave and received emotional and instrumental support before the disaster were significantly less likely to develop depressive symptoms after the disaster compared to those without support
Subaiya et al. (121)	To evaluate the association between socioeconomic status (SES) and storm recovery.	The study conducted a cross-sectional survey within the Rockaways 3 weeks after the hurricane made landfall to elicit information regarding basic utilities, food access, health, relief-effort opinions, and SES. It used a modified cluster sampling method to select households with a goal of 7–10 surveys per cluster.	• Lower-income households were more likely to worry about food than higher-income households. • A post-storm trend also existed among the lower-income group toward psychological disturbances.
Tortella-Feliu et al. (28)	To identify what factors may be associated with increased or decreased risk for PTSD	Researchers conducted an umbrella review of systematic reviews and meta-analyses of risk/protective factors for PTSD and assessed and graded the evidence of the association between each factor and PTSD.	• Being female or being indigenous people of the Americas; history of physical disease and family history of psychiatric disorder, and cumulative exposure to potentially traumatic experiences, trauma severity, and being trapped during an earthquake, showed convincing evidence of an association with PTSD.

resiliency in survivors of disasters. This section consists of several sub-sections, starting with gender, followed by age, ethnicity, social support, and social-economic status.

Gender

Momsen defines gender as "the socially acquired notions of masculinity and femininity by which women and men are identified" (20) (p. 2). Accepting the gendered perspective means considering the biological and psychological differences between men and women, whilst also analyzing their experiences in relation to situations and circumstances in which they were in.

Females have consistently been regarded as one of the key factors for post-disaster mental health problems (21–25). Many researches indicate that, psychological adverse consequences of disasters, such as PTSD and depression, are usually more serious for women survivors (6, 13, 26–28). Others like Brewin et al. (29) found that factors such as gender predicted PTSD in some populations but not in others.

In a study compared different populations experienced terrorist bombings (30), using structured diagnostic interviews to research the subjects. The study investigated victims who had experienced bombings of the US Embassy in Nairobi, Kenya, and bombings of the Oklahoma City Federal Building. The results revealed that, 6 months after the Oklahoma City bombing, among the 182 survivors, 22% of males and 40% of females displayed PTSD symptoms (30). Moreover, for the 227 survivors of the Nairobi bombing, 34% of males and 49% of females were detected to have PTSD symptoms (30). Similar results can be found in Galea's publication about the epidemiology of post-traumatic stress disorder after disasters (13) as well as in a study conducted about the survivors of the earthquake and tsunami in Aceh and Nias (31). Furthermore, Bonanno and Gupta also noted that female survivors are less likely than male survivors to be resilient in the period following catastrophic events (18). This gender difference has been observed in both adults and children, as well as in developed and developing countries, whilst the differences exist regardless of the type of mental disorder (7, 32). This reflects the higher prevalence of mood and psychological disorders among women after disasters (33).

When considering the reasons behind this gender difference, men can be physically and mentally better equipped to withstand a disaster's impact (34), whilst many studies believe differences are primarily caused by the traditional gender roles as well as the existing gender inequalities (8, 34–36). Women often experience unequal access to resources and relief assistance (37, 38), for instance, they may be forced to have "transactional sex" to acquire necessities of life such as food during emergencies (39). Moreover, domestic violence and rape cases may grow after disasters (40, 41). Additionally, poor sanitary conditions in sheltered accommodation can create not only physical but mental health risks also especially to women (39, 42). For example, in 1998, after the floods in Bangladesh, young girls reported perineal rashes and urinary tract infections mainly because they were not able to access clean water to wash menstrual rags, whilst also having no place to dry the rags (8). Furthermore, another burden for women is their caregiver roles and responsibilities at home, where work of this kind may

increase post-disaster and cause more stress and psychological problems (40).

However, what cannot be neglected is that there are examples of where mental health of males experiences were more adversely affected compared to females after disaster (43, 44). In the 3-year follow-up study about suicide rates in tsunami disaster-stricken areas following the Great East Japan Earthquake, with a time-series analysis and the Poisson distribution test, suicide rates in the tsunami disaster-stricken areas were compared to national averages. Orui et al. found that, in tsunami disaster-stricken areas, male suicide rates were remarkably lower than the national average during the initial post-disaster period and start to rise 2 years after (43). Besides, after decreased for seven months, the suicide rates of male in the inland areas increased to exceed the national average. By comparison, female post-disaster suicide rates did not change in both areas compared to the national average. Notably, the male suicide rates in the inland areas started to increase earlier compared to the tsunami-stricken areas, which may reflect the relative deficiency of mental healthcare services in the inland areas (43). Another study investigated farming suicides during the Victorian drought from 2001 to 2007 revealed the similar outcome (44). The study was carried out to explore whether farming suicides increased in Victoria during the prolonged drought in south eastern Australian. The results indicated that farming suicides accounted for just ∼3% if Victorian suicides. In total, the number of farming suicides was 110 for the year and ranged between 11 and 19 deaths each year, increasing and decreasing inconsistently from year to year. Males taken up around 95% of farming suicides, with firearms and hanging as the most frequently used methods and the majority of the death cases happening between 30 and 59 years old (44).

Age

Another recognized factor that affects people's mental health and resiliency following the natural and man-made disaster is their age.

According to the United Nations Convention on the Rights of the Child, children are defined as persons age at 18 and younger. Based on the statistical data, at the end of the 20th-century, disasters affected ∼66.5 million children each year (45). This data could probably triple over the second decade of the 21th-century, with an estimated 175 million children, each year, being affected by natural disasters (46). According to the research of the Population Reference Bureau, during the 2004 Indian Ocean tsunami, women and children were more likely to suffer physical and psychological problems than men were (47). Moreover, many studies indicate that children, especially those under 8 years of age, are especially vulnerable to psychological and mental health problems following disasters (48–53). The most common symptoms and diagnoses consist of anxiety disorders, such as PTSD, panic, and phobias. Depression, acute stress reactions, adjustment disorder, and even schizophrenia, has also been reported in child survivors (54, 55). The reasons why children are especially vulnerable, mentally, to disaster may be explained through their lack of understanding about the situation, whilst they may also feel less able to control the events and be less equipped to cope with difficult situations (7).

Among adults, in direct contrast to some commonly held ideas that getting old is related to increased dependency, ailment, incapacity, loss of self-control, and social isolation that may make older people more prone to being vulnerable to disaster and life crisis, studies have discovered that older people tend to be more immune to depression (56), substance use (57), and less consistently, PTSD (13) after traumatic events. In one study conducted by Rafiey et al. (58), 324 earthquake survivors were asked to complete a Mental Health Continuum-Short Form questionnaire to investigate the long-term effect of the earthquake. A one-way multivariate analysis of covariance (MANCOVA) using SPSS was used in the data analysis (58), with the findings demonstrating a higher level of positive mental health among elderly earthquake survivors than their younger counterparts. This suggests that advancing age, *per se*, does not contribute to increased vulnerability. This result could be caused by older people's knowledge and experience in developing coping skills in post disasters (58). In addition, some studies discovered that middle-aged adults are in general, at greater risk of developing psychopathological issues after being exposed to disasters (7). Cherry et al. (59) explained this phenomenon with the burden hypothesis: people at middle age are mentally more affected by disasters than other age groups "because of their role as the economic provider with asocial and financial responsibilities for their families. For some, dual responsibilities associated with caring for dependent children and elderly parents may double the perceived burden" (59) (p. 189).

Ethnicity

In the fourth edition of *Developmental-Behavioral Pediatrics* (60) ethnicity or ethnic group is defined as the membership of a culturally determined group or classifies by their unique cultural attributes, such as language and beliefs, usually in the context of a larger dominant society. They are frequently, but not necessarily, ranked within their societies (61). In a great many studies, ethnicity and status were proved to be one of the pre-disaster factors that have been related to mental health and resilience after disasters (7, 13, 62–64).

The study of mental health and resilience after disasters in minority groups has grown rapidly (65, 66). However, few researchers have compared African Americans, Anglos, and Latinos together, making the National Co-Morbidity Study (67) an important exception. The results of the study found that the lifetime rate of PTSD (7.8%) did not show a significant difference between whites, blacks, and Hispanics. Although black people experienced fewer traumas than whites, they were more inclined to develop PTSD once they were exposed to traumatic events.

In another study, 404 residents of southern Florida were interview six months after Hurricane Andrew (62). The participants consisted of equal numbers of Hispanics, non-Hispanic blacks, and Caucasians. Ninety-seven of the Latino interviewees decided to complete the interview in Spanish, while the rest of interviews were conducted in English. The study results indicate that people from different ethnic backgrounds differed markedly in the prevalence of PTSD (62). Specifically,

with 15% prevalence, Caucasian respondents displaying the lowest rate, Spanish-preferring Latinos showed the highest rate of 38%, and African Americans showed a rate of 23%, thus between these two extremes.

Other studies suggested that a high rate of psychological disorders and mental health problems, such as PTSD, have also been found among immigrants from Central American and Mexico (68). Whereas, low rates (4%) were found among victims of a severe flood in Puerto Rico (69), higher rates (32%) have been found among Latin Americans or Hispanics following disasters in Mexico (70), Chile (19%) (71), Colombia (42%) (72), and the U.S. (12%) (73). In Miquel et al. study published in 2019, they indicated that indigenous people of Americas showed convincing and highly suggestive evidence for PTSD (28). Therefore, to summarize the findings so far, some evidence indicates that survivors of different ethnic backgrounds have no significant difference in rates of post-disaster mental health problems, and some other studies suggesting that they do.

The majority of literature regarding social class and mental health examined *differential vulnerability* as one of the potential reasons why ethnic groups respond differently after disaster events (74, 75). Differential vulnerability implies that ethnic minorities are more affected by stressors (62). This view identifies that the context of which life events are experienced is important in understanding people's reactions toward stress. The most basic reasons for this are minorities' limited access to economic and social resources that might support them during traumatic periods (76). However, research has highlighted that there is more to the concept of ethnicity than simply socioeconomic status (7). The culture's unique and specific attitudes and beliefs could also play a role in ethnic group's abilities to cope with stress and trauma (65, 77, 78). Collectivism, for example, is a sense of oneness with other people, meaning the self is defined as part of a group (79), which is in contrast to individualist cultures, where relationships between members are closer, but then more distant with members outside of their own group. An extreme form of collectivism is familism (80, 81). This interconnectedness with family and friends is a valuable resource in coping with disasters, but in some cases, it may offer disadvantages as well. Kaniasty and Norris explained that, reluctance to ask for assistance could have serious implications in disaster-stricken situations where kin's supports might be depleted and insufficient (82). Moreover, familism frequently creates an acute sense of familial obligation that may cause increased stress and distress (83).

Social Support

Social support is a complex construct with numerous definitions (84). The term often refers to the quality and function of social relationships, specifically, it means having people like family members or close friends to turn to in times of need or crisis to provide care and help promote a positive self-image. Sippel et al. (84) indicated that social support could take many forms, such as social interactions, emotional support, instrumental/material support, information/cognitive support and so on.

Numerous literatures have shown that pre-disaster social support can decrease both exposure to natural disasters and

the adverse psychological effects of natural disaster exposure (85–90). The study conducted by Sasaki et al. examined if social support before disaster mitigates post-disaster depressive symptoms of older victims of the 2011 Great East Japan earthquake and tsunami (86). The survey was conducted among 2,293 participants who are more than 65 years old living in Iwanuma city two and a half years after the disaster. The results indicated that participants who received emotional and instrumental support before the disaster were significantly less likely to develop symptoms of depression after the disaster when compared with those who lacked supports (86). A similar conclusion has been found from Chan et al. (88) research among 492 survivors of Hurricane Katrina, which showed that higher levels of pre-disaster social support was related to lower mental health and psychological problems 1 year after storms.

Insufficient social support during the post-disaster period is associated with various psychological symptoms after the disaster (6, 7, 13, 26, 91), as well as disorders like PTSD (13) major depressive disorder (MDD) and prolonged grief disorder (PGD) (56). On the contrary, stronger social support resources have been related to greater resilience (18), which may function as a buffer against negative mental health effect of stressful events through influencing how people manage the situation (92). Further, available resources indicated that good social support plays a significant role in enhancing self-confidence, decreasing the likelihood of engaging in risky behaviors, such as excessive drinking and drug-taking, whilst also promoting more healthy coping strategies, such as active problem solving (93, 94).

In one study published in 2016, to investigate the predictors of recovery from disaster, victims of the 1998 Donting Lake flood who were diagnosed with PTSD in 2000 were measured for the prevalence rate of PTSD at follow-up sessions and addressing the predictive factors of PTSD after the flood (95). The results show that among the 321 participants with prior PTSD, 51 (15.89%) of the flood survivors keeps suffering from PTSD in 2013 and 2014. Moreover, people who had lost family members and friends, who were physically injured, and had poor social support or had a negative coping style were less likely to recover from PTSD (95). The logistic regression analysis displayed that the recovery from prior mental trauma was significantly related to social support, subjective support, and support utilization (95). This is in agreement with Dr. Hall's longitudinal research among survivors living in Northern Iraq, highlighting the complicated correlation between mental health symptoms and changes in social support networks among torture survivors (96). In Hall's study, the researchers evaluated if psychological distress symptoms in the survivors was associated with social resources changes 5 months later among 96 adult males and female's treatment-seeking torture survivors residing in Kurdistan, Iraq (96). The results indicated that higher mental health symptoms have a correlation with decreased social support. Moreover, the decline of social contact was associated with increased anxiety and PTSD symptoms. On the contrary, though, gaining social contact was related to decreasing depression and PTSD symptoms (96). Similar conclusion has been found from other researches, such as an investigation in children and their experience of disasters by Green et al. (52); Dalgleish's longitudinal study about a crisis

support following the *MS Herald of Free Enterprise* disaster (97); and a study by Arata's team aimed at exploring the coping strategies connected to technological disasters (25). Other studies include Johnson's research about psychiatric disorders among victims of courthouse shootings (98) and North's exploration about psychiatric disorders among survivors of the Oklahoma City Bombing (30).

Many neurocognitive systems and genetic mechanisms have been involved in linking social support and human resilience (99). One explanation for this is oxytocin. Neuropeptide oxytocin is a hormone released during social events and boosts pro-social activities by improving social recognition and the sense of trust (100). Zink and Meyer-Lindenberg discovered that the anxiolytic and pro-social effects of oxytocin appear related to improved activities of the prefrontal cortex and decreased amygdala activity (101). As a result, this decline in physiological reactivity to stress, especially chronic stress, has been related to positive psychological and physical health (84). Another possible explanation is that biochemical reactions can be triggered by social support and social environment (102, 103). One example is that some studies reported that "people who inherit a specific variation of the serotonin transporter gene, i.e., SS variation, are more likely to become depressed after stressful events compared to people who inherit other variants of the serotonin transporter gene" (104) (p. 4). Additionally, Kaufman's research team found that good quality social support offered protection against depression related to stress among children who were abused, even for individual who has the SS variation of the serotonin transporter gene. Consequently, it might be possible that gene expressions can be modified by the social environment (105–107).

Socioeconomic Status

The American Psychological Association defined socioeconomic status as the social standing or class of an individual or group. It is often measured as a combination of education, income, and occupation (108). This status has been a reliable and consistent predictor of a vast array of outcomes across one's life span, including physical and mental health (108). Through intensive research, socioeconomic status is believed to be one of the essential factors that has been associated with greater risk of psychopathological issues after disasters (7, 13, 18, 56, 57).

In a research from the World Bank and Global Facility for Disaster Reduction and Recovery (GFDRR), the authors mentioned that people around the world might depend on non-disaster aid programs, such as Medicare and unemployment insurance, to cope with effects following disasters (109). However, they emphasize that the post-disaster support organizations or programs can offer is limited, especially in developing nations. These programs are not designed or funded to offer fast improvement, as trauma events usually require, or to transfer help to victims in poverty are typically fewer than those to the upper crust (109).

The losses produced by the disaster, such as the property loss and damage, terrible living environment, disruptions in employment, education, health care access, social supports, and daily routine, will usually lead to the elevation of stress and

other mental health problems such as depression and anxiety, and the majority of these losses happen when victims of disasters are displaced (110). As noted, houses or apartments of families with low SES worldwide are more likely to be vulnerable to disasters, people of low SES are more likely to be displaced following disaster events. Fothergrill and Peek suggested that many low SES people, therefore, become homeless after a disaster (111). Previous studies indicated that displacement could affect survivors' mental health from several aspects. It usually disrupts the social support systems that mediate the mental health impacts and stress following disasters (90); It alters daily routines about home, work, school, social activities and, etc., (112); Further, it may also bring new stressors when housing conditions are unsatisfactory, or evacuees feel socially isolated, insecure, or that they are discriminated (113). Research has also noticed that families with subaverage incomes, people with unreliable employment, older adult women living in poverty, have difficulties in receiving housing loans from organizations and programs (114, 115). They believe that housing and displacement is commonly an overriding problem for low SES families at post-disaster periods, which is also one of the main stressors that result in mental health problems (116).

There are multiple studies that indicate that compared to people with high SES, low-income and low SES households lack access to resources that they need after disasters, therefore, they might experience a harder time in terms of stress s than those of higher income and SES (117–120). In a study conducted by Subaiya et al. explaining findings of an assessment conducted in the Rockaway Peninsula, part of New York City, 20 days after Superstorm Sandy, the authors reported that households from low SES notably expressed higher anxiety about food than people from high SES (121). The research team also found a trend toward psychological disturbance among low SES victims, although the trend was not statistically significant (121).

Another study on victims from Hurricane Ike, which happened in September 2008, discovered that two characteristics of low SES were significantly related to their greater likelihood of mental health problems, for example depression (122). For the 658 people who had been living in the area affected by the disaster and who was interviewed months later, survivors with a lower annual household income and fewer years of education were more likely to show mental health problems (122). A similar finding could be seen in the research on people affected by the Deepwater Horizon oil spill, which occurred between April to September 2010. Fan et al. discovered that people of low SES were much more easily to show feelings and symptoms of depression and had frequent mental distress after the disaster. Two traits related to low SES: being unemployed and low annual income, played a major role in this case (123).

Various other research also indicates that, individual with low SES face more obstacles to getting aid to assist them to reconstruct home and fulfill their other needs after disaster events. The stress associated with insufficient resources may create emotional and behavioral consequences (109), therefore people of lower SES experienced higher chances of psychological and physical problems, compared with higher SES following the experience of disasters.

Some Other Factors

Except those factors mentioned above, various other social determinants were proved by some studies that can affect mental health and resilience in the post-trauma period. For instance, previous trauma, childhood abuse, family psychiatric history, and subsequent life stress. In the study carried out by Brewin et al. (29), the meta-analyses were conducted on 14 separated risk factors for PTSD. Factors such as previous trauma, and general childhood adversity were proved to consistently predicted PTSD but to a different extent depends on the population studies and the method used. Also, factors such as psychiatric history, childhood abused experience, and reported family psychiatric history performed stronger predictive effects. Similar results were conducted by Miquel et al. in their umbrella review of risk factors for PTSD (28). In Brewin' s review, the effect size of all the risk factors operating during or after trauma such as subsequent life stress had somewhat strongest risk of PTSD (29).

Public Policy and Practice Implications

Efficient public policies and practices conducted during the pre, peri, and post-disaster periods can improve mental health outcome to a large extent (14). The World Bank and Global Facility for Disaster Reeducation and Recovery (GFDRR) report appeals for countries to take actions, at the government level, to reduce the vulnerability and increase the resilience of people suffering from disasters (124). Moreover, Fothergill and Peek (111) indicated that governments and other organizations worldwide should cooperatively work together to improve the security and well-being of people who experienced disaster events. Governments and those larger, multinational organizations are more likely to have the resources and authority to make policies that the general public do not (111). This section reviews several actions that could be conducted prior to, during, and after traumatic events to prevent, reduce, relieve the severity of, and treat mental disorders and promote healthy recovery.

Before and During Disaster: Anticipating and Preparing for Disasters

One significant action in pre-disaster preparation work is to avoid or minimize exposure to potential events related to disasters which can decrease the likelihood of additional stressors and mental health problems. There are several methods that local governments, communities, and organizations can adopt to reduce the possibilities and seriousness of the traumatic events. Firstly, as Fothergill and Peek (111) suggested, governments should develop policies to improve the safety of all housing, including low-income housing, and make housing affordable for people of low SES. They believe that this could involve requiring landlords to fund improvements or providing them with subsidies or other support for doing so. Secondly, when building new real estates in vulnerable areas, governments should identify the degrees of protection to be provided against specific disasters or hazards. The development of real estates in particularly vulnerable locations should be discouraged and building regulations could be modified to prevent collapse or damage to the real estate (14). McFarlane and Williams (9) pointed out, one of the reasons behind greater devastation,

injury, death, and housing loss following natural disasters in low-income countries is because these regulations are not present or enforced. Also, planning disaster-ready infrastructures such as sea defense walls is effective in reducing the impact of disasters, such as flooding caused by hurricanes (125). Local governments and communities can also invest in developing warning systems and response methods that are adaptable to various disaster situations, building on data gained from previous disasters, these systems need to operate efficiently in emergencies. Goldmann and Galea (14) suggested that government can offer incentives for power and water companies to create more robust systems to avoid extended loss of electricity, heat, and running water, which can serve as additional stressors during the post-disaster period if not provided. In the case of natural disasters, to the safe evacuation of people in the affected areas can reduce casualties. If people are evacuated, or planned to be evacuated, then well-functioning shelters, equipped with appropriate supplies and staffed to respond to victims' health needs during the disaster, are essential. Moreover, Organization (8) suggested that activities before disasters such as hazard mapping and vulnerability analysis, should integrate gender consideration, for instance considering how the vulnerability impacts differently on women and men, and how gender roles and status affect disaster-relief and mental health. Additionally, disaster workers, involved in rescue and relief measures, should be trained well in advance in the field of emotional aid and basic communication skills in dealing with traumatized victims, especially children (54).

After Disaster: Relieving Stress and Improving Mental Health Conditions

Various interventions and practices after the disaster have been developed to assist victims in different stages of the aftermath of the disaster. The intentions of preventing the development of and treating symptoms of psychopathology and improve mental health are the key focus of such interventions (14). Although individual resilience can be enhanced through personal skill training and positive interactions with families (e.g., cognitive reframing, physical fitness, couple-based intervention for PTSD) (126), effective practices as well as specific policies by the government are now seen as critical to post-disaster resilience (127).

First, government, communities, and related institutions should provide resources to guarantee a safe neighborhood with public spaces that promote exercise, affordable housing, access to healthcare and, high quality schools. These facilities might provide a significant improvement to resilience for the large number of survivors who live in destitute and dangerous communities (128, 129). Shim's research team addressed that, with the advancement in people's awareness of how social network factors impact on each individual, it could be possible to introduce societal interventions that promote resilience in a large population of individuals physically and emotionally (130). Political practices and interventions provide solutions to societal issues, such as poverty, housing and food shortage, poor education, and addressing the wealth gap which could have substantial effects on the resilience of survivors (130). Also, as

stated by Norris et al. (131) (p. 162), "when problems are shared, so must be solutions." Traumas, such as natural disasters and terrorist attacks usually destroyed several systems concurrently. Therefore, survivors are connected and rely on each other's coping techniques, especially during the post-disaster period. Governments and communities should encourage individuals with related experiences to prepare and organize solutions to help people come out of the hard times (84).

Psychological first aid (PFA), developed by the National Child Traumatic Stress Network and the National Center for PTSD, is an evidence-informed approach that consists of actions aimed at reducing initial post-disaster distress and supporting adaptive functioning that has already been taken by many governments and organizations (132, 133). PFA has three goals: ensure victim's safety and daily necessities, such as food, water, shelter, and medical supplies; relieve severe stress through addressing stress factors after traumatic events and providing stress-reduction techniques; thirdly, assist survivors to gain additional resources to help them rebuilt confidence and the feelings of control (14, 133). Some researchers have noted that PFA offers great promise, but further empirical research is needed to test the effectiveness of the approach over the long term (132).

The introduction of innovative, cost-effective interventions such as supportive text messaging, could also be taken into consideration by policymakers (134). Mobile phone technologies, for example, have been proven to have the potential to provide personalized support for patients, and can improve outcomes for many mental health issues as well as substance use disorders (135). The recent COVID-19 pandemic has had a significant psychological effect on people worldwide. Research has already highlighted that social distance, containment, and security measures have affected the relationship among people and their perception of empathy toward others (136, 137). Children, college students, and health workers are the most exposed groups who are especially vulnerable to PTSD, anxiety, depression, and other symptoms of distress (136). In Canada, Agyapong et al. (138) launched a daily supportive SMS text messaging program "Text4Hope" to test the changes in the level of stress, anxiety, and depression of subscribers after 6 weeks of exposure to the daily supportive SMS text messages during the COVID-19 pandemic. The results indicated that at the 6-week and 3-month time points, there was a statistically significant fall in mean score on the 10-item Perceived Stress Scale (PSS-10), the 9-item Patient Health Questionnaire and the 7-item Generalized Anxiety Disorder-7 (GAD-7) (138–140). Similar results could also be found in another study carried out by Agyapong et al. (141). This study evaluated the self-report of the impact of the "Text4Mood" program which delivered daily support text messages to subscribers on their mental well-being (141). Among the 894 subscribers who answered the self-report questionnaire, 38% of whom were diagnosed with a psychiatric disorder, 81.7% respondents felt the text message brought them more confidence in managing daily issues; 76.7% reported feeling more in charge of managing depression and anxiety issues, while 75.2% felt the sense of connection through the support system. Overall, 83.1% of participants felt "Text4Mood" improved their overall mental well-being (141). Agyapong et al. suggested that the

supportive text message system is therefore a convenient, cost-effective, and acceptable approach for delivering population-level psychological interventions (134, 138, 141). Moreover, the program also demonstrated a significant effect in relieving anxiety and stress levels during the COVID-19 pandemic, therefore, it could be adopt by governments as a mental health intervention to the general public during, or after, the natural disasters and other emergencies (138).

LIMITATIONS

This literature review has some important limitations. Firstly, this is a general literature search which qualitatively summarized the evidence and provide an overview of the topic rather than a systematic literature review. Data retrieval was conducted by only one researcher in a non-systematic way which did not account for the total number of studies obtained from the search, duplicates and non-relevant studies, and therefore, a Prisma diagram has not been included. Secondly, in this article, we only searched English language databases. Academic search that relies only on certain languages or from certain countries may result in failure to find many important studies published with other languages, irrespective of the research question and the avoidance of any language restrictions (142). Finally, factors such as "social support," "previous trauma," "childhood adversity," or "family psychiatric history" are indeed very general. However, as noted by Shalev et al. (143) it is probably easier to assess these "simplified" predictors in the real world, and they have been successfully applied in several fields of medicine (28). Notwithstanding the limitations of the study, this review provides insightful overview of the predictive vulnerability and protective social determinants which impact on the mental health and resiliency of survivors of disasters.

CONCLUSION AND FUTURE DIRECTION

There are numerous studies in the field of mental health and resilience after the experience of disasters. Some areas related to this field may benefit most from the existing and future research. Firstly, studies that transfer their main emphasis from the prevalence of mental health problems after the disaster, which has obviously been examined extensively, to a longitudinal assessment of disaster survivors to further elucidate disorder trajectories could offer valid contributions (6, 7, 13). Since several areas in this filed remain unclear, such as the course of mental illness such as PTSD after disaster (6), these types of studies are able to help researchers understand the possible

factors associated with various reasons behind mental health problems better. Moreover, it could help clarify populations that are more at risk and identify effective intervention strategies (6, 14). Secondly, the field requires studies that evaluate a broader range of psychopathological areas than the current study. Most of the studies about post-disaster mental health problems are focusing on assessed symptoms of PTSD, whilst few studies have targeted other possible post-disasters problems, such as anxiety, depression, and panic disorder (144).

Thirdly, additional researches concentrated on interventions that aim to prevent or reduce symptoms of mental illness among survivors of disasters is required (7, 144). Even though there are some interventions and treatment strategies which were deemed to be efficacious in randomized controlled experiments, effectiveness studies are in dire need for further evaluation of the curative effect of interventions on general populations with practicing clinicians (145) and their effect on preventing or reducing comorbidity such as substance use disorders (146, 147). The existing and future research may also benefit studies that investigate a wide range of potential risk factors from multiple perspectives, such as "biological and genetic characteristics that may predispose some victims to poor mental health outcomes but not others" (14) (p. 180). Additionally, studies could examine how the interaction of genetic and environmental characteristics produce diseases, such as how the change of the environment can affect our genes behave (103, 148).

In the end, as Généreux et al. noted, good governance is perhaps the single most important factor influencing the effectiveness of emergency preparedness, response, and recovery (149). With the existing research achievements, it is necessary for government and related organizations to reform policies, innovate practices, cultivate relationships, and share responsibility for ensuring the safety, health, and well-being of affected people.

AUTHOR CONTRIBUTIONS

WM drafted the initial manuscript. VA conceived the study and critically reviewed the initial manuscript. All authors contributed to the literature search design and approved the final draft before submission.

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Mental Health Symptoms Unexpectedly Increased in Students Aged 11–19 Years During the 3.5 Years After the 2016 Fort McMurray Wildfire: Findings From 9,376 Survey Responses

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In Fort McMurray, Alberta, Canada, the wildfire of May 2016 forced the population of 88,000 to rapidly evacuate in a traumatic and chaotic manner. Ten percentage of the homes in the city were destroyed, and many more structures were damaged. Since youth are particularly vulnerable to negative effects of natural disasters, we examined possible long-term psychological impacts. To assess this, we partnered with Fort McMurray Public and Catholic Schools, who surveyed Grade 7–12 students (aged 11–19) in November 2017, 2018, and 2019—i.e., at 1.5, 2.5, and 3.5 years after the wildfire. The survey included validated measurement scales for post-traumatic stress disorder (PTSD), depression, anxiety, drug use, alcohol use, tobacco use, quality of life, self-esteem, and resilience. Data analysis was done on large-scale anonymous surveys including 3,070 samples in 2017; 3,265 samples in 2018; and 3,041 samples in 2019. The results were unexpected and showed that all mental health symptoms increased from 2017 to 2019, with the exception of tobacco use. Consistent with this pattern, self-esteem and quality of life scores decreased. Resilience scores did not change significantly. Thus, mental health measures worsened, in contrast to our initial hypothesis that they would improve over time. Of note, we observed higher levels of mental health distress among older students, in females compared to male students, and in individuals with a minority gender identity, including transgender and gender-non-conforming individuals. These findings demonstrate that deleterious mental health effects can persist in youth for years following a wildfire disaster. This highlights the need for multi-year mental health support programs for youth in post-disaster situations. The indication that multi-year, post-disaster support

is warranted is relatively novel, although not unknown. There is a need to systematically investigate factors associated with youth recovery following a wildfire disaster, as well as efficacy of psychosocial strategies during later phases of disaster recovery relative to early post-disaster interventions.

INTRODUCTION

In May 2016, a large wildfire affected Fort McMurray, Alberta, Canada and the surrounding area. Called "The Beast" in the popular media (1), the wildfire necessitated the evacuation of the entire city on May 3, 2016, and over 88,000 residents were displaced for several weeks. In addition to damaging community structures and infrastructure, the fire destroyed 10% of the homes in Fort McMurray, leaving many individuals homeless. The fire burned 590,000 hectares of land before it was brought under control on July 4, 2016. Insurance costs for the damages were estimated at $3.6 billion by the Insurance Bureau of Canada, which made the Fort McMurray wildfire the most expensive insured catastrophe in Canadian history (2). Many individuals were left jobless due to damage and closure of local businesses. Social, emotional, and psychological difficulties also affected the community, as is typical after severe disasters (3, 4).

Disasters tend to impact children and youth in particular (5–10) given developmental vulnerabilities (cognitive, emotional, social, and physiological) associated with childhood and adolescence, including the need to rely on others for support (11). Our group has previously examined Fort McMurray school mental health surveys completed by Grade 7–12 students in November 2017 (12, 13). Brown et al. (12) reported elevated mental health symptoms for PTSD and depression compared to a control population from the same province which had not experienced a natural disaster. As reported in (13), individuals who were more personally impacted by the 2016 wildfire, such as having their home destroyed, exhibited greater symptoms of PTSD, depression, anxiety, and alcohol and/or substance misuse. These findings were consistent with previous findings of altered mental health in youth following natural disasters (9, 14).

Previous studies have also reported links between wildfires and adverse mental health effects in adults and children, including increased symptoms of PTSD (15–24), increased symptoms of depression and anxiety (17, 19, 23–28), mental health difficulties (18, 29, 30), reduction in health and well-being (31), increased consumption of anxiolytics-hypnotics (32), and decreased capacity to cope with adversity (33). The combined adverse impacts of wildfire disasters on individuals' mental health and coping abilities, particularly in youth, are

important because coping plays a major role in post-disaster recovery, and lack thereof can be detrimental to long-term mental health outcomes [also see (34)]. More generally, non-wildfire disasters, including floods, earthquakes, and tsunamis, have also been linked to adverse effects on mental health in adults and children in the form of increased symptoms or incidences of PTSD, major depressive disorder, suicidality, generalised anxiety disorder, and substance use disorder [see (8, 9, 35–39)]. Displacement caused by natural disasters (e.g., short- and long-term evacuation, homelessness) imposes additional physical, emotional, and psychosocial stress on families, which may then adversely affect longer-term development of children and youth (40).

Longitudinal studies, most of which have focused on adults, have reported long-term negative impacts on mental health from natural disasters (17, 25, 41–46). The pattern of long-term effects can be complex, with individuals exhibiting better recovery from some symptoms, such as depression or anxiety, but lesser recovery for others such as PTSD symptoms (47). Relatively few longitudinal studies have focused on mental health outcomes among youth following natural disaster, although studies of children and youth following Hurricane Katrina have shown long term impacts on mental health (48), with varying recovery trajectories for different groups (49, 50). We are aware of only three population studies that examined wildfire impacts on youth mental health, including one study focusing on PTSD and depression (19) and our previous Fort McMurray studies (12, 13).

In the present study, our hypothesis was that mental health symptoms among Fort McMurray youth would improve with time following the November 2017 survey. This hypothesis was based on theoretical work on trauma recovery, which consistently emphasises the role of time in the recovery process (4, 51, 52). To test this hypothesis, we examined mental health survey data collected by Fort McMurray school boards in Grades 7–12 in November across three consecutive years, including 2017, 2018, and 2019. This repeated testing was conducted 1.5, 2.5, and 3.5 years after the 2016 wildfire (All data were collected prior to the COVID-19 pandemic). We hypothesised specifically that symptoms of PTSD, depression, anxiety, and alcohol/substance use would steadily improve from 2017 to 2018 to 2019.

MATERIALS AND METHODS
Overview and Ethical Considerations

Information collected from students included questions on demographics, mental health, resilience, and personal exposure to and direct impacts of the wildfire. Measurement instruments

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Abbreviations: CPSS, Child PTSD Symptom Scale; CRAFFT, CRAFFT Questionnaire (proper name of the questionnaire is CRAFFT); CYRM-12, Child and Youth Resilience Measure; EMPATHY, Empowering a Multimodal Pathway Towards Healthy Youth project; FDR, false discovery rate; HADS, Hospital Anxiety and Depression Scale; Kidscreen-10, Kidscreen Questionnaire; PHQ-A, The Patient Health Questionnaire, Adolescent version; PTSD, post-traumatic stress disorder; Rosenberg, Rosenberg Self-Esteem Scale.

were selected by the school systems, informed by the relevant literature and advice from the University of Alberta research team. Written letters were sent to parents and guardians to inform them of the survey 2 weeks prior. Parents and guardians could have their child(ren) not participate in the survey, and students also independently had the option to participate or not in the survey as explained at the start of each survey session (see details below and Appendix A: Survey Description Script in the **Supplementary Material**). Survey data collection was intentionally anonymous, and participants were not asked for their names nor any other identifying information. The study design was approved by the University of Alberta's Health Research Ethics Board (ethics protocol number Pro00072669 approved June 26, 2017). This paper reports on findings from the anonymous survey data collected from both school boards.

Mental health surveys were conducted by the two school boards in Fort McMurray—Fort McMurray Public Schools and Fort McMurray Catholic Schools (henceforth, "Schools"). They asked all students in Grades 7–12 to complete the surveys in November 2017 (18 months after the 2016 wildfire), November 2018 (30 months post-wildfire), and November 2019 (42 months post-wildfire) (All data were collected before the COVID-19 pandemic). The survey was administered during regular class time as part of the standard curriculum to evaluate the support programs the Schools had put in place following the wildfire (see Appendix B: Mental Health Support Programs, in the **Supplementary Material**). The Schools determined that surveys would be done in November 2017, 2018, and 2019 as the month of November worked best given various logistical and staff capacity considerations.

Fort McMurray Public Schools and Fort McMurray Catholic Schools ("Schools") administered all aspects of survey data collection, including participant consent, in accordance with their standard procedures and policies. The Schools asked researchers from the University of Alberta for assistance in designing the survey and analysing the anonymous dataset.

Survey Questionnaires

The survey included 10 questionnaires (see **Table 1** for additional details):

1. Demographics Questionnaire (Demographics, 7 questions)—a custom-designed questionnaire assessing age, gender, and the student's grade and school.
2. Impact of Fire Questionnaire (IOF, 6 questions)—a custom-designed questionnaire to assess the impact of the 2016 wildfire on the student.
3. Child PTSD Symptom Scale (CPSS, 19 questions)—used to assess symptoms of post-traumatic stress disorder (PTSD) (53); total CPSS score ranges from 0 to 51.
4. Patient Health Questionnaire, Adolescent version (PHQ-A, 11 questions)—used to assess symptoms of depression and suicidality (54, 55); total PHQ-A score ranges from 0 to 27.
5. Hospital Anxiety and Depression Scale (HADS, 7 questions, anxiety-related questions only)—used to assess symptoms of anxiety (56); total HADS score ranges from 0 to 21.

6. CRAFFT Questionnaire (CRAFFT, 9 questions)—used to assess symptoms of alcohol and substance misuse (57, 58); total CRAFFT scores ranges from 0 to 6.
7. Tobacco Use Questionnaire (2 questions) – two questions on tobacco use: "During the past month, did you smoke tobacco products?" and "During the past month, did you use smokeless tobacco products?"
8. Rosenberg Self-Esteem Scale (Rosenberg, 10 questions)—used to assess self-esteem (59); total score ranges from 0 to 30 with higher scores indicating higher self-esteem.
9. Kidscreen Questionnaire (Kidscreen-10, 11 questions)—used to assess quality of life (60); total Kidscreen-10 score ranges from 0 to 44 with higher scores indicating better quality of life.
10. Child and Youth Resilience Measure (CYRM-12, 12 questions)—used to assess resilience to adverse experience or trauma (61); total CYRM-12 score ranges from 12 to 60.

Survey Administration Procedure

The vast majority (>98%) of students who completed the survey did so during regular school hours. A few students citing special circumstances completed the survey from home on their own computers. Depending on their school, students either completed the survey using a desktop computer in a computer laboratory or used laptops brought to their classroom. The survey website was based on an HTML/CSS front end and a back end server written in the Clojure programming language (http://clojure.org). A survey description script was read to each class at the beginning of the survey session (reproduced in the **Supplementary Material**). The script explained the purpose of the survey and provided instructions for completing the survey. It also explained that the survey was anonymous (participants were not asked for their names nor date of birth) and that participation was voluntary. Students had an opportunity to ask questions before participating. The survey battery included 96 questions in total. Participation required <20 min for most students, but a small number of students took up to 50 min. Participants were able to skip questions, but the survey description script and the survey website did encourage them to answer all questions.

Repeated Measurements in 2017, 2018, and 2019

The first mental health survey of Fort McMurray Grade 7–12 students was completed in November 2017 and was then repeated in November 2018 and November 2019. Many students were present for the survey across all 3 years. Other students were present for only 1 or 2 years. For example, students entering Grade 7 in September 2018 or September 2019 were not surveyed in *earlier* years (i.e., November 2017 and November 2018, respectively). Similarly, students graduating from Grade 12 in June 2018 or June 2019 were not re-surveyed the following November. Some students also moved to, or away from, Fort McMurray between 2017 and 2019. In summary, some of the surveys collected in 2017, 2018, and 2019 were completed by unique students (i.e., no repetition), although the majority were completed by the same students (i.e., repeated measures over 2 or 3 years). Because survey responses were anonymous, we were unable to link surveys completed by specific students from 1 year

TABLE 1 | Questionnaire details [table reproduced with permission from our previously-published paper Brown et al. (13)].

	Questions	Answer choices
Demographics questionnaire		
1	Are you at school right now, while you are taking the survey?	Yes, No
2	Are you a student?	Yes, No
3	What gender do you identify with?	Female, Male, Other, Prefer not to say
4	What is your age?	10 years or less, 11 years, 12 years, 13 years, 14 years, 15 years, 16 years, 17 years, 18 years, 19 years, 20 years or more
5	What school are you in currently?	Select from a list of all Ft McMurray schools with any classes in grades 7–12
6	What grade are you in currently?	7, 8, 9, 10, 11, 12, other
7	What school were you in for grade 6?	Select from a list of all Ft McMurray schools with grade 6
Impact of fire questionnaire		
1	Were in you or near Fort McMurray during any part of the 2016 wildfire?	Yes, No
2	Did you evacuate because of the fire?	Yes, No
3	Was your home destroyed by the fire?	Yes, No
4	Did you see the fire in person?	Yes, No
5	What school are you in?	Select from a list of all Ft McMurray schools with any classes in grades 7–12
6	What grade are you in?	7, 8, 9, 10, 11, 12, other
PATIENT HEALTH QUESTIONNAIRE (PHQ-A, DEPRESSION SYMPTOMS)		
Over the past 2 weeks, how often have you been bothered by any of the following problems?		
1	Feeling down, depressed, irritable or hopeless	Not at all, Several days, More than half the days, Nearly every day
2	Little interest or pleasure in doing things?	Not at all, Several days, More than half the days, Nearly every day
3	Trouble falling or staying asleep, or sleeping too much	Not at all, Several days, More than half the days, Nearly every day
4	Poor appetite, weight loss, or overeating?	Not at all, Several days, More than half the days, Nearly every day
5	Feeling tired, or having little energy?	Not at all, Several days, More than half the days, Nearly every day
6	Feeling bad about yourself-or that you are a failure or that you have let yourself or your family down	Not at all, Several days, More than half the days, Nearly every day
7	Trouble concentrating on things, such as school work, reading or watching television	Not at all, Several days, More than half the days, Nearly every day
8	Moving or speaking so slowly that other people could have noticed. Or the opposite-being so figety or restless that you have been moving around a lot more than usual	Not at all, Several days, More than half the days, Nearly every day
9	Thoughts that you would be better off dead, or of hurting yourself in some way	Not at all, Several days, More than half the days, Nearly every day
Questions 10 and 11 asked only if answer to question 9 is not "Not at all"		
10	Has there been a time in the past month when you have had serious thoughts about ending your life?	Yes, No
11	Have you ever, in your WHOLE LIFE, tried to kill yourself or made a suicide attempt?	Yes, No
HOSPITAL ANXIETY AND DEPRESSION SCALE (HADS, ANXIETY SYMPTOMS)		
Tick the box beside the reply that is closest to how you have been feeling in the past week. Don't take too long over you replies: your immediate is best		
1	I feel tense or wound up:	Most of the time; A lot of the time; From time to time, occasionally; Not at all
2	I get a sort of frightened feeling as if something bad is about to happen:	Very definitely and quite badly; Yes, but not too badly; A little, but it doesn't worry me; Not at all
3	Worrying thoughts go through my mind:	A great deal of the time; A lot of the time; From time to time, but not too often; Only occasionally
4	I can sit at ease and feel relaxed:	Definitely, Usually, Not often, Not at all
5	I get a sort of frightened feeling like 'butterflies' in the stomach:	Not at all, Occasionally, Quite often, Very often
6	I feel restless and have to be on the move:	Very much indeed, Quite a lot, Not very much, Not at all
7	I get sudden feelings of panic:	Very often indeed, Quite often, Not very often, Not at all
CPSS QUESTIONNAIRE (PTSD SYMPTOMS)		
Instructions to participant: below is a list of problems that kids sometimes have after experiencing an upsetting event. Read each one carefully		
and circle the number (0–3) that best describes how often that problem has bothered you in the last 2 weeks		
1	Please select your most distressing event:	2016 Fort McMurray wildfire, Death of someone close to you, Injury that you suffered, Physical assualt against you, Sexual assualt, Other

(Continued)

TABLE 1 | Continued

	Questions	Answer choices
2	How long as it been since the event (in years)?	<1 month, 2–5 months, 6–11 months, 1 year, 2 years, 3–5 years, 6–10 years, 11 or more years

Below is a list of problems that kids sometimes have after experiencing an upsetting event. Read each one carefully and circle the number (0–3)

that best describes how often that problem has bothered you in the last 2 weeks

3	Having upsetting thoughts or images about the event that came into your head when you didn't want them to	Not at all or only at one time, Once a week or less/once in a while, 2 to 4 times a week/half the time, 5 or more times a week/almost always
4	Having bad dreams or nightmares	Same as above
5	Acting or feeling as if the event was happening again (hearing something or seeing a picture about it and feeling as if I am there again)	Same as above
6	Feeling upset when you think about it or hear about the event (for e.g., feeling scared, angry, sad, guilty, etc)	Same as above
7	Having feelings in your body when you think about or hear about the event (for e.g., breaking out into a sweat, heart beating fast)	Same as above
8	Trying not to think about, talk about, or have feelings about the event	Same as above
9	Trying to avoid activities, people, or places that remind you of the traumatic event	Same as above
10	Not being able to remember an important part of the upsetting event	Same as above
11	Having much less interest or doing things you used to do	Same as above
12	Not feeling close to people around you	Same as above
13	Not being able to have strong feelings (for e.g., being unable to cry or unable to feel happy)	Same as above
14	Feeling as if your future plans or hopes will not come true (for e.g., you will not have a job or getting married or having kids)	Same as above
15	Having trouble falling or staying asleep	Same as above
16	Feeling irritable or having fits of anger	Same as above
17	Having trouble concentrating (for e.g., losing track of a storey on the television, forgetting what you read, not paying attention in class)	Same as above
18	Being overly careful (for e.g., checking to see who is around you and what is around you)	Same as above
19	Being jumpy or easily startled (for e.g., when someone walks up behind you)	Same as above

CRAFFT QUESTIONNAIRE (DRUGS/ALCOHOL/TABACCO)

During the past 12 months, did you:

1	Drink any alcohol (more than a few sips)?	Yes, No
2	Smoke any marijuana or hashish?	Yes, No
3	Use anything else to get high?	Yes, No
4	Have you ever ridden in a CAR driven by someone (including yourself) who was "high" or had been using alcohol or drugs?	Yes, No

Questions 5–9 asked only if "yes" to one or more of questions 1–3

5	Do you ever use alcohol or drugs to RELAX, feel better about yourself, or fit in?	Yes, No
6	Do you ever use alcohol or drugs while you are by yourself, or ALONE?	Yes, No
7	Do you every FORGET things you did while using alcohol or drugs?	Yes, No
8	Do your FAMILY or FRIENDS ever tell you that you should cut down on your drinking or drug use?	Yes, No
9	Have you ever gotten into TROUBLE while you were using alcohol or drugs?	Yes, No

Tobacco use questionnaire

1	During the past month, did you smoke tobacco products?	Yes, No
2	During the past month, did you use smokeless tobacco products?	Yes, No

Rosenberg self-esteem scale

1	On the whole, I am satisfied with myself	Strongly agree, Agree, Disagree, Strongly disagree
2	At times, I think I am no good at all	Strongly agree, Agree, Disagree, Strongly disagree

(Continued)

TABLE 1 | Continued

	Questions	Answer choices
3	I feel that I have a number of good qualities	Strongly agree, Agree, Disagree, Strongly disagree
4	I am able to do things as well as most other people	Strongly agree, Agree, Disagree, Strongly disagree
5	I feel I do not have much to be proud of	Strongly agree, Agree, Disagree, Strongly disagree
6	I certainly feel useless at times	Strongly agree, Agree, Disagree, Strongly disagree
7	I feel that I'm a person of worth, at least on an equal plane with others	Strongly agree, Agree, Disagree, Strongly disagree
8	I wish I could have more respect for myself	Strongly agree, Agree, Disagree, Strongly disagree
9	All in all, I am inclined to feel that I am a failure	Strongly agree, Agree, Disagree, Strongly disagree
10	I take a positive attitude towards myself	Strongly agree, Agree, Disagree, Strongly disagree
KIDSCREEN QUESTIONNAIRE (QUALITY OF LIFE)		
Thinking about the last week:		
1	Have you physically felt fit and well?	Not at all, Slightly, Moderately, Very, Extremely
2	Have you felt full of energy?	Never, Seldom, Quite often, Very often, Always
3	Have you felt sad?	Never, Seldom, Quite often, Very often, Always
4	Have you felt lonely?	Never, Seldom, Quite often, Very often, Always
5	Have you had enough time for yourself?	Never, Seldom, Quite often, Very often, Always
6	Have you been able to do the things that you want to do in your free time?	Never, Seldom, Quite often, Very often, Always
7	Have your parent(s) treated you fairly?	Never, Seldom, Quite often, Very often, Always
8	Have you had fun with your friends?	Never, Seldom, Quite often, Very often, Always
9	Have you got on well at school?	Not at all, Slightly, Moderately, Very, Extremely
10	Have you been able to pay attention?	Never, Seldom, Quite often, Very often, Always
11	In general, how would you say your health is?	Excellent, Very good, Good, Fair, Poor
CHILD AND YOUTH RESILIENCE MEASURE (CYRM-12)		
To what extent do the sentences below describe you? Select an answer for each statement		
1	I am able to solve my problems without harming myself or others	Not at all, A little, Some-what, Quite a bit, A lot
2	I know where to go in the community to get help	Not at all, A little, Some-what, Quite a bit, A lot
3	Getting an education is important to me	Not at all, A little, Some-what, Quite a bit, A lot
4	I try to finish what I start	Not at all, A little, Some-what, Quite a bit, A lot
5	I have people I look up to	Not at all, A little, Some-what, Quite a bit, A lot
6	My parents/caregivers know a lot about me	Not at all, A little, Some-what, Quite a bit, A lot
7	My family stands by me during difficult times	Not at all, A little, Some-what, Quite a bit, A lot
8	My friends stand by me during difficult times	Not at all, A little, Some-what, Quite a bit, A lot
9	I have opportunities to develop skills that will be useful later in life	Not at all, A little, Some-what, Quite a bit, A lot
10	I am treated fairly in my community	Not at all, A little, Some-what, Quite a bit, A lot
11	I feel I belong at school	Not at all, A little, Some-what, Quite a bit, A lot
12	I enjoy my cultural and family traditions	Not at all, A little, Some-what, Quite a bit, A lot

to the next. We therefore employed a between-subject analysis (treating all survey samples as independent) rather than using a repeated-measures, within-subject analysis over successive years. It is important to note that adopting a between-subject approach is statistically conservative as there is an expectation of increased overall error variance compared to the likely advantage of within-subject analysis.

Cut-Off Scores and Probable Diagnoses

Probable diagnoses of four different psychiatric conditions were established by thresholding each participant's scores on specific scales. Threshold values for probable diagnoses were derived from the relevant literature for each scale, as described below. Specific probable diagnoses included PTSD (based on the CPSS scale), depression (from the PHQ-A), anxiety (from

the HADS), and alcohol/substance use disorder (based on the CRAFFT).

The term "probable diagnosis" is used here, as opposed to "clinical diagnosis," because the scores were based on self-report scales rather than psychiatric clinical interviews. The literature reports good agreement between psychiatric clinical diagnoses of PTSD, depression, anxiety, and alcohol/substance use disorder with probable diagnoses derived from widely-published threshold scores for the above four questionnaires (57, 58, 62–65), and we have previously used this approach (66).

Probable PTSD was determined based on a CPSS score of 15 or more (65, 67). Probable depression was determined based on a PHQ-A score of 11 or more (63). Probable moderately severe depression was determined based on a PHQ-A score

of 15 or more (62). Suicidal thinking was determined from responses to two questions from the PHQ-A: question 9 "Over the past 2 weeks, how often have you been bothered by any of the following problems: Thoughts that you would be better off dead, or of hurting yourself in some way?" and question 10 "Has there been a time in the past month when you have had serious thoughts about ending your life?" Participants were assessed as exhibiting suicidal thinking if they answered "Several days," "More than half the days," or "Nearly every day" to PHQ-A question 9 and "Yes" to question 10. Participants answering "Not at all" to question 9 skipped (were not shown) question 10, and they were assessed as not exhibiting suicidal thinking. In addition, participants answering "Several days," "More than half the days," or "Nearly every day" to PHQ-A question 9 and "No" to question 10 were assessed as not exhibiting suicidal thinking (as distinct from thinking about self-harm) (PHQ-A question 11 was not considered in the definition of suicidal thinking). Probable anxiety was determined based on a HADS score of 11 or more (64). Probable alcohol/substance use disorder was determined based on a CRAFFT score of 2 or more (57, 58). Tobacco use was determined as answering "yes" to either of the two questions on the Tobacco Use Questionnaire. Finally, an "Any of 4 probable diagnoses" criterion was defined as being positive for one or more of the four probable diagnoses: PTSD, depression, anxiety, or alcohol/substance use disorder.

Dependent Variables and Statistical Effects Tested

We examined the following 15 dependent measures: (1) CPSS PTSD score, (2) PHQ-A depression score, (3) HADS anxiety score, (4) CRAFFT alcohol/substance use score, (5) Rosenberg self-esteem score, (6) Kidscreen quality of life score, (7) CYRM-12 resilience score, (8) percent probable PTSD, (9) percent probable depression, (10) percent probable moderately severe depression, (11) percent suicidal thinking, (12) percent probable anxiety, (13) percent probable alcohol/substance use disorder, (14) percent tobacco use, and (15) percent any of four probable diagnoses (See "Cut-off Scores and Probable Diagnoses" section above for details of scoring cut-offs used to determine probable diagnoses). In analysing data for a given measure (e.g., mean CPSS) or probable diagnosis (e.g., probable PTSD), we included only those participants who provided answers for all questions in the relevant questionnaire.

For each of the 15 dependent measures, we tested five statistical effects: (1) linear effect of time (2017 vs. 2018 vs. 2019), (2) linear effect of age (11 to 19 years old), (3) effect of female vs. male gender identity, (4) effect of other vs. female/male gender identity, and (5) effect of preferred not to say vs. female/male gender identity.

Participant age was determined by Demographics Questionnaire question 4 "What is your age?," with answer choices "10 years or less," "11 years," "12 years," "13 years," "14 years," "15 years," "16 years," "17 years," "18 years," "19 years," and "20 years or more." Note that participants answering "10 years or less" or "20 years or more" were excluded to enable modelling

of age as a linear variable (see "Data Exclusion" section in the Results).

Participant gender identity was determined based on Demographics Questionnaire question 3 "What gender do you identify with?," with answer choices "female," "male," "other," and "prefer not to say." Statistical test 3 (female vs. male) compared participants answering "female" vs. those answering "male." Test 4 (other vs. female/male) compared participants answering "other" vs. those answering either "female" or "male." Test 5 (preferred not to say vs. female/male) compared participants answering "prefer not to say" vs. those answering either "female" or "male." Each test of a gender effect included only those participants with the relevant gender identities (test 3: female and male; test 4: female, male, and other; test 5: female, male, and preferred not to say).

Details of Statistical Analysis

All statistical comparisons were done using permutation testing on the slope parameter from a fitted linear model, with a null hypothesis of zero slope. The linear model included a slope parameter for the effect variable (time, age, female vs. male, other vs. female/male, preferred not to say vs. female/male) as well as parameters for "nuisance variables" as described below. Mathematical details of the linear modelling procedure are included in the "Details of Linear Modelling" section below.

Permutation testing is a non-parametric method and was chosen for its robustness against non-normality. The number of iterations was 10^5 for all permutation tests. All tests were two-tailed (That is, to compute the p-value for a given test, the absolute value of the slope parameter fitted to the real data was compared against the absolute values of the 10^5 simulated slope parameters fitted to permuted data).

In total, our analysis of the five statistical effects for each of 15 dependent variables included 75 individual statistical tests. We addressed multiple comparisons using the Benjamini-Hochberg method for false discovery rate (FDR) correction. This method computed a threshold of $p = 0.025$ for FDR correction across all 75 tests.

Distributions of gender identities and ages were similar across time, and the distribution of gender identities was similar across different ages (see "Demographics" in the Results section). Nonetheless, to address the possibility that results for one effect might have been driven in part by some small difference in one or more of the other effect variables, we included "nuisance variables" in the linear models to which permutation testing was applied. To test effects of time (2017 vs. 2018 vs. 2019), we used a linear model with a term for time as well as nuisance variables including a covariate for age and four indicator variables for gender identity: female, male, other, and preferred not to say. For analyses on the effects of time, only the fitted slope parameter for time was used to generate p-values. Including the other nuisance variables allowed the model to separate out effects of age and gender from effects of time. Similarly, analyses of age used five nuisance variables, including a time covariate and four indicator variables for gender identities. Analyses of gender effects (female vs. male, other vs. female/male, preferred not to say vs. female/male) included time and age as nuisance variables.

As expected from a sample of students in Grade 7–12, there were substantially fewer participants who were 11 or 18–19 years old, compared to those who were 12–17 years old, at the time of data collection (see "Demographics" in the Results section). To address the possibility that results for effects of age might be driven by leverage effects from smaller sample numbers in the extremes (aged 11 or 18–19 years old), we ran a follow-up analysis which included only participants aged 12–17.

We performed all analyses using in-house computer code written in the Clojure programming language (http://clojure.org). The code for statistical testing and FDR correction is available at http://github.com/mbrown/mrgbstats.

Details of Linear Modelling

For a given analysis, we defined an effect variable x_i and a dependent variable y_i, as well as J covariate nuisance variables $v_{j,i}$ and K indicator nuisance variables $w_{k,i}$, where $i \in [1, N]$ with N being the number of surveys used in the analysis.

For analyses on effects of time or effects of age, the effect variable x_i was mean-centred to make it "independent" (orthogonal) to the intercept (i.e., constant offset). For analyses on effects of gender (female vs. male, other vs. female/male, preferred not to say vs. female/male), the effect variable was categorical and therefore not mean-centred. Covariate nuisance variables $v_{j,i}$ were mean-centred, and indicator nuisance variables $w_{k,i}$ were not mean-centred.

For analyses on effects of time or effects of age, we did not include an intercept term in the model (i.e., a constant offset column containing all ones in the model matrix). Because analyses of time and age included four nuisance indicator variables for gender identities, an intercept column would have been a linear combination of those four indicator variables, rendering the model matrix degenerate. The effect variable for time or for age was mean-centred and therefore orthogonal to the constant offset, in any case. For analyses of effects of gender, which did not have the four nuisance variables for gender, we did include a constant offset term.

For each analysis, we created a model matrix X from the effect variable x_i, J covariate nuisance variables $v_{j,i}$, and K indicator nuisance variables $w_{k,i}$, as well as a constant offset term for analyses of gender effects. Each survey i contributed one effect variable value, one dependent variable value, and one value for each of $(J + K)$ nuisance variables. For example, for analyses on effects of time, x_i was time; $v_{1,i}$ was age; $w_{1,i}$, $w_{2,i}$, $w_{3,i}$, and $w_{4,i}$ were indicator variables for gender identity, including female, male, other, and preferred not to say; and there was no constant offset column. To take a second example, for analyses of other vs. female/male gender identity, x_i was 0 for participants identifying as female or male and 1 for those with other gender identity; $v_{1,i}$ and $v_{2,i}$ were time and age, respectively; there were no indicator nuisance variables; and there was a constant offset column. We created a model matrix X with size N by $(1 + J + K)$ or else N by $(2 + J + K)$, for analyses without and with a constant offset column, respectively. The first column of X consisted of the effect variable values x_i. If a constant offset column was included, it was the second column. The next J columns were comprised of the mean-centred covariate nuisance variables $v_{j,i}$, and the last K columns were comprised of the indicator nuisance variables $w_{k,i}$.

We defined the vector $\hat{\beta} = (X^T X)^{-1} X^T \vec{y}$ where $\vec{y}$ was the vector of dependent variable values y_i. The slope parameter used for permutation testing was $\hat{\beta}_1$, the first element of $\hat{\beta}$, representing the fitted scaling parameter for the effect variable.

RESULTS

The survey was administered to all Grade 7–12 students in Fort McMurray, Alberta, Canada who were attending either the Public or Catholic schools on the days the survey was conducted during the month of November in 2017, 2018, and 2019. Five Public schools and two Catholic schools participated in the survey. In total, 9,920 surveys were collected during the period of 2017 to 2019. Forty five percentage were collected from Public schools and 55% from Catholic schools. As all surveys were anonymous, there was no way to identify which students did or did not repeat the survey over successive years.

Data Exclusion

Data from 544 surveys were excluded based the following exclusion criteria:

1. Participant answered "10 years or less" to the age question (Demographics Questionnaire question 4).
2. Participant answered "20 years or more" to the age question (Demographics Questionnaire question 4).
3. Participant gave inconsistent answers for positive and negative questions included in the Rosenberg questionnaire (for details, see Appendix C: Exclusion Criteria in the **Supplementary Material**).
4. Participant gave inconsistent answers for positive questions from the Rosenberg questionnaire and positive questions from the Kidscreen questionnaire (see Appendix C: Exclusion Criteria the **Supplementary Material**, for details).
5. Participant gave inconsistent answers among the non-reversed and reversed questions from the HADS questionnaire (For two of the HADS questions, the answer order is reversed to test for consistency; see details in **Supplementary Material**).

Criteria 1 and 2 above excluded participants with ambiguous age. The remaining participants had non-ambiguous ages in the range 11–19 years, allowing us to model effects of age as a linear variable. Criteria 3 to 5 above excluded participants who gave inconsistent answers, possibly because they were not paying attention to the survey or did not understand the questions. After exclusions, the final dataset included 9,376 surveys.

Demographics

Demographics for the 9,376 surveys were as follows. Self-reported gender identity was 47.3% female, 48.6% male, 1.7% other, and 2.4% preferred not to say. Age ranged from 11 to 19, and the mean age of participants was 14.3 years ± 1.8 (standard deviation). For additional demographic details, see **Table 2**. Distributions of gender identities and ages were similar across the 3 years of data collection (**Table 2**). The distribution of gender identities was similar across different ages as well (**Table 2**).

TABLE 2 | Demographics.

	Total collected	After exclusions	Total students enrolled	Recruitment rate
Number surveys collected and recruitment rates				
All 3 years	9,920	9,376	13,848	67.7%
2017	3,252	3,070	4,407	69.7%
2018	3,451	3,265	4,592	71.1%
2019	3,217	3,041	4,849	62.7%

	Female	Male	Other	Did not say
Gender distributions				
All 3 years	47.3%	48.6%	1.7%	2.4%
2017	48.3%	47.8%	1.6%	2.4%
2018	46.6%	49.9%	1.6%	2.0%
2019	47.0%	48.0%	1.9%	3.0%

	11 yrs	12 yrs	13 yrs	14 yrs	15 yrs	16 yrs	17 yrs	18 yrs	19 yrs
Age distributions									
All 3 years	2.7%	18.1%	17.7%	17.2%	16.4%	14.5%	11.0%	1.9%	0.6%
2017	2.4%	17.9%	17.2%	17.7%	15.5%	14.4%	12.2%	2.0%	0.7%
2018	2.6%	17.7%	17.2%	16.3%	17.9%	15.4%	10.2%	2.2%	0.6%
2019	3.0%	18.7%	18.8%	17.7%	15.7%	13.7%	10.6%	1.5%	0.4%

	11 yrs	12 yrs	13 yrs	14 yrs	15 yrs	16 yrs	17 yrs	18 yrs	19 yrs
Age distributions by gender									
All	2.7%	18.1%	17.7%	17.2%	16.4%	14.5%	11.0%	1.9%	0.6%
Female	2.9%	17.9%	17.2%	17.4%	16.7%	14.4%	11.2%	1.7%	0.6%
Male	2.3%	18.5%	17.7%	17.2%	16.2%	14.6%	10.8%	2.1%	0.5%
Other	4.5%	7.1%	23.7%	16.7%	18.6%	14.7%	11.5%	3.2%	0.0%
Did Not Say	3.1%	19.6%	24.0%	16.0%	13.3%	13.3%	8.9%	0.9%	0.9%

"Did Not Say" refers to participants who answered the question on gender identity with "Prefer not to say."

Changes Over Time (2017, 2018, 2019)

Table 3 shows results for analysis of changes over time. Permutation testing of the linear effect of time, with age and gender partialled out, indicated that 13 of the 15 dependent measures changed over time during the period from 2017 to 2019, with statistical significance surviving FDR multiple comparison correction. Scores for PTSD (CPSS), depression (PHQ-A), anxiety (HADS), and alcohol/substance use (CRAFFT) increased from 2017 to 2019. Self-esteem (Rosenberg) and quality of life (Kidscreen) scores decreased. Resilience (CYRM-12) scores did not change significantly. Rates of probable diagnoses of PTSD, depression, moderately severe depression, suicidal thinking, anxiety, alcohol/substance use disorder, and the "Any of 4 probable diagnoses" category all increased. Rates of tobacco use did not change significantly.

Effects of Age (11–19 Years Old)

Table 4 shows results for the analysis of age effects. Permutation testing of the linear effect of age over the range 11–19 years old, with time and gender partialled out, revealed that all 15 dependent measures changed with age, with statistical significance surviving FDR multiple comparison correction.

Scores for PTSD (CPSS), depression (PHQ-A), anxiety (HADS), and alcohol/substance use (CRAFFT) increased with age. Self-esteem (Rosenberg), quality of life (Kidscreen), and resilience (CYRM-12) scores decreased with age. Rates of probable diagnoses of PTSD, depression, moderately severe depression, suicidal thinking, anxiety, alcohol/substance use disorder, tobacco use, and the "Any of 4 probable diagnoses" category all increased with age.

We did follow-up analyses of age restricted to participants aged 12–17 years old, with time and gender partialled out. Suicidal thinking did not change significantly over time with participants aged 12–17 years ($p = 0.11$), in contrast to analysis of age 11–19 years, which found a statistically significant increase in the rate of suicidal thinking with age ($p = 0.0088$). The other 14 dependent measures exhibited the same pattern of statistically significant changes in analyses with age 12–17 years (CYRM-12 $p = 0.00038$, CPSS $p = 0.00002$, all other tests $p = 0.00001$) as compared to analyses with age 11–19 years.

Effects of Gender Identity

Tables 5–**7** present results of three analyses of gender identity. Gender identity was determined based on Demographics

TABLE 3 | Changes over time (2017, 2018, 2019).

Measure	N 2017	N 2018	N 2019	Score 2017	Score 2018	Score 2019	Slope	P-value	FDR
CPSS score (PTSD)	2,869	3,035	2,829	12.83 ± 11.47	13.03 ± 11.33	13.75 ± 11.87	0.47	0.0025	*
PHQ-A score (depression)	2,964	3,149	2,926	8.02 ± 6.47	8.23 ± 6.48	8.69 ± 6.70	0.36	0.00001	*
HADS score (anxiety)	2,983	3,170	2,939	7.74 ± 4.72	7.72 ± 4.68	8.01 ± 4.79	0.14	0.019	*
CRAFFT score (alcohol/drugs)	2,994	3,190	2,947	0.55 ± 1.26	0.63 ± 1.30	0.61 ± 1.32	0.04	0.014	*
Rosenberg score (self-esteem)	2,967	3,138	2,921	18.22 ± 6.57	18.01 ± 6.51	17.58 ± 6.68	−0.33	0.00011	*
Kidscreen score (quality of life)	2,977	3,171	2,926	26.97 ± 8.19	26.75 ± 8.37	26.40 ± 8.45	−0.33	0.0028	*
CYRM-12 score (resilience)	2,929	3,096	2,857	46.48 ± 9.17	46.97 ± 9.12	46.69 ± 9.31	0.12	0.32	

Measure	N 2017	N 2018	N 2019	Rate 2017	Rate 2018	Rate 2019	Slope	P-value	FDR
Probable PTSD	2,869	3,035	2,829	37%	39%	41%	2.18	0.00070	*
Probable depression	2,964	3,149	2,926	31%	31%	35%	2.20	0.00033	*
Probable moderately severe depression	2,964	3,149	2,926	17%	18%	20%	1.66	0.0011	*
Suicidal thinking	2,990	3,175	2,948	16%	16%	18%	1.15	0.018	*
Probable anxiety	2,983	3,170	2,939	27%	28%	31%	2.16	0.00020	*
Probable alcohol/substance use disorder	2,994	3,190	2,947	15%	17%	16%	1.21	0.012	*
Tobacco use	3,004	3,201	2,956	13%	15%	12%	−0.16	0.71	
Any of 4 probable diagnoses	3,052	3,240	3,023	46%	49%	51%	2.65	0.00004	*

Table shows participant numbers, summary statistics, and results for analysis of effects of time. N X columns indicate number of participants from year X. Score X columns show mean ± standard deviation (not standard error) for year X. Rate X columns indicate rates of probable diagnosis for year X. Slope is the fitted slope parameter from a linear model with age and gender partialled out (see discussion of nuisance variables in the Materials and Methods). The slope parameter indicates the linear relationship between time and the dependent variable, independent of age and gender. P-values were derived from permutation testing on the slope parameters. Comparisons with an asterisk under the FDR column survived FDR multiple comparison correction. P-threshold for FDR correction was 0.025.

Questionnaire question 3 "What gender do you identify with?," with answer choices "female," "male," "other," and "prefer not to say." Analyses of gender identity compared female vs. male (**Table 5**), other vs. female/male (**Table 6**), and preferred not to say vs. female/male (**Table 7**) (See "Dependent Variables and Statistical Effects Tested" in the Materials and Methods section for additional details). Analyses of gender effects were done using permutation testing, with time and age partialled. All 15 dependent measures showed significant differences for all three gender identity comparisons, with statistical significance surviving FDR multiple comparison correction for all tests. Scores for PTSD (CPSS), depression (PHQ-A), anxiety (HADS), and alcohol/substance use (CRAFFT) were higher in females vs. males, in those with other gender identity vs. females/males, and in those who preferred not to say vs. females/males. Self-esteem (Rosenberg), quality of life (Kidscreen), and resilience (CYRM-12) scores were lower in females, in participants with other gender identity, and in participants who preferred not to say. Rates of probable diagnoses of PTSD, depression, moderately severe depression, suicidal thinking, anxiety, alcohol/substance use disorder, tobacco use, and the "Any of 4 probable diagnoses" category were higher in females, in those with other gender identity, and in those who preferred not to say.

DISCUSSION

This study investigated the multi-year impacts of wildfires on youth mental health. We examined 9,376 mental health survey samples from students in Grades 7–12 in Fort McMurray, Alberta. Surveys were conducted in 2017, 2018, and 2019, in the aftermath of the 2016 Fort McMurray wildfire.

As we have previously reported, the Fort McMurray student population exhibited elevated rates of probable depression, suicidal thinking, and tobacco use; elevated symptoms of anxiety; and reduced scores for quality of life and self-esteem 18 months after the 2016 wildfire, as compared to a control population that had not recently experienced a natural disaster (12). At that time, we observed similar mental health patterns for youth who were not actually present in Fort McMurray during the 2016 wildfire, although youth with greater personal exposure to impacts of the fire (e.g., home destroyed) exhibited worse symptoms of PTSD, depression, anxiety, and alcohol/substance use and lower scores for self-esteem and quality of life (13). The current study provides evidence of ongoing long-term mental health impacts on youth 3.5 years (42 months) post-wildfire.

Longer Term Mental Health Impacts

The results from the present study indicate a slow but statistically significant trend of worsening mental health from 2017 to 2019, including increased symptom scores and increased rates of probable diagnoses of PTSD, depression, anxiety, drug use, and alcohol use. Quality of life and self-esteem scores also decreased from 2017 to 2019. Tobacco use and resilience scores did not change significantly. These findings are consistent with other studies reporting long-term negative impacts on mental health from natural disasters (41–45), although these studies are not

TABLE 4 | Effects of age (11–19 years old).

Measure	N 11	N 12	N 13	N 14	N 15	N 16	N 17	N 18	N 19	Score 11	Score 12	Score 13	Score 14	Score 15	Score 16	Score 17	Score 18	Score 19	Slope	P-value	FDR
CPSS score (PTSD)	216	1,540	1,525	1,521	1,444	1,294	977	168	48	13.09 ± 11.19	11.97 ± 10.83	12.99 ± 11.41	13.44 ± 11.68	12.61 ± 11.51	13.85 ± 11.73	14.39 ± 12.23	16.20 ± 12.21	16.44 ± 11.83	0.42	0.00001	*
PHQ-A score (depression)	225	1,611	1,592	1,572	1,486	1,326	1,002	175	50	7.23 ± 5.78	6.75 ± 5.86	7.62 ± 6.34	8.38 ± 6.69	8.43 ± 6.51	9.33 ± 6.85	10.03 ± 6.77	10.47 ± 6.47	11.28 ± 6.87	0.60	0.00001	*
HADS score (anxiety)	236	1,632	1,597	1,573	1,498	1,328	1,005	173	50	7.40 ± 4.35	7.13 ± 4.46	7.58 ± 4.65	7.72 ± 4.78	7.82 ± 4.73	8.33 ± 4.83	8.71 ± 4.92	8.91 ± 4.73	8.48 ± 4.27	0.27	0.00001	*
CRAFFT score (alcohol/drugs)	236	1,647	1,617	1,578	1,497	1,327	1,007	172	50	0.04 ± 0.32	0.12 ± 0.60	0.30 ± 0.92	0.49 ± 1.13	0.73 ± 1.41	1.01 ± 1.56	1.26 ± 1.68	1.11 ± 1.65	1.92 ± 2.33	0.22	0.00001	*
Rosenberg score (self-esteem)	233	1,618	1,590	1,562	1,481	1,323	998	171	50	18.63 ± 6.36	19.08 ± 6.35	18.13 ± 6.76	17.57 ± 6.76	17.83 ± 6.55	17.60 ± 6.62	17.17 ± 6.35	16.32 ± 5.87	15.84 ± 5.96	−0.33	0.00001	*
Kidscreen score (quality of life)	237	1,625	1,600	1,572	1,491	1,326	998	175	50	28.93 ± 8.20	29.22 ± 8.09	27.92 ± 8.13	26.72 ± 8.45	26.17 ± 7.94	24.92 ± 8.29	24.14 ± 8.11	23.42 ± 7.56	22.42 ± 8.02	−0.97	0.00001	*
CYRM-12 score (resilience)	225	1,585	1,550	1,537	1,470	1,308	988	171	48	47.48 ± 9.36	47.98 ± 8.87	46.46 ± 9.49	46.13 ± 9.46	46.78 ± 9.08	46.64 ± 8.89	46.32 ± 9.01	44.50 ± 9.76	45.73 ± 10.65	−0.25	0.00002	*

Measure	N 11	N 12	N 13	N 14	N 15	N 16	N 17	N 18	N 19	Rate 11	Rate 12	Rate 13	Rate 14	Rate 15	Rate 16	Rate 17	Rate 18	Rate 19	Slope	P-value	FDR
Probable PTSD	216	1,540	1,525	1,521	1,444	1,294	977	168	48	38%	34%	38%	40%	36%	41%	43%	53%	48%	1.65	0.00001	*
Probable depression	225	1,611	1,592	1,572	1,486	1,326	1,002	175	50	26%	22%	28%	33%	33%	38%	44%	43%	46%	3.68	0.00001	*
Probable moderately severe depression	225	1,611	1,592	1,572	1,486	1,326	1,002	175	50	12%	11%	16%	20%	17%	23%	27%	26%	34%	2.58	0.00001	*
Suicidal thinking	230	1,638	1,608	1,578	1,496	1,328	1,009	176	50	17%	14%	18%	17%	15%	17%	19%	23%	28%	0.57	0.0088	*
Probable anxiety	236	1,632	1,597	1,573	1,498	1,328	1,005	173	50	26%	22%	27%	28%	28%	33%	36%	40%	28%	2.35	0.00001	*
Probable alcohol/substance use disorder	236	1,647	1,617	1,578	1,497	1,327	1,007	172	50	1%	3%	8%	13%	20%	28%	35%	30%	42%	5.93	0.00001	*
Tobacco use	235	1,648	1,620	1,582	1,506	1,335	1,010	175	50	3%	4%	7%	11%	17%	21%	24%	22%	44%	4.01	0.00001	*
Any of 4 probable diagnoses	247	1,683	1,649	1,604	1,525	1,351	1,023	180	53	39%	37%	43%	49%	49%	57%	65%	63%	62%	4.64	0.00001	*

Table shows participant numbers, summary statistics, and results of analysis of effects of age 11 to 19 years old. N X columns indicate number of participants from age group X. Score X columns show mean ± standard deviation (not standard error) for age group X. Rate X columns indicate rates of probable diagnosis for age group X. Slope is the fitted slope parameter from a linear model with time and gender partialled out (see discussion of nuisance variables in the Materials and Methods). The slope parameter indicates the linear relationship between age and the dependent variable, independent of time and gender. P-values were derived from permutation testing on the slope parameters. Comparisons with an asterisk under the FDR column survived FDR multiple comparison correction. P-threshold for FDR correction was 0.025.

TABLE 5 | Effects female vs. male gender identity.

Measure	N male	N female	Score male	Score female	Slope	P-value	FDR
CPSS score (PTSD)	4,201	4,190	10.61 ± 10.30	15.39 ± 11.96	4.79	0.00001	*
PHQ-A score (depression)	4,391	4,297	6.76 ± 5.88	9.66 ± 6.75	2.90	0.00001	*
HADS score (anxiety)	4,405	4,325	6.52 ± 4.27	9.01 ± 4.77	2.50	0.00001	*
CRAFFT score (alcohol/drugs)	4,438	4,330	0.52 ± 1.20	0.64 ± 1.33	0.12	0.00002	*
Rosenberg score (self-esteem)	4,375	4,287	19.55 ± 6.15	16.53 ± 6.53	−3.02	0.00001	*
Kidscreen score (quality of life)	4,397	4,314	28.91 ± 7.72	24.72 ± 8.29	−4.20	0.00001	*
CYRM-12 score (resilience)	4,292	4,248	47.25 ± 9.05	46.64 ± 9.05	−0.62	0.0014	*

Measure	N male	N female	Rate male	Rate female	Slope	P-value	FDR
Probable PTSD	4,201	4,190	29%	47%	17.60	0.00001	*
Probable depression	4,391	4,297	23%	40%	17.56	0.00001	*
Probable moderately severe depression	4,391	4,297	12%	24%	12.54	0.00001	*
Suicidal thinking	4,426	4,326	12%	21%	8.48	0.00001	*
Probable anxiety	4,405	4,325	17%	38%	21.03	0.00001	*
Probable alcohol/substance use disorder	4,438	4,330	14%	17%	3.46	0.00001	*
Tobacco use	4,451	4,341	12%	14%	2.05	0.0040	*
Any of 4 probable diagnoses	4,532	4,402	39%	58%	19.02	0.00001	*

Table shows participant numbers, summary statistics, and results of analysis of effects of female vs. male gender identity. N X columns indicate number of participants identifying as gender X (female or male). Score X columns show mean ± standard deviation (not standard error) for gender X. Rate X columns indicate rates of probable diagnosis for gender X. Slope is the fitted slope parameter from a linear model with time and age partialled out (see discussion of nuisance variables in the Materials and Methods). The slope parameter indicates the linear relationship between the female vs. male effect variable and the dependent variable, independent of time and age. P-values were derived from permutation testing on the slope parameters. Comparisons with an asterisk under the FDR column survived FDR multiple comparison correction. P-threshold for FDR correction was 0.025.

TABLE 6 | Effects of other vs. female/male gender identity.

Measure	N female/male	N other	Score female/male	Score other	Slope	P-value	FDR
CPSS score (PTSD)	8,391	142	13.00 ± 11.42	19.38 ± 14.02	6.30	0.00001	*
PHQ-A score (depression)	8,688	145	8.20 ± 6.49	12.52 ± 7.67	4.18	0.00001	*
HADS score (anxiety)	8,730	150	7.75 ± 4.69	9.93 ± 5.11	2.13	0.00001	*
CRAFFT score (alcohol/drugs)	8,768	149	0.58 ± 1.27	1.13 ± 1.77	0.52	0.00001	*
Rosenberg score (self-esteem)	8,662	148	18.06 ± 6.52	14.25 ± 8.25	−3.74	0.00001	*
Kidscreen score (quality of life)	8,711	148	26.83 ± 8.28	22.98 ± 9.74	−3.64	0.00001	*
CYRM-12 score (resilience)	8,540	139	46.95 ± 9.05	40.28 ± 11.33	−6.64	0.00001	*

Measure	N female/male	N other	Rate female/male	Rate other	Slope	P-value	FDR
Probable PTSD	8,391	142	38%	56%	17.78	0.00003	*
Probable depression	8,688	145	32%	61%	28.19	0.00001	*
Probable moderately severe depression	8,688	145	18%	42%	23.71	0.00001	*
Suicidal thinking	8,752	150	16%	38%	21.54	0.00001	*
Probable anxiety	8,730	150	28%	43%	15.03	0.00006	*
Probable alcohol/substance use disorder	8,768	149	16%	28%	11.51	0.00024	*
Tobacco use	8,792	152	13%	24%	10.13	0.00027	*
Any of 4 probable diagnoses	8,934	156	48%	69%	20.03	0.00002	*

Table shows participant numbers, summary statistics, and results of analysis of effects of other vs. female/male gender identity. N X columns indicate number of participants identifying as gender X (other or female/male). Score X columns show mean ± standard deviation (not standard error) for gender X. Rate X columns indicate rates of probable diagnosis for gender X. Slope is the fitted slope parameter from a linear model with time and age partialled out (see discussion of nuisance variables in the Materials and Methods). The slope parameter indicates the linear relationship between the other vs. female/male effect variable and the dependent variable, independent of time and age. P-values were derived from permutation testing on the slope parameters. Comparisons with an asterisk under the FDR column survived FDR multiple comparison correction. P-threshold for FDR correction was 0.025.

TABLE 7 | Effects of "prefer not to say" vs. female/male gender identity.

Measure	N female/male	N preferred not to say	Score female/male	Score preferred not to say	Slope	P-value	FDR
CPSS score (PTSD)	8,391	200	13.00 ± 11.42	17.09 ± 13.66	4.11	0.00001	*
PHQ-A score (depression)	8,688	206	8.20 ± 6.49	10.25 ± 7.21	2.14	0.00001	*
HADS score (anxiety)	8,730	212	7.75 ± 4.69	9.11 ± 5.50	1.40	0.00004	*
CRAFFT score (alcohol/drugs)	8,768	214	0.58 ± 1.27	0.93 ± 1.62	0.41	0.00001	*
Rosenberg score (self-esteem)	8,662	216	18.06 ± 6.52	15.54 ± 6.87	−2.56	0.00001	*
Kidscreen score (quality of life)	8,711	215	26.83 ± 8.28	24.33 ± 8.97	−2.70	0.00001	*
CYRM-12 score (resilience)	8,540	203	46.95 ± 9.05	41.62 ± 10.59	−5.40	0.00001	*

Measure	N female/male	N preferred not to say	Rate female/male %	Rate preferred not to say %	Slope	P-value	FDR
Probable PTSD	8,391	200	38	51	12.88	0.00022	*
Probable depression	8,688	206	32	43	12.19	0.00024	*
Probable moderately severe depression	8,688	206	18	29	11.80	0.00003	*
Suicidal thinking	8,752	211	16	26	9.81	0.00018	*
Probable anxiety	8,730	212	28	43	15.35	0.00001	*
Probable alcohol/substance use disorder	8,768	214	16	25	10.66	0.00006	*
Tobacco use	8,792	217	13	19	7.44	0.0012	*
Any of 4 probable diagnoses	8,934	225	48	62	14.50	0.00003	*

Table shows participant numbers, summary statistics, and results of analysis of effects of preferred not to say vs. female/male gender identity. N X columns indicate number of participants identifying as gender X (preferred not to say or female/male). Score X columns show mean ± standard deviation (not standard error) for gender X. Rate X columns indicate rates of probable diagnosis for gender X. Slope is the fitted slope parameter from a linear model with time and age partialled out (see discussion of nuisance variables in the Materials and Methods). The slope parameter indicates the linear relationship between the preferred not to say vs. female/male effect variable and the dependent variable, independent of time and age. P-values were derived from permutation testing on the slope parameters. Comparisons with an asterisk under the FDR column survived FDR multiple comparison correction. P-threshold for FDR correction was 0.025.

directly comparable because they focused on mental health in adulthood and/or used different outcome measures.

Our results do not support our hypothesis that mental health would improve with time following the 2016 wildfire. One possibility is that 3.5 years may not be sufficient time for this population to recover from the adverse mental health effects of the wildfire, though that possibility seems unlikely in light of reports that many individuals affected by disaster do recover within 1–2 years (4). Theories of recovery from trauma identify various factors important to the recovery process including a sense of safety and stability, self- and community efficacy, hope, support from family and friends, social support, and social connectedness (4, 51, 52). It is possible that one or more factors important to recovery may be at issue. For example, Fort McMurray has experienced an economic downturn related to the reduction in oil prices starting in 2014, and this may negatively affect the community's sense of stability and hope. Future studies would be needed to test this suggestion.

It is noteworthy that CYRM-12 resilience measures did not change significantly with time ($p = 0.27$), indicating that the above-discussed changes in mental health measures may not be attributable to a change in resilience.

There was a statistically significant increase in suicidal thinking with age in the analysis of participants aged 11–19 ($p = 0.0088$) but not in the analysis of participants aged 12–17 ($p = 0.11$). The difference in results seems to be driven by the larger proportion of students aged 18 and 19 exhibiting suicidal

thinking (18 years: 23%, 19 years: 28%) compared to younger students (14–19%) (see **Table 4**).

Age-Related Differences in Mental Health Impact

We observed worse average scores on all 15 dependent measures in older vs. younger students. Specifically, older students exhibited higher mental health symptom scores, higher rates of probable diagnoses, and lower scores for self-esteem, quality of life, and resilience. These results are consistent with previous reports of increased mental health impairment among older youth compared to younger youth post-disaster (68), as well as higher rates of mental health symptoms in older adolescents more generally (69). As has been suggested by others (68), one possible interpretation of this finding, that would bear future exploration, is that greater awareness among older youth regarding challenges facing their families and the larger community (rebuilding, economic implications, etc.), as well as concerns they may have regarding their future, may negatively influence their well-being compared to younger youth. That older students also exhibited higher mental health symptom scores and lower resilience scores is consistent previous research showing an association between lesser resilience and worse mental health outcomes following disaster (28, 35, 70, 71) and with theoretical conceptions of resilience and its role in buffering the individual's mental health from harm due to adverse experiences (72–74). Reduced resilience may have played a role in making

older students more vulnerable to developing negative mental health symptoms.

Differences in Mental Health Related to Gender Identity

Our analyses revealed worse average scores on all 15 dependent measures in students identifying as female vs. male, in students with other gender identity vs. females/males, and students who preferred not to say their gender identity vs. females/males. These specific groups of students exhibited higher mental health symptom scores, higher rates of probable diagnoses, and lower scores for self-esteem, quality of life, and resilience.

We interpret participants answering "other" to the question of their gender identity as belonging to a gender minority, including transgender or gender non-conforming. For participants who preferred not to answer the demographics question on gender identity, some presumably identified as female or male but did not want to say so, while others presumably identified as a gender minority, including transgender or gender-non-conforming. Given that the group who preferred not to answer exhibited significantly worse mental health results than those identifying as female or male, we suspect that a majority of the group who preferred not to answer in fact belonged to a gender minority, including transgender or gender-non-conforming.

The finding of worse mental health scores in females compared to males is consistent with a previous report of higher rates of mental health symptoms post-natural disaster in females vs. males (75). We are not aware of any previous studies examining the impact of natural disaster on the mental health of gender minorities, including transgender and gender non-conforming individuals. It is a benefit of our population study approach, with its large sample size, that we are able to do so for the first time. More generally, our results are consistent with previous reports indicating higher rates of mental health symptoms in gender minorities, including transgender and gender-non-conforming individuals, both adults and youth (76–79). Resilience scores were lower for females vs. males and for gender minorities vs. females/males, which is consistent with previous studies showing an association between lesser resilience and worse mental health outcomes following disaster (28, 35, 70, 71). This suggests that reduced resilience may have been a factor in specific groups' developing more negative mental health symptoms.

Implications

The destructive nature of disasters tends to attract funding from government and charities to address the immediate aftermath of a disaster. Our results provide an example of worsening mental health impacts in youth during the period 1.5–3.5 years following a wildfire disaster. This has occurred in the context of an ongoing, whole-of-community "build back better" approach to post-wildfire recovery in the area (80), as well as multiple challenges that have faced the community since the 2016 wildfire, including a downturn in the economy (Additional challenges include disastrous flooding following the 2020 spring ice breakup and the outbreak of the COVID-19 pandemic in 2020, though

these occurred after the last survey data collection was completed in 2019). Our results underscore the need for multi-year funding, interventions, and policies to address not only the short-term physical damage but also the long-term negative mental health effects of natural disasters.

In addition to focusing on symptomatology, there is a need to investigate factors associated with post-disaster recovery processes, as well as efficacy of psychosocial strategies during later phases of recovery relative to early interventions, while also recognising complex and evolving, social-ecological post-disaster contexts. As an example, given that specific groups exhibited greater negative mental health effects, namely older youth, females, and gender minorities, interventions and policies may be more effective if they take into account developmental stage and gender identity with respect to mitigating these effects.

Limitations

Our analysis included a large dataset of 9,376 survey responses. Conducting full clinical interviews with this large number of participants is not feasible, and so we used clinical measures based on self-report questionnaires, which is a limitation of the study. As noted above, in addition to the 2016 wildfire, Fort McMurray has experienced an economic downturn since 2014. The resulting job losses and financial impacts on families also likely had an effect on youth mental health in addition to the 2016 wildfire. We are not aware of any study specifically on the effects of Alberta's economic downturn on youth mental health, though one report found a negative mental health impact in adults (81). Additionally, given that this study utilised anonymous data, we were not able to identify longitudinal trends in individuals, only in groups.

CONCLUSION

This study presents a cross-sectional statistical analysis of longitudinal mental health measurements in a population of Fort McMurray youth in Grades 7–12 during the period of 1.5–3.5 years following the 2016 Alberta wildfire. Findings indicate that there was a long-term trend of worsening mental health during that period. These observations support previous reports that youth and communities experience long-term mental health impacts following major natural disasters, such as wildfires. Our findings emphasise the need for multi-year funding and programs to support child and youth mental health in communities that have experienced such disasters.

AUTHOR'S NOTE

Some portions of the manuscript, in the Materials and Methods section, are based on similar material from two previous papers (12, 13) presenting findings from separate analyses of the data from Fort McMurray collected in 2017 only.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Requests for data access should be made by email to the corresponding author.

ETHICS STATEMENT

This study involving human participants was reviewed and approved by the University of Alberta's Health Research Ethics Board (ethics protocol number Pro00072669 approved June 26, 2017). Data were collected as part of the Fort McMurray Public and Catholic Schools' standard curriculum to evaluate their support programs. Written informed consent from the participants' legal guardian/next of kin was not required to participate in this study, in accordance with the national legislation and the institutional requirements. Parents/guardians were notified of the study 2 weeks prior and were given the opportunity to opt their child(ren) out of the study. Participants themselves were given the opportunity to opt out of the study, as was explained to them at the beginning of each study survey session.

AUTHOR CONTRIBUTIONS

MB, VA, AG, PB-M, JD, CM-H, JO, MM, SN, DK, and PS: study design. MM, SN, and DK: data collection. MB, HP, IC, and PS: analysis. MB, HP, AG, IC, PB-M, JD, CM-H, BL, and PS: manuscript preparation. All authors contributed to the article and approved the submitted version.

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SUPPLEMENTARY MATERIAL

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Beirut Ammonium Nitrate Blast: Analysis, Review, and Recommendations

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A massive chemical detonation occurred on August 4, 2020 in the Port of Beirut, Lebanon. An uncontrolled fire in an adjacent warehouse ignited ~2,750 tons of Ammonium Nitrate (AN), producing one of the most devastating blasts in recent history. The blast supersonic pressure and heat wave claimed the lives of 220 people and injured more than 6,500 instantaneously, with severe damage to the nearby dense residential and commercial areas. This review represents one of the in-depth reports to provide a detailed analysis of the Beirut blast and its health and environmental implications. It further reviews prior AN incidents and suggests actionable recommendations and strategies to optimize chemical safety measures, improve emergency preparedness, and mitigate the delayed clinical effects of blast and toxic gas exposures. These recommended actionable steps offer a starting point for government officials and policymakers to build frameworks, adopt regulations, and implement chemical safety protocols to ensure safe storage of hazardous materials as well as reorganizing healthcare system disaster preparedness to improve emergency preparedness in response to similar large-scale disasters and promote population safety. Future clinical efforts should involve detailed assessment of physical injuries sustained by blast victims, with systemic mitigation and possible treatment of late blast effects involving individuals, communities and the region at large.

Keywords: ammonium nitrate explosion, blast injury, Beirut, emergency preparedness, health hazard, traumatic brain injury

INTRODUCTION

Chemical explosions cause large disasters and civilian mass casualties. Throughout history, chemical explosions, particularly those caused by Ammonium Nitrate (AN) have caused tragedies with devastating human and infrastructure loss, disturbing all functional aspects of affected communities (1, 2). The latest AN blast in Beirut was categorized as the third most devastating urban explosions of all time after the Hiroshima and Nagasaki nuclear bombings at the end of world war II (3).

The Beirut explosion created a massive blast that produced a 140 m wide crater and an earthquake of a 3.3 magnitude on a Richter scale, killing nearly 220 individuals and injuring more than 6,500 instantly, while leaving ~300,000 people homeless (4). Over and above the

human tragedy, this large disaster damaged 9 of the capital's hospitals (5) and hampered access to healthcare for nearly 160,000 patients. The blast further damaged schools, commercial centers, museums, news organizations, and foreign embassies which hindered communication and exchange of essential information with local staff, residents and travelers with pressing need for accurate and timely instructions on urgent matters. The blast estimated economic burden exceeds 6.7 Billion US dollars (6). In addition, the blast AN ignition released toxic gases that posed a real threat to Beirut's 2.4 million residents, particularly when mixed with sea humidity and dust particles emitted from the demolished and collapsed buildings.

This review complements recent reports (7–18) and further provide an in-depth analysis of the Beirut blast and its health and environmental implications, and suggests actionable recommendations and strategies.

BEIRUT BLAST: HEALTH AND ENVIRONMENT IMPLICATIONS

Beirut Blast: Context and Timeline

Lebanon, an upper middle-income country, is located on the Mediterranean Sea. The port of Beirut is Lebanon's main entry point in its capital city Beirut with its strategic geographic location at the nexus of three continents: Europe, East Asia, and Africa. The port is one of the largest ports in the Middle East, a regional hub providing major imports for the Eastern Mediterranean region including Syria, Jordan, Iraq, and the Persian Gulf States. It spreads over a 1.2 Km^2 area with terminals for passengers, general cargo, and containers, in addition to a grain silo and a duty-free zone. The general cargo area included 12 warehouses. The grain silo contained 85% of the country's grain, mainly imported from Eastern Europe through vessels and sucked directly into the silos' cells at a 600 mt/h vacuum-suction speed (19) **Figure 1**. The port channels more than two-thirds of Lebanon's total external trade. With an average annual revenue of USD 313 Million and a net profit of ~USD 124 Million in 2017, the port of Beirut is a vital element of the fragile Lebanese economy, where almost 90% of the port's cargo are imported goods required to satisfy local needs (19).

At 5:55 pm local Beirut time, Tuesday August 4, 2020, an uncontrolled fire erupted at a fireworks warehouse in Hangar 12 of the Port of Beirut (PoB). The Beirut fire department deployed a team of nine firefighters and a paramedic to the scene, however, the team failed to control the fierce and intense fire. The warehouse ignited at 6:07 pm causing the first explosion. Approximately 30 s later, a subsequent massive blast occurred in the AN warehouse, next to the grain silos as shown in **Figure 2**.

The blast was caused by a large amount of AN exceeding 2.7 kilotons, fueled by the initial flames emitted from the adjacent burning warehouse. The destructive AN detonation resulted in an instantaneous massive blast that was heard in Cyprus 125 miles away in the Mediterranean Sea. The epicenter structures were demolished, along with nearby warehouses, grain silos, and docked ships. The resulting 140-m-wide crater was filled with seawater (**Figure 3**). In addition to the large ground crater, the
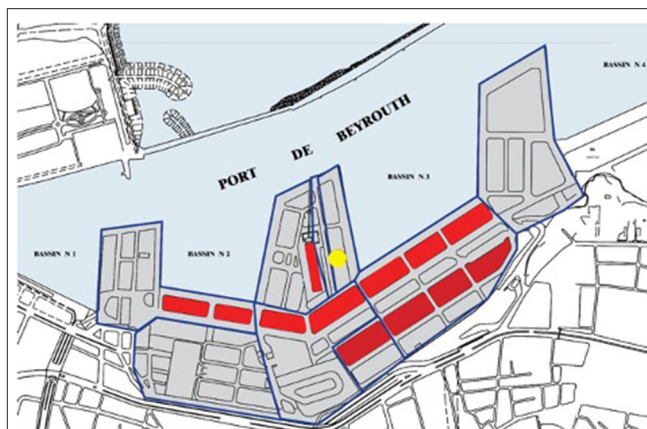
FIGURE 1 | Blast location at the port of Beirut and adjacent warehouses. The yellow circle refers to the blast location in hangar 12 next to the grain silos and fireworks warehouses. Red rectangles depict the warehouses.

explosion created a massive red-orange smoke plume surrounded by a white mushroom pressure cloud. The produced pressure was equivalent to a 3.3 magnitude on a Richter scale, accompanied by a seismic heat and a shockwave that traveled at a supersonic speed, demolishing most of the urban neighborhood around the port and shattering windows as far as 10 km across the Beirut metropolis. Those experiencing the blast felt the earth shake prior to the arrival of the blast wave. In addition to the destruction of most of Beirut port and its grain silos concrete structure, the explosion heavily damaged 50,000 residential houses, along with 178 schools and 9 hospitals, including a children's specialized hospital.

Health Implications

Beirut Blast Injuries

Understanding the common types of injuries associated with blasts is essential to developing an appropriate emergency response and treatment plan. We documented the initial acute management of blast victims presenting to the American University of Beirut Medical Center (AUBMC), a Beirut tertiary hospital of 350-bed capacity, located ~2.5 miles away from the blast site. Injuries were characterized and classified into primary, secondary, tertiary, and quaternary injuries with a particular focus on the neurological manifestations and long-term detrimental outcomes of blast brain injuries.

Disaster Acute Management

The unique characteristics of the Beirut disaster imposed a series of challenges to local tertiary hospitals ranging from the provision of acute care and management to the mass casualties to the anticipation of the chronic effects of the blast overpressure and toxic gas exposure. One of these Beirut tertiary hospitals was the American University of Beirut Medical Center (AUBMC). The key challenge that AUBMC faced along with other neighboring hospitals is the urgent need to continue its provision of service and adequate disaster response despite suffering from partial structural damages and sustaining injuries among its hospital

staff. Further to dealing with its own emergency situation, the hospital received nearly 360 victims in its 42-capacity Emergency Department (ED). Of those, 270 were treated and released at ED, 108 were admitted and 9 were dead on arrival (20). In the 3 days following the explosion, 68 operations were performed on admitted patients. The greatest diagnostic challenges for the hospital clinicians at all levels of care in the aftermath of the disaster was dealing with the large numbers of casualties and multiple penetrating injuries. Despite activation of the hospital disaster plan, patients presented at a scale much larger than what the hospital resources and capacity could accommodate. Electronic health systems failed to accommodate the surge of patients. The overwhelming surge of injuries hindered formal documentation of patient records; many injured presented without identification. These difficulties to overcome using interim triage and on-site informal record keeping were adopted to achieve effective emergency care (20).

Injury Characteristics

Almost all Port of Beirut employees along with the deployed firefighters at the blast scene died instantly due to their severe injuries. Beirut residents suffered from multiple mechanisms of injuries within a radius of 6 miles from the epicenter and were affected by a mushroom-like cloud of ammonium nitrate (**Figure 4**). Upon the detonation of Beirut explosive, the initial blast wave produced a millisecond-long supersonic positive pressure gradient wave subsequent to a lengthier negative pressure that expanded outwardly from the blast epicenter across Beirut residential areas (21, 22). Thousands of Beirut disaster victims presented to local hospitals for injury acute management. These victims experienced various mechanisms of blast injuries caused by the explosion pressure and heat wave. The reported injuries align with the Centers for Disease Control and Prevention (CDC) classification of blast injury (23, 24) and were classified into:

Primary Injury or Barotrauma
Victims mainly suffered from lung damage and eye/eardrum ruptures due to the blast over-pressurization and under-pressurization waves.

Secondary Injury
Victims sustained deep penetrating injuries, traumatic brain injuries and intracranial bleeding, and extremities amputations caused by propelled debris fragments.

Tertiary Injury
Victims suffered from ear/eye traumatic injuries, fractured/amputated extremities, and concussion due to structural collapse, and blast wind wave that displaced victims leading to body impact, head acceleration and injury.

Quaternary Injury
Victims suffered from toxicity and thermal burns due to gas intoxication and fire. Although a limited number of patients suffered from burns, it is assumed that most burn victims were dead on arrival (DOA).

Some or combinations of these injuring mechanisms were experienced by the blast victims. For further information, please refer to the CDC application (https://apps.apple.com/us/app/cdc-blast-injury/id890434999).
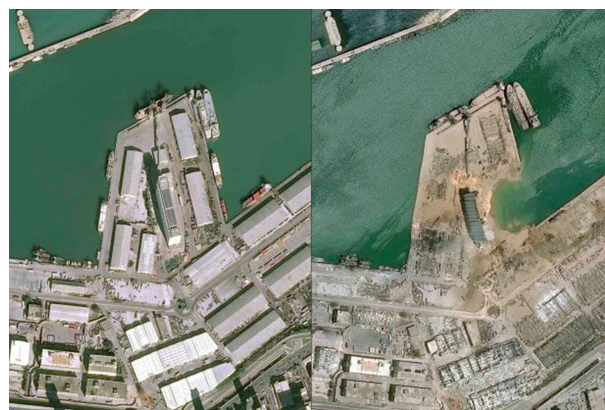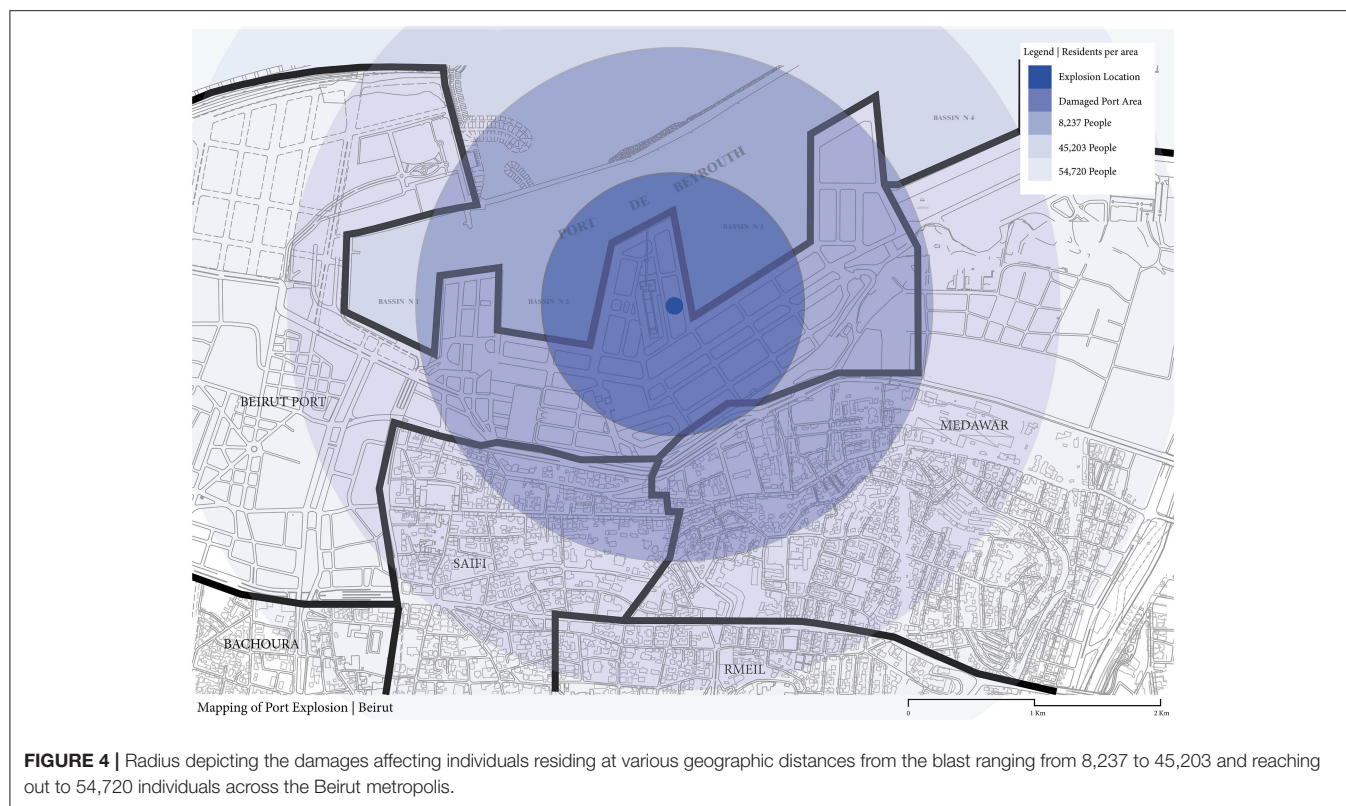

FIGURE 3 | Satellite picture for the Beirut explosion (before and after).

FIGURE 2 | Blast explosion at time 5:55 pm (initial explosion) and at 6:08 pm (orange and mushroom cloud) at the port of Beirut (Source online).

FIGURE 4 | Radius depicting the damages affecting individuals residing at various geographic distances from the blast ranging from 8,237 to 45,203 and reaching out to 54,720 individuals across the Beirut metropolis.

Environment Implications

Beirut Blast Toxicity

The Beirut blast disaster produced enormous white and dark brown fumes covering a large portion of the city. Emission of irritating white fumes and brown fumes characteristically occur during the decomposition of AN. Initially, four chemical species are formed in the gas phase: white ammonia nitrate mist (NH_3), HNO_3, nitrous oxide (N_2O), and H_2O vapor (25). In confinement, AN completely decomposes allowing for the reaction of the four gases to form water vapor, nitrogen, and toxic brown fumes mainly consisting of nitric oxides (NOx). The most hazardous NOx are nitric oxide (NO) and nitrogen dioxide (NO_2). Only one or two breaths of the NOx stream can cause severe toxicity. NO_2 is heavier than air, hence exposure can result in asphyxiation. Odor provides an overt warning for acute exposures. Compared to adults, exposed children may receive greater doses of NO_2 due to body size and proximity to ground level and the large surface area of their lungs (26).

NO_2 can damage the respiratory system in several different ways. First, by its conversion into nitric and nitrous acids in the distal airways, damaging alveolar structure. Secondly, by causing oxidative stress through generation of free radicals, which results in protein oxidation, lipid peroxidation, and cell membrane damage (27). In addition, an indirect effect caused by NO_2 is the alteration of macrophage and immune functions, thereby increasing the risk of lung infections (28). This possibly includes increased risk of COVID-19 infection given that the Beirut blast took place during the ongoing pandemic. A sharp increase in

COVID-19 positive cases was observed exactly 10 days after the blast COVID cases increased (from 177 cases on August 3 to 334 cases on August 14) (https://www.moph.gov.lb/en).

The primary site of NOx toxicity usually involves the lower respiratory tract. At low concentrations, symptoms including abdominal pain, nausea, headache, fatigue, coughing, and difficulty breathing are common. In some cases, an asymptomatic period of up to 30 h in exposed subjects may be followed by bronchospasms and pulmonary edema. In cases of an intense exposure, swelling of tissues in the throat and burns may occur, as well as obstruction of the upper respiratory airways (29). The initial effect may also be followed by fibrous obstruction of the bronchioles several weeks later. Such late obstruction presents as a group of additional symptoms including fever and chills, coughing and bleeding in the lungs, cyanosis of the skin, shortness of breath, and in extreme cases a respiratory failure (30). In addition, victims of inhalation may suffer from the reactive airways dysfunction syndrome (RADS), even after an acute exposure. Absorption of NOx into the circulation may lead to methemoglobunemia, a sensation of chest congestion, a dilated heart, and possibly circulatory collapse.

The Beirut explosion also produced large amounts of particulate matter that remained suspended in air for days; this effect has probably impacted more people than any other blast pollutant. Emitted PM may consist of sulfates, nitrates, ammonia, sodium chloride, black carbon, and mineral dust. It includes a complex mixture of organic and inorganic substances suspended in the air. Emitted particles with a diameter of

around 10 microns or less (PM$_{10}$) comprise blast demolition dust capable of affecting the upper respiratory airways. Those with a diameter of 2.5 microns or less (PM$_{2.5}$) are released from combustion materials, namely fuel burning. PM$_{2.5}$ may spread into the alveolar region of the lung, and may enter the blood stream, causing a long-term public health concern. Prolonged periods of exposure to respirable particulates PM$_{2.5}$ increases the risk of cardiopulmonary morbidity and mortality (31). Exposed individuals with reactive airways disease may be at higher risk of illness in an environment with elevated PM$_{10}$ and PM$_{2.5}$.

The long-term environmental repercussions of the Beirut explosion remain unexplored. The impact of the AN explosion mushroom cloud smoke, rain precipitation 5 days following the blast, and the fire-water drainage require study. In the current case of the Beirut explosion, chemical release was quite rapid. The resulting toxic plumes were dispersed within 24 h and scattered into the atmosphere to below detectable limits. Given the prevailing wind direction in Lebanon, most of the affected areas were located toward the Northeast, downwind of Ground Zero. In addition, toxic dust was deposited on surfaces and settled on the ground in areas downwind of the port and may have re-suspended in the air with activities during the recovery operations. AN is a plant nutrient, with low toxicity to aquatic life (TLM 96: 10–100 ppm), and is highly biodegradable, hence is not expected to bioconcentrate or accumulate in its original form, particularly that most of it had decomposed in the explosion. On the other hand, the observed rainfall on Day 5 following the blast may have driven re-suspended particulates to runoff into the water supply system and may have dispersed in soil. The impact on drinking water quality and potentially affected soils requires further investigation.

At the same time, environmental and health concerns continue over chemical substances stored at the damaged port warehouses, including 9.5 tons of Class I insecticides which disappeared completely after the blast, along with small amounts of picric acid and methanol, according to the International Environmental Emergency Coordination Cell. In addition, during additional preliminary site surveys conducted one week after the blast, the following substances were found at various warehouses at Port of Beirut: petroleum oils, calcium hypochlorite, benzoyl peroxide, hydrofluoric acids, in addition to other potential hazardous materials, some with insufficient labeling, or are unreachable due to building conditions.

Beirut Blast AN Safety Hazard

The Beirut explosion was caused by ~2.75 kiloton of Nitropril^{TM} stored in FIBC bags. Based on the manufacturer's technical data sheet, the product is classified as security sensitive material consisting of a low-density porous white to off-white prilled grade of ammonium nitrate NH$_4$NO$_3$ (AN), composed of 99% AN, with a total nitrogen mass of 34%. It is specifically designed to be used as an oxidizer in blasting agents. Prilled AN is an acidic water-soluble chemical, with hygroscopic properties. Many studies have reported on the hazardous aspects of products containing AN (32, 33). The related hazards may be classified into three categories: fire, thermal decomposition, and explosion. While AN reacts with organic material, reducing agents, and

metal powder, it is not combustible on its own. Nevertheless, its presence increases the intensity of an initiating fire. In cases of a fire where AN is heated above 190–210°C, irreversible decomposition occurs, yielding toxic gases (34).

According to its material safety data sheet (MSDS), NitroprilTM storage requirements include that it be kept dry, away from an ignition or heat source and mainly stored in areas that are well-ventilated. The absence of proper storage conditions coupled with a lengthy storage time (since 2013) in Hangar 12 of the Beirut port, exacerbated the conditions of storage of Nitropril^{TM} bags. The manufacturer warns users that an adjacent detonation or a major fire involves risk of explosion. Confinement of material can also result in detonation according to the product *(write out)* MSDS. Additional dynamics of the Beirut explosion remain uncertain so far. The investigation, however, shows that one or more of these scenarios is likely to have occurred in the context of this explosion. Moreover, in the case of fire, it is recommended by the manufacturer to, first, open up the storage area to provide maximum ventilation, and secondly, to evacuate all personnel to a minimum of 1,000 m away from the site to save first responders and prevent death.

DISCUSSION

Characteristics of Existing Ammonium Nitrate Incidents

In the absence of an official report on the root causes of the explosion, we conducted a thorough review of the literature of previous AN incidents to help in gaining insights into the potential root causes of the Beirut disaster. We retrieved information pertaining to AN tragic events that have occurred since 1916. AN blast precipitating factors were investigated including storage techniques (confinement in massive piles), absence of adequate ventilation, chemical contamination (mixture with incompatible materials), humidity (sea air moisture), and exposure to an external thermal source (ignition caused by fire or flames). We further examined AN safety hazard and potential environmental and health implications of these AN incidents compared to the Beirut blast.

Reviewing existing literature, we have identified top AN explosions in each country and compared them to other AN incidents. Since 1916, more than 30 AN tragic events occurred worldwide at industrial sites or during transportation (1, 2, 35–37). We have selected the top AN explosion in each of these countries in terms of its weight and resulting fatalities. Our analysis suggests that multiple interlinked factors typically result in AN detonation (**Table 1**).

Previous AN incidents confirm that uncontrolled fires were the leading root cause for the majority of AN detonation incidents (2, 35, 44, 45). When exposed to heat, high pressure, and temperatures above 190°C, AN decomposes leading to an explosion that may be significantly amplified by confined space storage. Among factors that contributed to the devastating impact of the AN detonation in Beirut is the stockpiling of large amounts of AN in one geographic location which was closely associated with the amplified impact of the explosions in previous

TABLE 1 | Characteristics for the top 6 most devastating ammonium nitrate explosions globally.

Location	Year	Setting	AN in tons	Explosion root cause	Fatalities	Injuries
Beirut, Lebanon	2020	Port	2,750	Uncontrolled fire ignition	220	6,500
Texas City, USA	1947	Ship	2,086	Uncontrolled fire ignition	581	5,000
Tianjin, China	2015	Port	800	Uncontrolled fire ignition	165	798
Faversham, United Kingdom	1916	AN based factory	700	Uncontrolled fire ignition	115	
Oppau, Germany	1921	AN based factory	450	AN contamination with industrial explosives	561	1,952
New Brunswick, Canada	1947	AN based factory	400	Uncontrolled fire ignition	0	0
Toulouse, France	2001	Plant fertilizer	200	AN contamination with chloride	30	2,242
Tessenderlo, Belguim	1942	AN based factory	150	AN contamination with industrial explosives	189	900
Wayandra, Australia	2014	Transportation	56	Road traffic accident	0	8
Coahuila, Mexico	2007	Transportation	28	Road traffic accident	37	150
Barracas, Spain	2004	Transportation	25	Road Traffic Accident	2	5
Buzau, Romania	2004	Transportation	20	Road traffic accident	18	13
Oulu, Finland	1963	AN based Factory	10	AN contamination with industrial explosives	10	

See (1, 2, 35, 37–47).

similar AN incidents, causing a massive number of casualties (**Table 1**). Causalities claimed by the AN explosion substantially varied based on the AN storage distance from residential areas. Whether in a factory (37), a fertilizer plant (1, 2) or a warehouse (45), urban AN storage and proximity to residential areas greatly increased the numbers and severity of blast injuries. This proxy effect was clearly demonstrated in the large number of causalities reported at multiple AN incidents in the US, China, and Germany. Our review suggests similarities in lingering factors including violation of safety regulations, coupled with improper AN storage requirements and handling. Secondly, contamination of AN is another root cause that hardens AN stockpiles, exacerbating its hazardous risks and ultimately contributing to a massive detonation as in the case of AN incidents in France and Germany (1, 37).

Analysis of Environmental and Health Implications of Similar AN Incidents

We have examined the difference and similarities across AN events and in comparison to the Beirut blast. Understanding similar past AN events can provide additional information on blast injuries often classified into four categories based on their mechanisms.

Similar to Beirut blast injury manifestations, brain trauma, pneumothorax, and laceration or contusion of abdominal organs were common primary blast injuries witnessed in the Tianjin and West Texas (46, 47). The Tianjin incident indicates that ears are the most frequently damaged and affected organs in a blast, usually in the form of tympanic membrane perforation (47), while 14% of the 252 injured in the West Texas explosion suffered tinnitus and hearing problems with 5% experiencing tympanic membrane perforation (47).

In the cases of Beirut disaster, residents of nearby populated areas near the port sustained severe injuries from the heatwave and overpressure as blast overpressure was enhanced by the reflections from buildings, blocks, or vehicles. Reflected blast leads to enhanced overpressure effects even after a single

blast incident (36). Though not visible, primary blast injury, depending on overpressure, leads to a spectrum of neurological manifestations and brain injuries (48, 49). Mild or moderate blast injuries from primary blast barotrauma often remain uncharacterized and in many cases their chronic effects are undiagnosed as a result of the visible symptoms and the lack of an available specific diagnostic marker (50). Several factors contribute to the extent and pattern of blast injuries including the environment (e.g., surrounding barriers), device composition, and most importantly, the distance between the victim and the blast (50–52).

The difference in the ambient pressure (i.e., the outer atmospheric pressure and the inner pressure) can result in injury of the hollow gas-filled organs [i.e., the lungs, gastrointestinal tract, and the auditory system, traumatic blast brain injury (bTBI)] and in blast TBI and impact /acceleration injuries (21, 23, 52–55). Although blast bTBI may share some characteristics with blunt or even open head TBI, blast-induced non-inertial mTBI is attracting more attention as a unique clinical entity (51, 56, 57).

Similar to Beirut blast, secondary blast injuries were the most observed types of injury (84%) following the Tianjin explosion (47). Blast pressure and wind resulted in the displacement of debris, which caused injury to the head, face, neck, chest, arms, and hands (47). Moreover, several victims of the West Texas incident suffered from lacerations and penetrating trauma, with 12% presenting eye injuries (46). Debris introduced foreign bodies disrupting soft tissues and leading to extensive injury and infection beyond the superficial wound and long-term health complications (58).

As for the tertiary blast injuries, several similarities manifested across AN incidents. The aftermath of the Tianjin explosion led to many traumatic amputations, fractures, concussions, and sprains (46, 47). Similarly, almost 20% of West Texas blast survivors sustained a traumatic head injury or concussion, indicating their high prevalence (46). Post-treatment studies suggest that blast victims are more likely to continue opioid use

after discharge and experience reduced improvement in pain intensity (46).

Burns were quaternary blast injuries seen in Tianjin (47). The high prevalence of burn injuries was mainly due to victims' proximity to the center of the incident and their risk of exposure to secondary explosions. Burn injury was associated with greater likelihood of mortality due to their degree of impact on multiple systems (47). Emergency responders often sustain the most cases of burns. Inhalation injuries are also a major source of concern associated with blast incidents, especially due to ammonium nitrate, smoke, and subsequent chemical poisoning (58).

Across all AN incidents, many victims of AN events were reported to suffer from multiple types of blast injuries and their long-term consequences. Furthermore, psychiatric conditions such as post-traumatic stress disorder, anxiety, depression, and substance misuse occur following exposure to an explosion. The medical research community has evaluated in some detail the blast-induced physiologic and pathophysiologic brain alterations due to blast overpressure and impulse (52, 59). The blast induces neuropathological molecular changes in the brain as the blast wave passes through the person's skull and brain water or, in the case of high overpressures which rotate or/and accelerate the head, impact and acceleration injuries occur. Alternatively, indirect hydraulic interactions can be initiated with kinetic energy transfer from the compressed body organs to the body's fluid phase causing oscillating pressure waves, reaching the brain through the venous system (60). Thus, the blast injury mediates its neuropathological effects via different mechanisms. Notably, blast injuries, depending on intensity, may involve macro- and microstructural as well ultrastructural intracellular alterations, changes in cortical thickness and volumetric reduction, and functional network and connectivity changes, as shown in blast mild traumatic brain injury (mild TBI) experimental models (61), as well as diffuse axonal injuries (62–66). Blast injury, mainly mild TBI concussion can result in chronic neurobehavioral and neurostructural change at time points ranging from months to years post-injury (67, 68).

Importantly, the nature of neurobehavioral and neuropathological brain changes attributed to blast mTBI, even with a single blast event, leads to long term detrimental outcomes, due to accumulation of brain-specific proteins such as tau and TDP-43 proteins (54). Afflicted mTBI victims develop later neurobehavioral effects including anxiety, post-traumatic stress disorder (PTSD), depression, and suicidality (67, 69). These individuals may be asymptomatic early but later develop neurocognitive, neuro-psychologic, motor, and consciousness changes at later stages (29, 30). Mild TBI, also referred to as concussion, historically offer considerable challenges not only to the individual but to caregivers and family as well (50, 70). Subsequent to blast injuries, neuropsychological effects of blast and blunt trauma are among the main health concern issues. Many blast victims reported balance problems and as well as neuropsychological impairments such as PTSD, anxiety, and depression. Most of those symptoms described above overlap with those experienced by impact/acceleration injuries that cause mTBI/concussion (71–73). Given the limited success of clinical

examination and other diagnostic modalities for assessing TBI generally (74, 75), circulating biomarkers, including UCH-L1, GFAP and most recently NfL, have been found to be sensitive and clinically useful tools to improve the accuracy of diagnosis and outcome prediction, both acutely and in the case of NfL chronically (76–79).

ACTIONABLE RECOMMENDATIONS

Various plausible factors likely triggered the Beirut Blast. Accordingly, lessons learned and a series of actionable recommendations are suggested to promote population safety and improve emergency response.

Hazard Materials Regulation and Storage Requirement

This explosion marks a serious regulatory failure. The detonation of the AN-based product likely occurred when storage conditions deteriorated: confinement of material, impurity contamination, or a thermal/ignition source. Dangerous reactions between AN and other products include chlorinated compounds, organic materials, and heavy metals, particularly when exposed to the molten AN (1). Investigation of prior AN disasters in different parts of the world guided policy on AN management and safety (**Table 1**). In Lebanon, the Beirut explosion highlights the need for a national Chemical Regulatory Agency to oversee and implement chemical safety measures and adopt preventive strategies for the entire country. In addition, the local port administration and other concerned authorities require stronger technical support and credentialled inspectors to ensure a high level of safety to improve management of chemical storage facilities, ensure safe storage and handling of chemicals, and develop effective emergency response plans.

An urgent need exists to adopt and enforce standard safety regulations and procedures, particularly in the transport and storage of hazardous materials. The government should introduce safety measures to ensure storage of these materials at suitable distances from population centers and residential areas. Following the West, Texas explosion, President Obama in the United States formed a working group, "Improving Chemical Facility Safety and Security," that was co-chaired by the Department of Homeland Security, the Environmental Protection Agency (EPA), and the Department of Labor (2). The Lebanese government might consider recruiting stakeholders including practitioners and academicians to identify best practices as part of an executive oversight committee or working group, or as part of the existing Chemical Biological, Radio Nuclear Events Preparedness Program (CBRN). Similar steps would likely improve operational coordination, enhance information sharing between different governmental bodies, and modernize policies and regulations on chemical safety. The suggested committee would coordinate activities across the different governmental entities involved in managing chemicals (e.g., Ministries of Defense, Agriculture, Environment, Public Health…etc.), in order to address safety and security issues as well as to reduce risks associated with hazardous chemicals to

handlers, operators, and the community at large. Committee activities may include developing tools, training programs, and resources to strengthen emergency response at the level of the Lebanese Civil Defense, ministries, and municipalities. This could also include sharing information with first responders to build their capacity in planning and responding to similar incidents, reviewing all policies and regulations associated with chemical safety and security, issuing clear guiding documents to educate and raise the awareness of all stakeholders, and coordinating information sharing across the intergovernmental entities communities.

Laminated Glass in Urban Settings

Given the high risk of secondary blast injuries, the use of laminated glass in urban buildings is critical to reduce building glass fragmentation from explosions and associated consequences. Laminated glass has proven to be effective in combatting blast waves. Following an explosion, glass debris is a known cause of injuries. Laminated glass helps to retain glass fragments on a "polyvinyl butyral (PVB) interlayer upon fracture" (80) while alleviating the effects of scattered and fragmented glass pieces that present a main threat to people following an explosion.

Hospital Disaster Preparedness

One of the major challenges to medical response was the blast destruction to rural hospitals. Three major hospitals were non-functional, while three others were partially damaged, reducing their ability to admit patients and provide treatment (81). The Beirut explosion produced an overwhelming number of casualties layered upon the escalating national numbers of COVID-19 patients, further straining resources of the healthcare system (82). The massive influx of blast victims exceeded local hospital capacities and the provision of emergency care. Many of Beirut's main hospitals are located near the blast site and were severely damaged, thus reducing hospital capacity in the city by almost one third. Evacuation of damaged hospitals forced the transfer of critically sick COVID-19 patients on ventilators to other health facilities. Many died due to delayed care related to lack of bed capacity. Lessons learned from this tragic disaster should inform the design of hospital preparedness and emergency response plans to deal with other large-scale disasters and mass casualty events.

Crowd Control and Triaging Away From Hospitals

Crowd control is vital in the aftermath event of an explosion. It must be mediated by responsible parties (i.e., the police) to facilitate the work of first responders. Another major challenge faced by medical responders was the surge of less injured casualties (i.e., the "walking wounded") first by private transportation or walking to hospitals, while the more injured arrived later by emergency medical services vehicles (83). With limited medical responders and supplies at medical centers, there is a need for crowd control and triaging of simple injuries away from hospitals. Triage mistakes following the Tianjin explosion were major contributors to the surge of medical administration

into the hospitals, leading to misallocation of limited resources (47). The walking wounded should be separated from seriously injured casualties through crowd communication and control by a triage officer (83). They can be directed to a collection point to assess their injury severity, determine the degree of urgency and allocate them to a site of treatment accordingly. Establishing first aid sites near the disaster location can reduce crowding of hospitals by less severe cases (83).

Emergency Response

Adequate preparedness and proper emergency response for chemical spills or chemical-related fire were lacking in Beirut as in many other metropolitan areas. The impact of the explosion was clearly exacerbated by absence of risk reduction and management plans. It is crucial to provide essential training for immediate first responders (firefighters, police, emergency medical services) to adopt safety procedures and avoid toxic exposures. Communication and coordination among multiple entities are key to ensure harmonized multi-site and multi-disciplinary collaboration to provide timely responses. These measures could potentially reduce the adverse impacts of future disasters.

Investment in Blast Related Health Training

A paucity of blast related training exists in Lebanon, even though the country and the Region is prone to man-made disasters and protracted armed conflicts. In fact, blast injury is the main cause of military TBI during wars in the Middle East, accounting for more than 60% of all combat wounds in current conflicts and the majority of the 423,000 TBI injuries affecting US service members and veterans. This recent Beirut blast events highlights the need to invest in blast related health training for professionals external to military medicine. Training such as STOP THE BLEED (84), is critical to educate health professionals on large-scale disaster preparedness, response, and recovery, in order to save critically injured and to meet similar future disasters.

Translational Opportunities for Research

This event provides a unique opportunity to assess the chronic effects of blast injury detonation, namely the primary barotrauma due to peak overpressure (within a radius of 6 miles) and the quaternary toxic gases due to the AN intoxication. Apart from the experimental animal studies in blast shock tubes, this unfortunate open blast event provides a translational opportunity to perform a longitudinal study of biomarkers on blast victims that can be tracked across time. Brain-specific mild TBI biomarkers (UCH-L1, NfL, and GFAP) along with inflammatory markers IL-6 and CRP. These measures cans be coupled with a neurological and neuroimaging assessment at chronic time points. It can be anticipated that a proportion of blast injured victims will manifest mental illnesses such as PTSD and depression that need to be recognized and treated a sequalae of brain injury. Diagnostic and treatment measures for such a cohort in Beirut offer the promise of benefit to all those suffering from the disabling effects of traumatic brain injury. This could only be achieved if a detailed registry of all victims

is established and maintained, with individual-level information and geocoded data.

CONCLUSION

This paper provides an overview of the health and environmental implications of the Beirut explosion. We suggested a series of recommendations as a starting point for health professionals and policymakers to build frameworks, adopt regulations, and implement chemical safety protocols on one hand, and to reshape healthcare system emergency preparedness to be able to respond efficiently to similar large-scale disasters, on the other hand. Future studies should focus on the assessment of physical and emotional blast injuries with a thorough examination of the blast devastating impacts on individuals, communities and the country.

AUTHOR CONTRIBUTIONS

SA-H, RD, HD, and FK conceptualized the idea and contributed to drafting the manuscript. SM and HK contributed to manuscript review. All authors have contributed to the editing of the manuscript. All authors have approved the final version of the paper.

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The Fort McMurray Mommy Baby Study: A Protocol to Reduce Maternal Stress Due to the 2016 Fort McMurray Wood Buffalo, Alberta, Canada Wildfire

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Introduction: Data show that maternal stress triggered by exposure to a natural disaster before, during or just after pregnancy is associated with adverse pregnancy and newborn outcomes. In this paper, the first aim is to describe our efforts to test a simple, low-cost intervention to large numbers of women following a major natural disaster. The second aim is to outline the challenges faced and lessons learned during the execution of this natural disaster study.

Methods: The setting was the May 2016 Fort McMurray Wood Buffalo wildfire in northern Alberta, Canada. Women who were pregnant or preconception at the time of the disaster were invited to participate via social media. This prospective cohort study included a randomized controlled trial to test the effectiveness of an expressive writing intervention on the levels of prenatal maternal stress and maternal, birth, and early childhood outcomes. At recruitment and at multiple timepoints postpartum, a battery of questionnaires was administered to evaluate objective and subjective stress exposure to the fire as well as maternal mental health, resilience and its contributing factors as well as infant developmental milestones. Qualitative content analysis of the expressive writing was conducted.

Discussion: There is an increasing need to develop effective, wide-spread, rapid, and low-cost interventions to reduce prenatal maternal stress, increase resilience, and improve pregnancy outcomes following a natural disaster. Though analysis of data is ongoing, we highlight the strengths of this study which include strong community participation, rapid recruitment of eligible participants, low-cost intervention and data acquisition, and successful testing of the intervention. We acknowledge the challenges we encountered including the high rate of participant disqualifications or losses due to

incomplete collection of online data; evacuation, dispersal, and inconsistent return to homes; and the high levels of stress accumulated post-disaster which led to inability to complete the study. Despite potential challenges, there remains a need for such research amid natural disasters.

INTRODUCTION

Climate change is causing more natural disasters. Their frequent worldwide occurrences wreak havoc upon families, particularly at-risk pregnant women. Hurricanes, floods, and wildfires have been linked with increased rates of preterm birth, low birth weight, and other adverse birth outcomes (1–3). Not only can natural disasters and their subsequent prenatal maternal stress (PNMS) have substantial impact on maternal and birth outcomes, they can also significantly impact child developmental outcomes.

The 2016 Fort McMurray Wildfire

On May 1st, 2016, a wildfire started in the northern Albertan region of Fort McMurray Wood Buffalo (FMWB). Within 3 days, the fire had massively multiplied in size and approached the town of Fort McMurray and nearby municipalities, forcing a mass evacuation of 88,000 people. This natural disaster became Canada's worst in every respect with an estimated cost of $9 billion (4). Twenty-four hundred buildings (10% of total), mostly family houses, were destroyed. Many structures left intact experienced significant smoke damage or ash contamination (5). During the height of the fire, the air pollution index rose to 38 on a 10-point scale (6–8). The town's water supply was contaminated and the large amount of residual ash and soil contained 19 different toxic metals and compounds reaching levels 20 times above recommended limits (5, 9). Residents were not allowed to return to the city until June 1, and then only limited numbers were permitted access. Over the next 2 weeks, about half of the evacuees returned, and it would take until September for the remainder with intact homes to return (10). It took much longer for those whose homes were destroyed to return, and some never did. Even before the wildfire, many FMWB families were experiencing economic difficulties due to layoffs or decreased working hours owing to lower oil prices and demand affecting community mental health (11). Psychologists and other experts predicted that after families returned to their homes, cases of domestic abuse and interpersonal violence would likely increase due to the stressors and uncertainties brought on by this natural disaster (12).

The Developmental Origins of Health and Disease (DOHaD) theory posits that multiple environmental factors operating on the mother before, during, and after pregnancy and while breastfeeding can influence the development of the child in ways that may favor survival in the short-term but may also compromise health in the longer-term (13). Increasing attention has been paid to the environment and experiences of the mother during pregnancy; consequently, PNMS has become an important subject of research. Animal (14–16) and human (17–19) research on PNMS suggest that exposure of the pregnant or preconception individual to stress is associated with a host of negative maternal health and pregnancy outcomes (e.g., preterm birth, gestational diabetes, preeclampsia, fetal growth restriction) as well as adverse developmental trajectories for the offspring - especially on the neurodevelopmental (20) and metabolic level, such as obesity (21), diabetes (22, 23), and cardiovascular issues (24). In addition, past maternal experiences with depression, exposure to adverse life events prior to pregnancy or environmental stressors in the woman's previous generations are thought to have similar adverse consequences as do immediate stressors (25–27).

Previous research studying pregnant women exposed to sudden-onset natural disasters such as the 1998 Quebec Ice Storm (28), the 2009 Iowa Floods (29), and the 2011 Queensland Floods (30) have attempted to disentangle the effects of maternal objective stress exposure, their cognitive appraisal, and their subjective distress due to the disasters on their own mental health and their children's development. These studies demonstrate significant effects of one or more of these aspects of the mothers' stress experience on maternal mood (29, 31), birth outcomes (32, 33), the cognitive (34, 35), behavioral (36–38), and motor (39, 40) development of their children, as well as immune (41, 42) and metabolic health (43, 44). Many of these outcomes have been shown to be mediated by epigenetic effects, still visible at age 13 (45, 46). The results of these disaster studies often suggest that the sex of the child, or the timing of the stressor *in utero*, moderates the impact of the stressor (32, 40).

Beyond prenatal exposure, stress either before conception or soon after birth may also have programming effects. Because an individual's hypothalamic-pituitary-adrenal (HPA) axis can be disrupted for months or even years after a severe disaster (47–49), maternal exposure to a disaster in the months before conception could conceivably influence the earliest moments of embryonic development (50, 51). As for postnatal effects, although the fetal programming hypothesis is based on the connection between the maternal HPA axis and fetal development via the placenta and umbilical cord, maternal stress may also be directly communicated to the young infant via breast milk and maternal behavior (52–54).

Allostatic Load and Resilience

Whereas a natural disaster is most often limited in time, its resulting stress factors are not. Traumatic events add a considerable amount of stress to the stress load an individual has amassed over the course of its lifetime. Moreover, a short-term natural disaster is often followed by a host of stressors in

its aftermath among which are physical and/or environmental, psychological, social, and financial factors. The wear and tear on the body due to the accumulation of life stressors is called allostatic load (AL) (55, 56). AL is the totality of the stressors acting on the body at any given time, both psychological and physical stressors, and how the body attempts to maintain homeostasis in the face of stress. When a threshold is reached at which the body can no longer cope with the AL, the risk increases to develop numerous disease processes associated with allostatic load including preterm birth, susceptibility to infection, and adverse newborn neurodevelopment (57, 58).

Resilience can be defined at the personal or individual level as well as from a socio-ecological perspective. At the individual level, resilience includes physiological, biological, individual, social, and environmental protective factors (59). It is thought of as a dynamic process, the capacity to bounce back, cope with, and recover from adverse events and trauma in order to maintain health and well-being (60). Psychological resilience is considered a major moderator of the relationship between the experience of trauma and the development of posttraumatic psychopathology (61, 62). Social-ecological resilience on the other hand is defined by Folke et al. (63) as the "capacity to adapt or transform in the face of change in socio-ecological systems, particularly unexpected change, in ways that continue to support human well-being (p. 41)" (63). Resilience can also be interpreted in relation to posttraumatic growth, focussing more on "bounce forward" than "bounce back" after experiencing traumatic events.

Cumulatively, the increased allostatic load due to a natural disaster and consequent uncertainty and disruption of lives, toxic chemical ingestion, and the pro-inflammatory stimulus of pollutants in air, water, and soil have the potential to accumulate to the point where individual resilience is overcome and people lose the ability to cope. In this situation they become vulnerable to adverse health outcomes and disease. Hence stress-related adverse outcomes in the case of pregnancy are the difference between an individual's (or a community's) allostatic load and resilience. Improving outcomes requires reducing allostatic load and/or increasing resilience.

Interventions to Reduce Allostatic Load or Increase Resilience

Several studies indicate that interventions with highly anxious mothers, including reassurance of the fetus' health using additional ultrasound sessions (64, 65), group prenatal care (66), and prenatal education on preparing for childbirth and motherhood (67), may improve perinatal outcomes. However, although a systematic review found that web-based programs for perinatal mental health appear promising, significant gaps in the literature remain (68). The challenge to which we responded was to provide a simple, inexpensive, timely intervention to a large number of women who had experienced the FMWB disaster while pregnant or shortly preconception.

Aims

The first aim of this paper is to describe our efforts to develop a protocol to deliver and test a rapid intervention to a large number of women following a disaster. The second goal is to outline the challenges faced and lessons learned during the execution of this

natural disaster study. It is important to share how challenges were dealt with because the protocol with modifications has been applied in other natural disaster research to date (Houston's Hurricane Harvey) and may be used in future studies.

As this study had a number of objectives, we conceptualized unique objectives and measures for each of the overall aims of this study.

Illuminating the Resilience of Pregnant Women Post-trauma: Qualitative Thematic Content Analysis of an Expressive Writing Intervention

We aimed to determine the extent to which a brief, online expressive writing intervention supports maternal resilience. The research questions guiding this project were: (1) Does expressive writing support resilience, reduce stress, and improve outcomes? (2) What thoughts, feelings, themes, experiences, actions, relationships, and factors do the women write about that reflect aspects of resilience? (3) In their post-writing reflections, how effective do the women find expressive writing to be?

Intervention: Expressive Writing
Since the 1980's James W. Pennebaker has developed, tested, and refined a simple intervention to help people deal with stressors utilizing expressive writing (69, 70). Narratives or stories reveal both the individual and collective resilience strategies (71). Short bursts of expressive writing (i.e., 15–20 min) were shown to be sufficient to allow for emotional disclosure, the active ingredient in the intervention (70, 72–74), and to improve biochemical markers of physical and immune functioning as well as other physical health outcomes and healthcare utilization (75–83). Each subject in this study was randomly assigned to one of three treatment groups developed in consultation with J. Pennebaker: (1) the expressive writing group, writing about their innermost feelings (active group), (2) a writing group addressing non-emotional issues of healthy lifestyle (non-expressive writing group), and (3) women who did not receive any writing instructions (control or no-intervention group). Expressive writing accesses innermost thoughts and feelings and is a self-reflective learning activity that allows for review and cognitive processing of what has been written and thereby relieves anxiety and builds resilience (73, 74, 81, 84). The format makes participant involvement easy and convenient, even at a distance (85).

Prenatal Maternal Stress, Maternal, and Child Outcomes: Effectiveness of a Post-disaster Writing Intervention

Our second goal was to determine the effect that maternal exposure to the FMWB wildfire had on birth outcomes, maternal psychopathology, and infant developmental outcomes. We also aimed to ascertain the effectiveness of the effective writing intervention and its impact on these same outcomes. We hypothesized that maternal objective stress exposure, cognitive appraisal, and subjective stress from the fires would have significant effects on birth outcomes, maternal psychopathology (at 12 months post-wildfire), and infant outcomes (at 18 months of age). In addition, we posited that the effects of PNMS would be moderated by the timing of maternal exposure to the

wildfire (from 6 months preconception to 9 months gestation). Finally, we proposed that the PNMS effects from the wildfire would be significantly greater in the no-intervention group and the non-expressive writing group than in the active expressive writing group and that the strength of the buffering effect of the intervention would vary according to the perinatal timing of exposure to the wildfire as well as the intervention.

METHODS

Setting and Recruitment

The study was designed as a prospective cohort study with a randomized controlled trial to test the effectiveness of an expressive writing intervention. The Fort McMurray Wood Buffalo region has around 1,250 births per year such that ~1,850 women were estimated to be pregnant or about to conceive at the time of the evacuation. Eligible participants included English-speaking women who were pregnant or within 6 months of conception when evacuated due to the 2016 Fort McMurray Wood Buffalo wildfire. Although it was a requirement that participants were residents of the FMWB region at the time of the wildfire, we recognized that some would not return to the community and indeed were not planning on returning at the time we commenced recruitment, which occurred between November 2016 and October 2018. Therefore, women who had temporarily or permanently moved away from the community of FMWB were still welcome to participate.

Study recruitment occurred primarily via social media platforms such as Facebook using targeted advertising. Additionally, we promoted the study and its potential benefits through television and radio features, which encouraged interested mothers to visit the study website[1] and join the study. Women with multiple pregnancies or with fetuses diagnosed with congenital anomalies were not eligible to participate while women who did not complete the consent and recruitment questionnaires did not receive the intervention. In addition, mothers who experienced a perinatal death or stillbirth after recruitment were withdrawn from the study such that no further questionnaires were administered.

Of the 339 records in the database, 309 were individual participants of which 222 participants filled out sufficient recruitment questionnaires to be included in at least part of the analyses. The other records were removed because of ineligibility or not containing sufficient data. A total of 204 women completed the recruitment stage and were randomized for the expressive writing intervention. The numbers of participants in each of the intervention and control groups were as follows: 69 participants in the expressive writing group, 68 participants in the non-expressive writing group, and 67 in the control group. Of these, 110 ultimately completed the objective stress questionnaire 24 months after the fire (**Figure 1**).

Consent and Ethical Approval

This research protocol was reviewed and received ethical approval from the Health Research Ethics Board Health Panel

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[1]www.mommybabyfmm.com.

at the University of Alberta (PRO-000067510). Eligible women were given information outlining the study purpose, benefits and risks of participating, and methods for withdrawal, prior to consenting to participate. They were also provided telephone contact information for the study coordinator should they wish to ask further questions about the study.

Data Storage and Privacy

All data are stored in an online secure REDCap (Research Electronic Data Capture) database, hosted by the Women and Children's Health Research Institute at the University of Alberta, Edmonton, AB, Canada (86). Except for the 18-month postpartum evaluation, study consent, questionnaires, and the intervention were delivered electronically, although participants were given the opportunity to complete the MOMSS questionnaire by phone or to receive a paper copy in the mail. Data from the face-to-face assessment was entered manually. Upon completing the consent form, women were asked to supply their name, email address, and date of birth. This information was used to automatically send personalized invitations to complete the surveys and as login information for the participants for the questionnaires. Personal identifying information was solely available within the REDCap database and only accessible by selected team members. For analyses, the REDCap data were converted into Microsoft Word, Microsoft Excel, and SPSS documents using anonymous participant identifiers and date shifting, which were stored on a separate secure research drive and/or password protected.
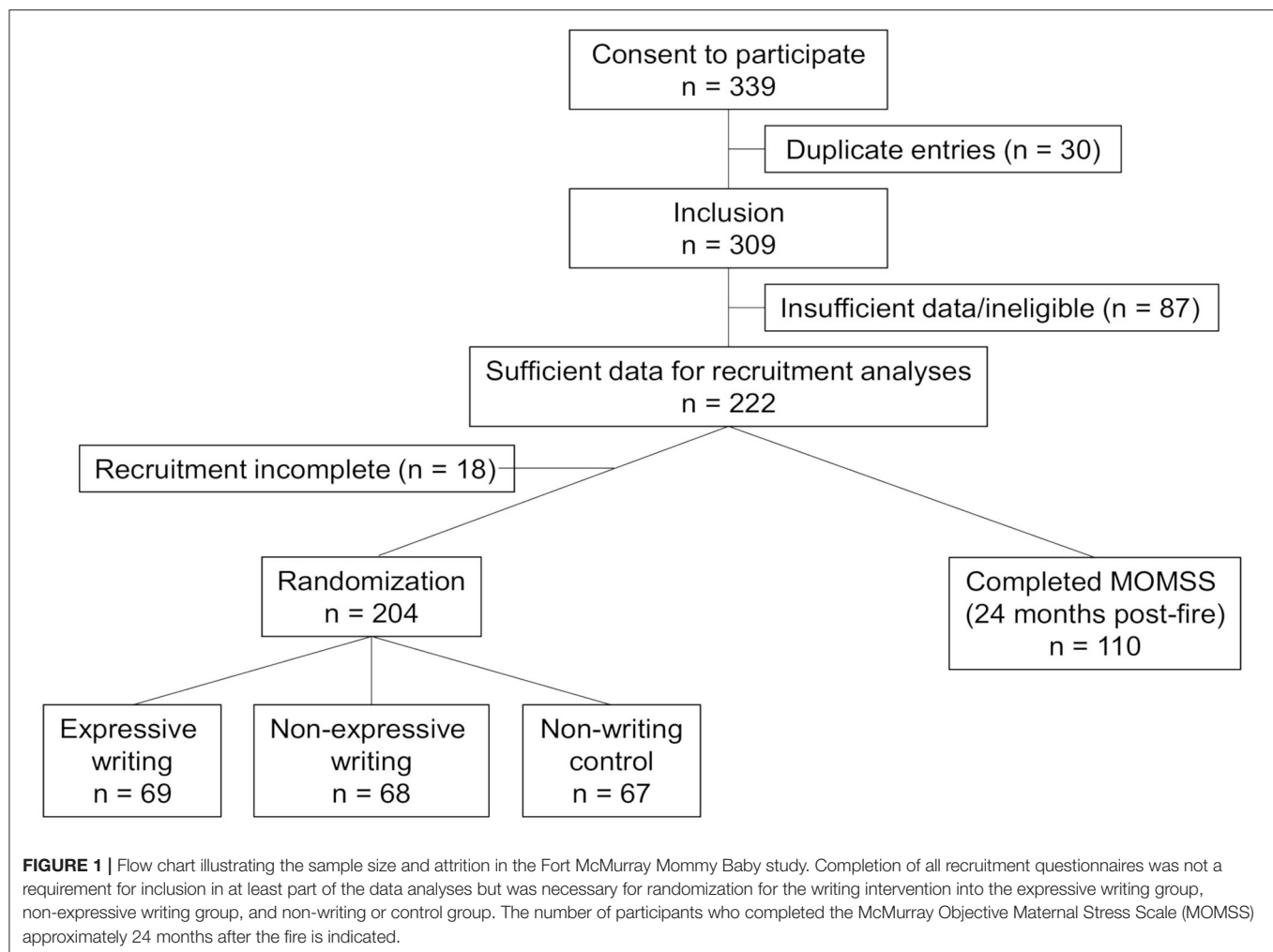
Intervention

After completing the recruitment questionnaires, participants were randomized for the expressive writing intervention into one of three writing groups as discussed above. The two active writing groups (expressive and non-expressive) were asked to write each day for four consecutive days with the following instructions: "In narrative form, please write constantly without stopping for 15 minutes about the topic. Provide as much factual detail and description as possible." After each writing session, participants were asked to indicate to what extent, on a scale from 1 to 4, they were experiencing stress-related symptoms and emotions. Invitations to complete the writing tasks were sent out via email, containing a link to the writing exercise. Participants were asked to complete one exercise per day within 24 h of receiving the email invitation. **Supplementary Table 1** provides an overview of the questions and topics included in the intervention.

Quantitative Measures

All women recruited into the Fort McMurray Mommy Baby study were administered the same questionnaires. Upon completion of the study consent, women were asked to fill in a demographics questionnaire providing socioeconomic data (parental education, job classification, and estimated income), relationship status, obstetric history, and delivery date of the index pregnancy. The study protocol also included psychometric questionnaires as discussed below. An overview of the timing of the questionnaires is available in **Table 1**.

FIGURE 1 | Flow chart illustrating the sample size and attrition in the Fort McMurray Mommy Baby study. Completion of all recruitment questionnaires was not a requirement for inclusion in at least part of the data analyses but was necessary for randomization for the writing intervention into the expressive writing group, non-expressive writing group, and non-writing or control group. The number of participants who completed the McMurray Objective Maternal Stress Scale (MOMSS) approximately 24 months after the fire is indicated.

Wildfire-Related Questionnaires

Objective Stress (24 Months Post-fire)

The degree of objective hardship due to the fire was measured by a questionnaire tapping into four categories of trauma exposure: Threat (e.g., threat to life or physical integrity), Loss (e.g., of persons or property), Scope (e.g., length of evacuation and interruption of communication), and Change (e.g., amount of displacement, change in routine). The McMurray Objective Maternal Stress Score (MOMSS) is based on similar questionnaires developed for previous natural disaster studies examining the objective stress experienced by participants in the Quebec ice storm as well as Iowa and Queensland floods (28–30). As this was the first post-wildfire population the team approached, a new questionnaire was developed. Because each disaster is different, the MOMSS includes questions about threat, loss, scope, and change that were tailored specifically to the FMWB wildfire. Responses on each category are scored to a maximum of 50 points/category for Change and Scope but −4 to 50 for Loss (−2/−4 for increase in household income in 2016), for a total possible score of 200. For Threat, a possible 5 additional points were given for injuries to partner and/or children and

for witnessing flames touching the mother's own home. A fifth category, Thwart, consists of elements impeding or slowing the mother's ability to leave the city as well as external barriers to get all family members to safety, but was not included in the overall score. The invitation to complete the questionnaire was sent out 24 months after the fire to all women who had completed recruitment questionnaires.

Peritraumatic Distress and Dissociation (Recruitment)

Subjective distress is at least in part determined by peritraumatic distress and dissociation. Peritraumatic distress, assessed with the 13-item Peritraumatic Distress Inventory (PDI), is the degree of distress experienced at the time of or immediately after the disaster as recalled at a later point in time (88). Peritraumatic dissociation on the other hand is measured using the 10-item Peritraumatic Dissociative Experiences Questionnaire (PDEQ) and estimates the severity of dissociative-like experiences such as amnesia, derealization, depersonalization, altered perception of time, and out-of-body experiences (89). Both questionnaires are scored on a 5-point Likert scale from "Not at all" to "Extremely true." Together, these measures serve as a predictor of which

TABLE 1 | Fort McMurray Mommy Baby Study data collection tools and timing.

Measures	Recruitment	4 months postpartum	12 months postpartum	18 months postpartum	24 months post-fire
Maternal assessment questionnaires					
Subjective stress (IES-R)	X				X
Peritraumatic Dissociation (PDEQ)	X				
Peritraumatic Distress (PDI)	X				
Resilience (CD-RISC)	X				X
Depression (EPDS)	X	X	X		X
State Anxiety (STAI-State)	X	X	X		X
Coping Style (Brief COPE)	X				X
Perceived Stress (PSS)	X	X	X		X
Social Support (SSQ)	X	X	X		X
Life Events (LES)		X	X		X
Obstetric and neonatal history questionnaire (87)		X			
Adverse Childhood Experiences (ACE)					X
Objective Stress (MOMMS)					X
Resilience statement					X
Cognitive appraisal					X
Child assessment questionnaires completed by parent					
Developmental milestones (ASQ)		X	X		
Language development (MB-CDI)			X		
Social and emotional development (BITSEA)		X	X		
Child assessment: face-to-face					
Development (Bayley III)				X	
Solo and Joint Free Play Protocol				X	
Height and weight				X	
Anthropometric measures and body composition				X	

ACE, Adverse Childhood Experiences; ASQ, Ages and Stages Questionnaire; Bayley III, Bayley-III Scales of Infant and Toddler Development; BITSEA, Brief Infant Toddler Social and Emotional Assessment; CD-RISC, Connor-Davidson Resilience Score; COPE, Coping Orientations to Problems Experienced; EPDS, Edinburgh Postpartum Depression Scale; IES-R, Impact of Events Scale – Revised; LES, Life Experiences Survey; MB-CDI, McArthur-Bates Communicative Development Inventory; MOMMS, McMurray Objective Maternal Stress Score; PDEQ, Peritraumatic Dissociative Experiences Questionnaire; PDI, Peritraumatic Distress Inventory; PSS, Perceived Stress Scale; STAI, State-Trait Anxiety Inventory; SSQ, Social Support Questionnaire.

participants may be at increased risk of developing posttraumatic stress disorder (PTSD).

Subjective Stress (Recruitment, 24 Months Post-fire)

The Impact of Event Scale-Revised (IES-R) is used to assess the severity of PTSD symptoms in relation to traumatic events, as experienced in the 7 days preceding completion of the questionnaire (90). This 22-item questionnaire, with scores ranging from "Not at all" (0) to "Extremely" (4), yields a total score as well as scores for three categories of PTSD symptoms: intrusive thoughts, avoidance, and hyperarousal. This particular scale was chosen for our study as it enables comparisons to previous disaster studies including Project Ice Storm, the Iowa Flood Study, and Queensland Flood Study (35, 91, 92).

Maternal Psychological Health, Psychosocial Factors, and Other Maternal Measures

Maternal Anxiety (Recruitment, 4 and 12 Months Postpartum, 24 Months Post-fire)

Maternal anxiety was measured using the State-Trait Anxiety Inventory (STAI) (93), which asks participants how they generally feel, i.e., trait anxiety such as "I am content; I am a steady person," or currently feel, assessing state anxiety with statements including "I feel tense; I feel frightened," and is rated on a 4-point Likert scale from "Almost Never" to "Almost Always." Internal consistency and test-retest reliability coefficients have been shown to range between 0.69 and 0.95 (93, 94).

Depression (Recruitment, 4 and 12 Months Postpartum, 24 Months Post-fire)

The Edinburgh Postnatal Depression Scale (EPDS) was used to measure maternal depression (95, 96). The EPDS is a 10-item questionnaire that indicates whether a woman has depressive symptoms including guilt, sleep disturbance, low energy, and suicidal ideations. It has been validated for antenatal and postpartum mothers as well as in women who have delivered more than 1 year prior to administration (95, 97). In English-speaking mothers, a cut-off score of 13 or more is suggested for probable major depression in postpartum women whereas 15 or more may be used antenatally (98). The EPDS, rated on a 4-point Likert scale (0–3), has high test-retest reliability and good internal consistency (Cronbach's alpha > 0.8) (99).

Coping Style (Recruitment, 24 Months Post-fire)

The Coping Orientations to Problems Experienced (COPE) and the abbreviated version Brief COPE identify coping strategies participants use when experiencing stress (100). The latter is a 28-item questionnaire that measures the way participants have been coping with stress in their lives over the last month with answers ranging from "Not true at all" to "True nearly all of the time" (101). It assesses 14 means of coping such as self-distraction, denial, substance use, positive reframing, humor, religion, and acceptance, which can be categorized into emotion and problem-focused coping as well as dysfunctional coping (102).

Life Events (4 and 12 Months Postpartum, 24 Months Post-fire)

The Life Experiences Survey (LES) used in this study is a 24-item score, derived from the original 57-item self-report questionnaire designed to inventory life changes participants experienced in the last year (103). Here, we asked about life events since conception of the child in the study, outside of the wildfire. It lists life changes in love and relationships such as marital status, health including pregnancy, pregnancy complications, and major illness of self as well as death and illness of loved ones, work-related and financial changes, and crime-related events. In addition to indicating whether the event occurred, participants are asked to rate the perceived impact of the event on a 7-point Likert scale ranging from "Extremely Negative (−3)" to "Extremely Positive (+3)."

Resilience (Recruitment, 24 Months Post-fire)

The Connor-Davidson Resilience Scale-25 (CD-RISC) is a 25-item questionnaire that measures resilience by asking participants how they may have felt over the preceding month (60). The scale covers several aspects of resilience including self-efficacy, sense of humor, attachment to others, the ability to adapt to change, optimism, and faith rated on a 5-point Likert scale ranging from "Not true at all" to "True nearly all the time." The total score is used in analyses with low scores indicating low levels of resilience.

Resilience and Cognitive Appraisal (24 Months Post-fire)

At the 24 month post-fire timepoint, participants were also asked to respond to the following statement: "When things go wrong in my life it generally takes me a long time to get back to normal," scored from "Don't agree at all (1)" to "Agree a lot (5)." Thus, for this statement, a lower score indicates higher levels of resilience. At the same time, cognitive appraisal of the fire was assessed by a single question, as follows: "Taking into account all of the effects of the Fort McMurray and Alberta wildfires on you and your family, what would you say have been the overall consequences of the event?" The consequences were also rated on a 5-point scale, from "Very negative," over "Neutral, there were no consequences at all" to "Very positive."

Social Support (Recruitment, 4 and 12 Months Postpartum)

The Social Support Questionnaire (Short Form) (SSQ) is a 6-item survey that asks participants about both the social support they have available to them as well as their level of satisfaction

with the support available (104). The SSQ is a two-part survey, with part 1 asking participants to name their social supports in specific circumstances, if any, and the relationship to them while the second part asks participants to indicate their satisfaction with these supports, ranging from "Very satisfied" (6) to "Very dissatisfied" (1).

Perceived Stress (Recruitment, 4 and 12 Months Postpartum, 24 Months Post-fire)

The Perceived Stress Scale (PSS) was designed to evaluate the extent to which certain situations in the participant's life were considered stressful and thus how these situations affect individual feelings and the levels of perceived stress (105). It is a 14-item measure asking about thoughts and feelings in the past month, rated on a 5-point scale ranging from "Never" to "Very often." Multiple items are stated in a positive way, e.g., "how often have you felt that you were on top of things" and are reverse coded such that higher scores indicate higher stress levels.

Adverse Childhood Experiences (24 Months Post-fire)

The Adverse Childhood Experiences (ACE) questionnaire, consisting of 10 questions, asks participants about personal experiences of abuse (psychological, physical, and sexual), as well as dysfunctionality within the household including mental illness, criminal behavior, violence against the participant's mother (106). The number of ACEs have been associated with increased risk of preterm birth (25) as well as risk behaviors and disease in adulthood (107, 108).

Developmental Milestones

Infant Development (4 and 12 Months Postpartum)

The Ages and Stages Questionnaire (ASQ) is a 30-item survey that asks mothers to assess five domains of infant development: communication, gross motor, fine motor, problem solving, and personal-social (109). It allows for the evaluation of developmental progress across these areas and is intended to catch delays in young children. Mothers are supplied with age-appropriate questionnaires and asked to answer questions using a 3-point Likert scale ranging from "Yes" to "Sometimes" to "Not yet." At the end of the questionnaire, a list of overall questions is included assessing concerns regarding development noted by the parents. Examples are "Has your baby had any medical problems in the last several months?", "Do you have concerns about your baby's behavior?" and "Does anything about your baby worry you?". In the current study the ASQ-III 6 months and ASQ-III 12 months were used (110).

Language Abilities (12 and 18 Months Postpartum)

The MacArthur-Bates Communicative Development Inventories (MB-CDI) are instruments for assessing the communicative skills of infants (Words and Gestures) and toddlers (Words and Sentences) (111). We used the Infant form (Level 1), intended for 8- to 18-month-old children, limited to an 89-word vocabulary checklist for parents to indicate words that their child "understands" or "says."

Social-Emotional Development (4 and 12 Months Postpartum)

The Brief Infant- Toddler Social Emotional Assessment (BITSEA) is a 42-item questionnaire that asks mothers about social-emotional and behavioral competencies and problems in their infants (112). It assesses behavior as observed over the last month, scored on a 3-point Likert scale ("Not true/rarely; Somewhat true/sometimes; Very true/often"). In addition, parents are asked to respond to two questions with possible answers ranging from "Not at all" to "Very worried," i.e., "How worried are you about your child's behavior, emotions, and relationships?" and "How worried are you about your child's language development?" The different areas evaluated are then combined into two separate scales. The Competencies scale covers 11 items reflecting social-emotional abilities (e.g., empathy, imitation/play skills) whereas the Problems scale reflects internalizing and externalizing problems, maladaptive and atypical behaviors as well as dysregulation. A third scale, the BITSEA Autism score, combines 19 problem and competence items associated with Autism Spectrum Disorders (113, 114).

Face-To-Face Assessments: Mother and Child (18 Months)

Anthropometric Measures and Body Composition

At the children's age of ~18 months, parents were offered a face-to-face assessment with a trained experimenter. The child's body composition was evaluated, examining height, weight, head circumference as well as anthropometric measurements including mid-upper arm, waist, and calf circumferences, and triceps and subscapular skinfolds. In addition, maternal height, weight, and pregnancy status were recorded.

Cognitive and Motor Functioning

Cognitive, fine and gross motor abilities were assessed using the Bayley-III Scales of Infant and Toddler Development (115). Cognitive development is assessed through examination of thinking and problem solving, while motor development is assessed through examination of fine and gross motor skills.

Play Levels, Emotional Availability, and Attachment Relationships

During the face-to-face sessions, these were assessed and videotaped.

Analytical Methods

Qualitative Analysis

We conducted an analysis of study participants' expressive writing entries using qualitative methodology to elucidate both their resilience factors and the effectiveness of expressive writing on their resilience. Findings from this qualitative analysis were compared and contrasted with data from other study measures including the Connor-Davidson Resilience Scale (CD-RISC) (60) and with qualitative data from other disasters. Since the expressive writing intervention was administered electronically only using online journals, transcription for data analysis was not required. The Word documents containing the writing entries linked to a numeric participant identifier were uploaded into

NVivo 12 (QSR International, Melbourne, Australia) to facilitate coding according to the six phases of thematic analysis (116). These are (1) familiarization; (2) coding; (3) theme generation; (4) review of themes; (5) theme definition and naming; and (6) writing up with data analysis using an inductive approach.

Quantitative Data Analysis

All quantitative data are/were analyzed using Microsoft Excel and IBM SPSS (IBM Corp, Armonk, NY, USA) after thorough data cleaning and checking. Imputation of missing values was performed using the expectation-maximization method (117). The timing of the fire in relation to the stage of pregnancy at exposure (preconception, first, second, and third trimester), was determined by calculating the number of days between the start of the fire (May 1, 2016) and the best estimated due date. Preconception exposure was defined as having a due date more than 280 days after the fire and evacuation. First trimester exposure corresponded to due dates falling 187–279 days following May 1, second trimester between 94 and 186 days, and third trimester 0–93 days. Statistical tests conducted and planned for these data include demographic statistics using parametric and non-parametric tests according to normality of distribution and homogeneity of variance; Pearson and Spearman correlations; structural equation modeling; multiple linear regression with interaction terms in moderation models; repeated measures regression models. Timing of the fire will be/was included as one of the covariates in the moderation analyses. Significant interactions are further investigated using the PROCESS macro v3.4 for SPSS (118). Probing the interaction reveals the magnitude and significance of simple or conditional effects of a predictor according to the level of the moderator. Furthermore, using the Johnson-Neyman procedure, it indicates the region of significance, the moderator transition points at which the conditional effects of the predictor achieve or lose significance. The coordinates provided by PROCESS can then be used to graph interaction figures.

Dissemination

Data collection was finalized by October 2018, with data analyses ongoing. During the study, preliminary results were shared with the FMWB community as well as policy makers on several occasions. Data resulting from this study have been presented at local, national, and international meetings. Two papers have been published (119, 120) while several others are under review or in preparation.

DISCUSSION

The Fort McMurray Mommy Baby study was designed to test the effectiveness of an expressive writing intervention on a vulnerable population, i.e., pregnant and preconception women exposed to a natural disaster, and its effects on maternal, birth, and child developmental outcomes. We employed a low-cost intervention that was widely deployed electronically or by traditional mail. It required a small commitment in terms of time, physical or mental involvement from participants over 4 days. This was enough input to allow for emotional disclosure, the active ingredient of

the intervention. As time passes for the participants, the tool could be re-used by them to manage stress and build personal resilience. Since upwards of 1.5 billion people have been affected by natural disasters in the last decade alone (121), it is more than likely that the need for such tools will increase. This is imperative to assure the health of future generations.

Strengths and Challenges

In the development and execution of this protocol for a prospective randomized controlled trial in the aftermath of a natural disaster, we faced many challenges. While we were able to overcome some, others were insurmountable. Nevertheless, we feel it is important to share the lessons we learned so disaster research and the development of interventions for preconception and pregnant women and their children can move forward, even in these challenging research environments.

Strengths of the Study

Throughout this study, we employed community-based participatory research principles (122) which acknowledged the unique knowledge needs of the FMWB community, the need for involvement throughout the research process, and importance of dissemination of study findings on an ongoing basis. In the months following the wildfire, prior to establishing formal study funding, we met with several leaders within the community to co-design the study protocol including participant recruitment and retention strategies. We also invited a participant, a local mother who was pregnant during the wildfire, to be a member of our research team. She provided valuable insight into the social structure of the community, suggestions on recruitment strategies, and feedback on the study measures. Furthermore, despite the extensive distance between the research institution and the community (450 km), the research team made several trips to refine recruitment strategies and monitor the progress of the study. We also organized "forums" for key stakeholders in the community (i.e., study participants, policy makers, and community leaders) to share preliminary findings, strengthen the relationship with the community, and inquire about any modifications that needed to be made to the protocol.

In addition to the strong relationships with the FMWB community that were built during the development of the protocol, other strengths of this study included the rapid recruitment of eligible participants, low-cost intervention and data acquisition, and successful testing of the intervention. We were able to recruit approximately one-sixth ($n = 309$) of all estimated eligible women ($n = 1,850$) who were pregnant or within 6 months preconception at the time of the wildfire. As there were a number of other studies occurring within the community during the same time frame and our participants experienced significant disruptions to their personal lives with many leaving the geographical area, we consider this sample size and recruitment successful given the circumstances. The use of REDCap limited the costs associated with the collection of the study data. As well, the expressive writing intervention was simple and low-cost largely because it was administered via REDCap. Given the university's extensive experience with REDCap, the establishment of the database for the Fort

McMurray Mommy Baby Study facilitated the rapid rollout of a subsequent disaster study (Hurricane Harvey in Texas, USA). A final strength of this study involved the successful testing of an expressive writing intervention in the context of a natural disaster. To our knowledge, this had not been previously carried out.

Challenges of Disaster Research

What makes populations who have gone through natural disasters interesting, i.e., experiencing a sudden severe stressor in a quasi-random manner that impacts a large community, inherently also creates limitations. Protocols for a post-disaster study are unique and, in most cases, not immediately available. Developing the protocol, acquiring funding, and setting up the study takes time, which causes delays in data collection and introduces the risk of recall bias. Furthermore, due to the nature of disasters, such protocols cannot be executed in controlled environments. Even when carefully planned, actually carrying out the study is difficult, not in the least because of the time-sensitivity. In fact, the circumstances of the Fort McMurray Wood Buffalo wildfire and its aftermath required us to modify the protocol and be flexible and creative as the project unfolded in order to ensure sufficient quality data collection. Adequate funds only became available ∼one year after the fire. As such, we were not able to hire a research coordinator and research assistant, take on an aggressive recruitment strategy or offer incentives until Spring 2017. This, at least in part, resulted in a major revision of the envisioned sample size. Another adjustment that was required was a revision of the timeline to perform the in-person developmental assessment. In accordance with our previous disaster studies, this evaluation was initially planned for when the infants were 16 months old (30). Because of the delay in funding as well as difficulties in finding a qualified research nurse, this evaluation had to be postponed for 2 months. Moreover, we were only able to assess 33 children.

The objective stress questionnaire was distributed to the participants later than scheduled as well. As this was our first post-fire study, a new survey needed to be designed. The development of the questionnaire requires an in-depth understanding of the complex geographic, social, and economic environment, with a need for extensive examination and preparation. This was hindered by the fact that none of the members of the research team lived in the community as well as the distance.

The obvious need for quick development of a protocol and application for funding may also hinder the quality of the study in the long term. In the time frame available to design the study and apply for funding, it may not be possible to set up an optimal multidisciplinary research team or contact experts. This may lead to important questions not being asked. Another consideration is how participants interact with the online secure database because there is not enough time for beta testing. For example, some individuals participated more than once, and the database should have prevented this. A number of data entry mistakes required extensive data cleaning. This is an inherent problem when participants enter data on mobile devices. Also, email invitations are easy to overlook or forget as there is no physical

reminder of the questionnaire. Participants received up to five reminder emails with the link to the appropriate questionnaire.

Careful thought also needs to be given to the time required to complete the questionnaires. The initial batch of surveys in this study took over 1 h to complete. Moreover, often when there is no immediate tangible benefit to participants, they will not continue completing the questionnaires. In an effort to minimize this problem and in recognition of the significant time commitment required to complete the surveys, we decided while the study was ongoing to compensate participants for their time with $50 gift cards for online purchases. To further encourage completion of the questionnaires, the order of the surveys was changed, partly in recognition of the fact that several of the questions may have been perceived as difficult or sensitive and could have caused participants to drop out. Aside from the number and length of the questionnaires, another element to keep in mind is to not overly study the community undergoing significant stress as this can lead to research fatigue. At the time of the current study, multiple others were being conducted, several funded through the same government agency, each with their own demands. When individuals participate in different studies at the same time, it may be possible that these demands increase stress and that potential positive effects of participation may be canceled out.

In addition, disentangling the effects of exposure to a disaster from the alterations in mental health that are inherently associated with the reproductive period without overwhelming participants with numerous questionnaires is very difficult. Although pregnancy and childbirth are physiological processes and not illnesses, they can be associated with negative psychological experiences related to unexpected pregnancy, loss of a pregnancy, challenging obstetric history, and maternal and fetal complications. Moreover, one needs to consider other traumatic events in a woman's life, ranging from adverse childhood experiences to other life events and difficult environmental circumstances, i.e., racism, violence, unemployment, substance abuse, and socioeconomic struggles, prior to, during, and after pregnancy and childbirth (25, 123–125). The latter is especially the case in disaster research since recruitment is often only possible after a considerable time lag, during which much in addition to the disaster could have occurred in a woman's life. The Adverse Childhood Experiences questionnaire and Life Experiences Survey were included in the protocol but were only completed by a limited number of participants, preventing us from correcting for these events in analyzing the data.

Limitations

A limitation of disaster-related studies is that the stress is not limited to the event itself; it continues to accumulate due to the consequences of the event and may therefore affect who participates in the study. This leads to two problems inherent in such studies: that some participants may not be able to have the time or the focus to participate in the study due to being overwhelmed by stress, and that it may be the least affected by stress who are disproportionately represented in the study. Ongoing stress may derive from temporary housing

or relocation issues, fear for the safety, health, and well-being of loved ones, economic and/or food insecurities, and in the case of the FMWB disaster, longer-term disputes with insurance agencies.

Recommendations

Our recommendations for future studies that test interventions to improve pregnancy outcomes in the midst of disasters are: (1) recruit in larger communities where many more participants live so that the power of the study is maintained in spite of the participant attrition due to all the reasons described here. (2) Recruit the most stressed participants into your study in order to create a robust effect size so that your intervention has the largest effect possible. For instance, during the current coronavirus pandemic there are many pregnant women, some of whom are highly stressed. Focus your recruitment on those you consider to be the most stressed. (3) Prepare in advance for a disaster intervention study. It is possible for investigative teams to obtain ethical approval (or at least in a draft form), develop their protocols, interventions, and database tools in advance of a natural disaster. Then, when a significant disaster strikes a community, the team can quickly implement their study. The costs for this preparedness are surprisingly low; it is the analysis phase of the study that is more expensive due to research staff costs. However, once the data are gathered, it is easier to obtain funding for these analyses.

CONCLUSION

The first purpose of this paper was to describe the development of a protocol to test an intervention offered to pregnant and preconception women following a disaster. The Fort McMurray Mommy Baby Study was the first study attempting to reduce stress in preconception and pregnant women after a catastrophic natural disaster. Previous studies largely documented the degree of stress women experiencing a natural disaster had and the effects of that stress on their pregnancy outcomes and the developmental trajectories of their children. Similar studies evaluate the impact of these events at both the community and the individual level, but none have attempted to reduce stress, increase resilience, and thereby improve outcomes. These are the problems the research in this field needs to address.

The second purpose was to outline the challenges encountered in the context of this research. As a first study in this regard, we experienced several challenges. These included the *a priori* study design not conforming to the realities of a post-disaster environment in a remote community. There were challenges with participant recruitment and retention that led to consequent loss of data, reduced sample size, and gaps in the data. There might also have been selection and recall biases. Last, even though we started organizing the study as soon as the disaster occurred, it took 6 months to obtain ethical approval, funding, and to initiate the study. This time lag may have led to some of the problems encountered. Fortunately, this is an iterative process whereby improvements will occur with repeated attempts to respond to

future natural disasters with studies that test interventions to improve outcomes.

DATA AVAILABILITY STATEMENT

The original contributions presented in the study are included in the article/**Supplementary Material**, further inquiries can be directed to the corresponding author.

ETHICS STATEMENT

This study involving human participants was reviewed and approved by Health Research Ethics Board Health Panel, University of Alberta. The participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

Each author contributed to the design of the study. AH drafted the manuscript, which was revised and completed by AH, BV, JO, and DO. All authors contributed to the article and approved the submitted version.

SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpubh.2021.601375/full#supplementary-material

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Collective Trauma and Mental Health in Adolescents: A Retrospective Cohort Study of the Effects of Retraumatization

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In the wake of the massive Canadian wildfire of May 2016 in the area of Fort McMurray Alberta, we observed increased rates of mental health problems, particularly post-traumatic stress disorder (PTSD), in school-aged adolescents (ages 11–19). Surprisingly, we did not see these rates decline over the 3.5-year follow-up period. Additionally, our research suggested that the impact of this mass incident resulted in other unanticipated effects, including the finding that children who were not present for and relatively unaffected by the wildfire showed a similar PTSD symptom profile to children more directly involved, suggesting some degree of spillover or stress contagion. A potential explanation for these high rates in individuals who were not present could be undiagnosed retraumatization in some of the students. To investigate this possibility, we compared two groups of students: those who reported the wildfire as their most significant trauma ($n = 740$) and those who had their most significant trauma prior to the wildfire ($n = 295$). Those with significant pre-existing trauma had significantly higher rates of both depression and PTSD symptoms, although, unexpectedly the groups exhibited no differences in anxiety level. Taken together, this evidence suggests retraumatization is both longer-lasting and more widespread than might be predicted on a case-by-case basis, suggesting the need to reconceptualize the role of past trauma history in present symptomatology. These findings point to the need to recognize that crises instigated by natural disasters are mass phenomena which expose those involved to numerous unanticipated risks. New trauma-informed treatment approaches are required that incorporate sensitivity to the collective impact of mass crises, and recognize the risk of poorer long-term mental health outcomes for those who experienced trauma in the past.

Keywords: collective trauma, retraumatization, post-traumatic stress disorder, adolescent, trauma informed practice, stress contagion, sexual abuse trauma

INTRODUCTION

Mass trauma events such as the Canadian wildfire of May 2016 in the area of Fort McMurray Alberta provide a unique opportunity to examine how an entire population reacts to a traumatic event, and different factors that might affect the risk profile of individuals in these circumstances. In May 2016, a severe wildfire burned 590,000 hectares and caused the mass evacuation of all 88,000 residents of this remote northern Canadian, energy industry-focused town. In this study, we sought to examine whether adolescents who had undergone previous significant trauma prior to the wildfire would be impacted differently than those undergoing trauma for the first time.

It is reasonable to assume that previous trauma could be associated with heightened reactivity to a new trauma event, due to what has been termed retraumatization. In behavioral terms, chronic maltreatment has been shown to hinder maturation, increasing risk for PTSD symptoms (1), as well as internalizing and externalizing behaviors (2). This is possibly due to structural and/or functional alterations in the brain (3) occurring as a product of prolonged hypothalamic pituitary adrenal (HPA) axis activation (4); accordingly, it has been posited that permanent sensitization of this pathway is a consequence of childhood abuse (5). Structural changes in the amygdala have recently been confirmed in human subjects (6). Given these neural changes, retraumatization—a condition in which an individual with pre-existing trauma is triggered by a new stressor, presumably responding more quickly or intensely—is a potential outcome. Indeed, a number of studies appear to confirm that an earlier trauma carries repercussions for how one reacts to later trauma (7, 8), potentially suggesting changes in stress reactivity (5). What has been less recognized is the propensity for these kinds of underlying issues to inform how one responds in a mass trauma situation, in which it is unclear exactly which individuals are at increased risk for retraumatization.

In the present study, we used data from adolescents who experienced the Fort McMurray wildfire to compare the rates of mental health conditions in individuals with, or without, significant trauma prior to the wildfire. Although, a thorough examination of Adverse Childhood Events (ACEs) would have been ideal, our current analysis was limited to retrospective self-reports of whether or not the individuals had experienced some worse self-reported trauma prior to the wildfire. Aside from the mental health diagnostic information, we also examined increased propensity for recent suicidal ideation and rates of suicide attempts overall, as previous research has posited particularly high rates of suicidality amongst disaster survivors (9). Thus, the goal of the present analysis was to compare negative mental health symptomatology between the two groups. We hypothesized that adolescents who had experienced prior trauma would show poorer mental health, specifically higher rates of anxiety, depression, and post-traumatic stress disorder (PTSD), and higher rates of recent suicidal ideation and lifetime suicide attempts.

METHODS

Survey Administration Procedure

The full mental health survey was developed by the Fort McMurray school systems in conjunction with the research team to evaluate their post-wildfire programming. They administered all aspects of data collection, as per their standard procedures and policies. Accordingly, all students enrolled in either junior or senior high schools in both Public and Catholic School Districts in Fort McMurray were invited to participate in data collection, although, parents could opt their child(ren) out if desired (fewer than 10 exemptions were requested). The total survey battery consisted of 96 questions [for full description of measures see **Table 1**; a detailed question-by-question breakdown has been published elsewhere (10)]. Use of all survey methods and materials was approved by the Health Research Ethics Boards (ethics protocol number Pro00072669) at the University of Alberta, Canada. Students completed multiple mental health questionnaires each year for a 3-year period starting in November 2017. Because the Fort McMurray school boards mandated that students complete the questionnaires anonymously (procedure described in detail below), there was no way to track individuals from year-to-year, so data analysis for this study was confined to a cross-sectional analysis. Accordingly, the data in this study represent the third round of data collection (gathered approximately 3.5 years post-wildfire), selected on the conservative premise that this timeframe would give individuals the maximum amount of time for recovery.

Data collection occurred over a 9-day period in November 2019, during which all 6 school sites were visited by the data collection team. Students were excused from normal classroom activities in order to complete the questionnaires, with no penalty for non-participation. Students were seated in a classroom together, fitted with separate computer monitors (either laptops or desktops, depending upon the school); these were either the school's computer room, a library, or in some instances a convenient classroom, and they seated on average 25–50 students. A script explaining why data were being gathered, outlining expectations regarding their behavior during data collection, and that thanked them for their participation, was read to the students by a member of the data collection team. Students were asked to try to answer every question, but informed that they could skip any questions that they did not understand, or that made them feel uncomfortable. Students were ensured their answers would be kept anonymous, and were not asked for their names, nor were they assigned unique identifiers (ID numbers). They were asked to fill out the questionnaires individually, without consulting or discussing with those around them, however staff were available to answer questions in the event of any questions, or in the event of any technical difficulties. Sessions averaged 20–25 min, although, students were given as much time as they required to complete the questionnaires.

Data Analysis

To assess effects of collective traumatization on long-lasting PTSD and related mental health characteristics, this retrospective cohort study specifically compared two groups: those exposed

TABLE 1 | List of measures administered to junior and senior high students after Fort McMurray wildfire (2017–2019).

Instrument name	Author(s)	Domain measured	Format
Ft. McMurray demographics questionnaire	Brown et al. (10)	Gathers basic demographic information, including name, age, sex, grade, school, and homelessness.	Seven items with pre-specified choices.
Impact of fire questionnaire	Brown et al. (10)	Custom questionnaire designed to assess impact of the 2016 wildfire.	Six items: 4 y/n items measure proximity and impact of fire, plus two assess school affiliation.
Patient Health Questionnaire, Adolescent version (PHQ-A)	Johnson et al. (11)	Assesses depression symptom severity (past 2 weeks) as well as suicidal ideation (past month) and history of previous suicide attempts (lifetime). Probable depression is defined as having a PHQ-A score of 11 or more (12).	Nine depression items measured on a 4 point Likert scale assess frequency of symptoms, plus 2 y/n suicidality questions; total score from 0 to 27 (depression); suicide score is an additional 2 points (scored separately).
Hospital Anxiety and Depression Scale (HADS), anxiety-related questions only	Zigmond and Snaith (13)	Assesses symptoms of anxiety in the past week. Probable anxiety is defined as having a HADS score of 11 or more (14).	Seven items on a 4 point Likert scale, with items for both frequency and severity; score from 0 to 21
Child PTSD Symptom Scale (CPSS)	Foa et al. (15)	Assesses PTSD symptoms. Symptoms grouped into three subcategories: re-experiencing, avoidance, and hyperarousal. Two additional items query about the most distressing event the respondent has experienced and when it occurred. Probable PTSD is defined by a CPSS score of 16 or more (16).	Nineteen questions: 17 items measured on a 4 point Likert scale assess frequency of symptoms from 0 to 51; additional two items offer pre-specified choices.
CRAFFT questionnaire (CRAFFT)	Knight et al. (17)	Assesses symptoms of alcohol and substance misuse over the past 12 months. Probable alcohol/substance use disorder was defined as having a CRAFFT score of 2 or more (17, 18).	Nine items, scored y/n from 0 to 9.
Tobacco use items	Brown et al. (10)	Items added to CRAFFT regarding tobacco and smokeless tobacco use.	Two items, scored y/n from 0 to 2.
Rosenberg self-esteem scale	Rosenberg (19)	Assesses self-esteem, with items reflecting agreement with how well the concepts describe the respondent.	Ten items on a 4 point Likert scale measuring agreement; provides a score from 0 to 30.
Kidscreen questionnaire (Kidscreen-10)	Ravens-Sieberer et al. (20)	Assesses quality of life in terms of how the respondent has been feeling, opportunities for recreation, and socialization	Eleven items on a 5 point Likert scale measuring frequency; provides a score from 0 to 44.
Child and Youth Resilience Measure (CYRM-12)	Liebenberg et al. (21)	Assesses the resources available to individuals that may bolster their resilience.	Twelve items on a 5 point Likert scale measuring agreement; provides a score from 12 to 60[†].

[†] Scores for these scales recoded to maintain consistency amongst study measures.

only to the collective trauma (wildfire), and those with a history of previous childhood trauma. A two-tailed, independent-samples t-test was conducted to compare the mental health variables described above in the prior trauma group with those who listed the wildfire as their most traumatic event (no previous trauma). All means were tested at the 95% probability level, with pairwise deletion used for missing data. Analyses were completed using IBM SPSS Statistics-v26 software.

Fort McMurray students who were available and willing to participate in the survey comprised 3,041 youth aged 11–19 years, who completed the questionnaires. Data from 105 students (3.5%) were eliminated due to exceedingly low rates of questionnaire item responses, leaving an overall sample size of 2,936. A detailed subject flow diagram is presented in **Figure 1**.

Because all students present between grades 7 and 12 participated (i.e., the entire junior/high school population of Fort McMurray present at the time of testing), no sample size

calculation was performed. Although, there were no specified exclusion criteria for the study, individuals not attending class at the time were not included. Additionally, adolescents of that age going to school in rural areas outside the Fort McMurray townsite were also not included.

Mental Health Questionnaires of Interest

For the purposes of this investigation, the following measures were examined:

- *Depression*—Patient Health Questionnaire, Adolescent version (PHQ-A, 11 questions) (11): Assesses symptoms of depression. Scores for severity range from 0 to 27.
- *Suicidality*—Patient Health Questionnaire, Adolescent version (PHQ-A, 2 questions). In addition to the depression items, the PHQ-A specifically queries regarding suicidal thoughts, as reflected in 2 y/n items: *"Over the past 2 weeks, how often have*
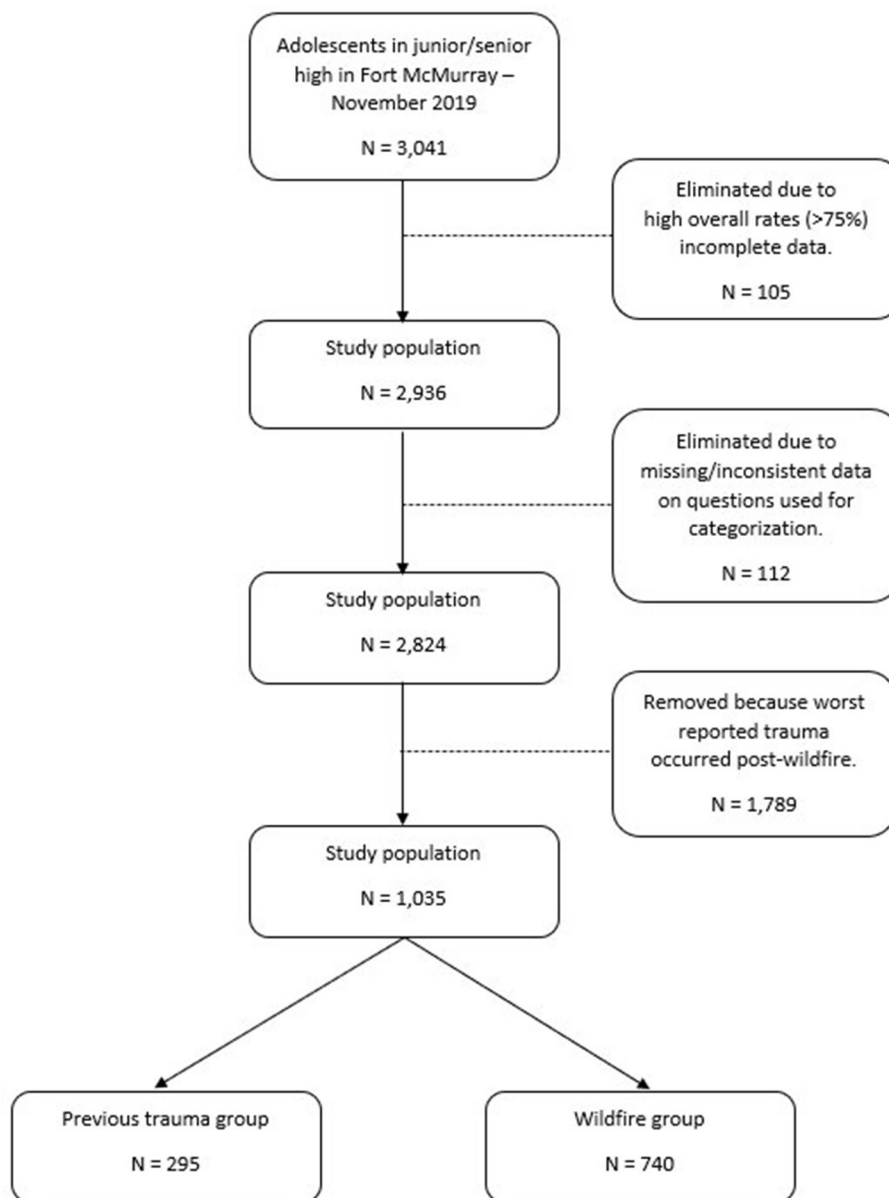
FIGURE 1 | Subject flow diagram illustrating number of individuals in each group.

you been bothered by any of the following problems? Thoughts that you would be better off dead, or of hurting yourself in some way?" and *"Has there been a time in the past month when you have had serious thoughts about ending your life?"* These items were presented only if the respondent acknowledged thoughts regarding hurting him/herself or feeling they would be better off dead on at least several occasions per week. Scores for these items were coded 0 = No, 1 = Yes.

- *Anxiety*—Hospital Anxiety and Depression Scale (HADS, 7 questions; Anxiety items only) (13): Assesses symptoms of anxiety; scores for anxiety symptom severity range from 0 to 21.

- *PTSD*—Child PTSD Symptom Scale (CPSS, 19 questions) (15): Assesses symptoms of post-traumatic stress disorder (PTSD); scores of PTSD symptom severity range from 0 to 51. Scores can also be grouped into three subcategories: re-experiencing, avoidance, and hyperarousal.

Individual items were also recoded where necessary such that a higher score reflected increased symptom severity. Where necessary, measures were recoded such that the base score for the Likert scale was 0 (reflecting absence of symptoms), for consistency between questionnaires.

RESULTS

To examine effects of previous traumatization on reaction to the wildfire, students were selected if they indicated that the wildfire was the worst trauma they had experienced ("wildfire group"), or if they indicated that they had experienced a worse trauma prior to the wildfire ("prior trauma" group). This information was assessed using two questionnaire items: *"Please select the most distressing event you have experienced"* and *"How long has it been since the event from the previous question."*

Notably, nearly two-thirds (1789; 63.3%) of the total sample was excluded at this stage because they reported their most significant trauma had occurred in the time period *following* the wildfire. With this group excluded, the study sample consisted of 295 students in the "prior trauma" group and 740 students in the "wildfire" group (where this was their most significant trauma). Thus, of the 1,035 students who had reported a traumatic event up until and including the wildfire, almost a third (28.5%) had been previously traumatized.

Characteristics of the Study Sample

Demographic characteristics of the 1,035 participants were as follows. Gender identity analysis corresponded to an approximately equal binary distribution, with 47.1% identifying as female, 47.7% as male, in addition 2.4% identified as other, and 2.6% preferred not to say. Age ranged from 11 to 19; mean (SD) age was 14.19 (1.78), with the median being 14. Junior high (grades 7–9) comprised 56.1% of the sample), with the remaining 43.9% in high school (grades 10–12), with the median being grade 9.

Exposure to wildfire was assessed using the following four y/n items, which were summed to generate a "total exposure" score. Students reported being in or near Fort McMurray at the time of the wildfire comprised 955 (92.4%). Among these students, 964 (93.3%) had to evacuate because of the fire but only 830 (80.2%) reported actually seeing the wildfire. Of these students, 133 (12.9%) reported that their home was destroyed. For these four items, students on average scored 2.79 (0.895), with the median being 3.

Of the prior trauma group, 107 (36.3%) reported that their worst trauma was the death of someone close to them; 36 (12.2%) reported it was a sexual assault; 22 (7.5%) reported that it was an injury they had suffered; and 6 (2%) said it was a physical assault. Another 124 (42%) did not specify the nature of the trauma. Over two-thirds of this group (68.5%) reported that that trauma had occurred between 6 and 10 years prior to completing the survey, while the remainder (31.5%) reported it was over 11 years prior.

Group Comparisons

Comparing the two groups (see **Table 2**), individuals in the prior trauma group were significantly more likely to be male than those in the wildfire group (58.2 vs. 47.3%; χ^2 (1) = 9.41, $p = 0.00$; all comparisons presented as prior trauma vs. wildfire, respectively). They were also 6 months older on average (M [SD]) (14.52 [1.76] vs. 14.04 [1.77]; $t_{1032} = 3.97$, $p < 0.01$). The prior trauma group experienced lower mean levels of exposure to the wildfire, and the

overall variability in their scores was much higher (2.24 [1.26] vs. 3.01 [0.57]; $t_{341} = -10.01$, $p < 0.01$).

In terms of the mental health variables, there was a significant between-groups difference for both Depression ($t_{463} = 2.74$, $p < 0.01$) and PTSD ($t_{449} = 2.99$, $p < 0.01$), with students who reported previous trauma showing elevated rates on both measures. Results also indicated a an increased value of lifetime suicide risk for the prior trauma group compared to the wildfire group (M = 0.37, SD = 0.49 vs. M = 0.27, SD = 0.45; $t_{179} = 1.69$, $p = 0.09$), although, this difference was not significant. There was also no significant difference in suicidal ideation in the past month (M = 0.53 SD = 0.50 vs. M = 0.46, SD = 0.50; $t_{261} = 0.97$, $p = 0.34$).

In contrast to the findings for both depression and PTSD, there was no statistically significant between-group difference in terms of level of anxiety, although, the wildfire group exhibited slightly higher mean levels (M = 7.29, SD = 5.00 vs. M = 7.62, SD = 4.62; $t_{498} = -0.97$, $p = 0.33$). The three factors comprising the PTSD variable were not consistently affected, with the factors of re-experiencing ($t_{448} = 3.48$, $p < 0.01$) and avoidance ($t_{459} = 3.53$, $p < 0.01$) showing increased symptomatology in the prior trauma group, while no between-groups difference was observed for the hyperarousal factor ($t_{493} = 1.00$, $p = 0.32$).

Because a high number of individuals did not specify the nature of the trauma, the analysis was repeated excluding this group, to determine whether the pattern of statistical findings would be maintained. Using only specified trauma respondents, all of the significant effects from the initial analysis remained, but the hyperarousal factor ($t_{234} = 3.00$, $p < 0.05$) and lifetime suicide risk ($t_{99} = 2.52$, $p < 0.05$) were also significantly different.

Examination of Potential Confounding Effects

To ensure these findings could not be better explained by confounding effects of age or sex, a one-way multivariate analysis of covariance (MANCOVA) was performed. The CPSS total score was removed from the analysis, due to its high correlations with its underlying factors, which were retained. Additionally, the suicide variables were dropped, as their inclusion resulted in undesirably low n's in the overall model (n's < 80).

The MANCOVA was performed with anxiety, depression, and the three PTSD variables (re-experiencing, avoidance, and hyperarousal) as the dependent variables, age, and sex as the covariates, weight, and two groups (prior trauma and wildfire only) of the independent variable. There was a statistically significant difference between the prior trauma and wildfire groups on these five dependent variables after controlling for age and sex, $F_{(5,951)} = 9.394$, $p < 0.001$, Pillai's Trace = 0.047, partial $\eta^2 = 0.047$.

Univariate analyses revealed prior traumatization had a negative impact on depression $F_{(1,957)} = 6.49$, $p = 0.011$, partial $\eta^2 = 0.007$, and two of the three PTSD variables: re-experiencing $F_{(1,957)} = 18.94$, $p < 0.001$, partial $\eta^2 = 0.019$, and avoidance $F_{(1,957)} = 13.85$, $p < 0.001$, partial $\eta^2 = 0.014$. Prior trauma was unrelated to either level of anxiety $F_{(1,957)} = 0.24$, $p = 0.627$,

TABLE 2 | Independent *t*-test comparison of prior trauma group (*n* = 295) vs. wildfire alone (*n* = 740) conditions.

	Previous trauma Gp			Wildfire Gp			*t*-value
	n	M	SD	*n*	M	SD	
Demographic variables							
Sex (male)	273	58.2%	0.49	708	47.3%	0.50	3.09**
Age	295	14.52	1.76	739	14.04	1.77	3.97**
Exposure to wildfire	294	2.24	1.26	793	3.01	0.57	−10.01**
Mental Health variables							
Anxiety	292	7.29	5.00	738	7.62	4.62	ns
Depression	291	8.68	7.02	733	7.40	5.95	2.74**
PTSD	289	12.97	12.48	731	10.50	10.24	2.99**
– re-experiencing	294	3.07	3.72	735	2.23	2.96	3.48**
– avoidance	292	5.05	5.45	733	3.78	4.53	3.53**
– hyperarousal	290	4.80	4.31	732	4.51	3.96	ns
Serious thoughts of suicide – past month[1]	95	0.53	0.50	168	0.46	0.50	ns
Previous suicide attempt – lifetime[1]	94	0.37	0.49	167	0.27	0.45	1.69[†]

M, mean; SD, standard deviation.
[†] *0.05> p <0.10.*
**p < 0.01.
[1]*Suicide questions coded as: 0 = no, 1 = yes.*

partial η^2 = 0.000 or PTSD hyperarousal $F_{(1,957)}$ = 1.68, p = 0.195, partial η^2 = 0.002. Mean scores are displayed for the prior trauma and wildfire groups as a function of trauma type in **Table 3**.

Subgroup Analysis

To more directly investigate the effect of retraumatization, subgroup analysis with MANCOVA, was also performed to examine effects of type of trauma on the mental health variables, while controlling again for age and sex. Analyses were conducted for anxiety, depression, and PTSD. Again, suicide was excluded from the analysis. As only four individuals reported physical abuse as their worst trauma, these individuals as well as those who did not specify the exact nature of the trauma were eliminated from further analysis.

There was a statistically significant difference in mental health scores as a function of the different trauma types, after controlling for both age and sex, $F_{(15,2499)}$ = 6.752, p < 0.001, Pillai's Trace = 0.117, partial n = 0.039. Given the significance of the overall test, results of the dependent variables were considered separately. Univariate analyses revealed that trauma type had significant effects on all the mental health variables (all F's > 7.00, p's <0.001).

Post-hoc tests using Bonferroni correction confirmed that the difference can be attributed to higher scores for survivors of sexual abuse, as compared to the other three categories of trauma (death, injury, and the wildfire itself). This was true for all mental health variables except PTSD re-experiencing, where there was also a significant difference between death of a loved one and the other two types (but sexual trauma was still highest). It appears that sexual abuse is associated with a statistically significant increase in mental health problems in retraumatized adolescents.

Mean (SD) scores for the these mental health variables as a function of trauma type are displayed in **Table 4**.

DISCUSSION

This study of retraumatization vs. newly acquired trauma suggests those who experienced prior trauma had higher rates of mental ill-health. In order to examine the effects of retraumatization, we examined the difference between the mental health of adolescents who had experienced a former traumatic event, compared to those whose first trauma was reported as the 2016 Fort McMurray wildfire. Individuals who experienced prior trauma had significantly higher rates of both depression and PTSD, but not in anxiety or risk of suicide. These results suggest a clear deleterious effect of previous trauma on current functioning, in the face of collective trauma.

With respect to PTSD, participants with previous trauma showed no difference in hypervigilance compared to the wildfire group; i.e., they were no more likely to confirm: *Having trouble concentrating* (1.06 [1.10] vs. 0.95 [1.02]); or *Having trouble falling or staying asleep* (1.13 [1.15] vs. 1.04 [1.13]). This is of interest because hypervigilance may be a sign of sympathetic activation (22). High rates of PTSD (37%) observed in adolescents even several years after the wildfire (23) remain both surprising and concerning as, for example, Bonanno's (24) review of chronic PTSD following experience of traumatic events suggests rates are typically much lower, between 6.6 and 17.8%. There maybe specific trajectories that put some individuals at increased risk for chronic distress (25). Persistent dysregulation has been described in cases of complex PTSD, in which trauma disrupts formative developmental periods (26). We suggest the high PTSD rates observed in this study could be

TABLE 3 | Means (SD) of mental health variables and MANCOVA results of differences between the prior trauma and wildfire groups, while controlling for age and sex.

Mental health variable	Trauma Group		$F_{(1,957)}$
	Prior trauma group (n = 265)	Wildfire group (n = 694)	
Anxiety	7.10 (4.84)	7.51 (4.64)	0.24
Depression	8.35 (6.85)	7.34 (5.92)	6.49*
PTSD—re-experiencing	2.94 (3.59)	2.16 (2.91)	18.94**
PTSD—avoidance	4.79 (5.23)	3.69 (4.48)	13.85**
PTSD—hyperarousal	4.61 (4.11)	4.44 (3.96)	1.68

*p < 0.05.
**p < 0.01.

TABLE 4 | Means (SD) of mental health variables and MANCOVA results of differences between different types of trauma, while controlling for age and sex.

Mental health variable	Trauma Type				$F_{(3,837)}$
	Wildfire (n = 694)	Death of someone close to you (n = 97)	Injury that you suffered (n = 22)	Sexual assault against you (n = 28)	
Anxiety	7.51 (4.64)	7.30 (4.59)	5.86 (5.03)	11.61 (3.80)[a]	7.06**
Depression	7.34 (5.92)	8.28 (6.23)	7.86 (7.75)	15.18 (7.06)[a]	13.98**
PTSD—re-experiencing	2.16 (2.91)[c]	3.22 (3.51)[b]	2.23 (3.62)[c]	6.57 (4.09)[a]	24.27**
PTSD—avoidance	3.69 (4.48)	4.47 (4.49)	4.55 (4.82)	10.79 (5.64)[a]	22.61**
PTSD—hyperarousal	4.44 (3.96)	4.74 (3.78)	4.05 (4.53)	8.64 (3.65)[a]	10.72**

**p < 0.01.
Italicized superscript letters indicate post-hoc analyses where one group differs statistically from the others.

partially mediated by undiagnosed retraumatization, with PTSD presenting differently between the groups.

There remains a need to explore a broader array of differential individual and contextual impacts (27) that may contribute to elevated rates of PTSD. While our rates were comparable to those observed in children and adolescents (28.6% of whom showed mild PTSD) following an Australian wildfire (28), that study looked at functioning 6 months post-event, in contrast to our data following 3.5 years. The influence of the ongoing, significant economic downturn Fort McMurray experienced following the wildfire should also be considered. In that period, a drop in the price of oil dramatically slowed economic recovery of the region, which had cumulative negative effects on a large proportion of the local population – many of whom worked directly in the oil and gas sector. This consequent widespread job loss accompanied a precipitous drop in housing prices. Those individuals willing to relocate to find employment elsewhere were paying for mortgages on homes they could no longer afford to sell, given low home valuations. This massive shift in circumstances meant that many adolescents in Fort McMurray endured the difficulties associated with evacuation and displacement due to the wildfire, only to return to face issues in terms of their parents' job loss and subsequent mental ill-health. The fact that nearly two-thirds (63.3%) of the current sample were excluded from analysis because they reported that their worst trauma had occurred *since* the wildfire supports this interpretation. It is worth noting that these kinds of contextual issues are particularly difficult for

children, because most of these decisions are at the discretion of their caregivers, who ultimately make the decision as to whether or not to remain in the environment. This raises the question of whether young children may have a different profile compared to adolescents and young adults in this context, as young Canadian children typically have little or no sense of responsibility or control over their circumstances. One might speculate that, in order to return to pre-trauma levels of PTSD, adolescents require a return to a sense of normalcy in which they no longer feel a need to be "on their guard." One possible interpretation is that, given dire economic and social circumstances that have been experienced since the wildfire, "across the board" normalcy has not yet returned to Fort McMurray. Ironically, wildfire remains a significant risk given increased temperatures and drier conditions due to climate change (29).

Retraumatization may look different in the context of a mass trauma event, such as the wildfire, compared to an individual-level stressor. First, some unknown proportion of individuals are at risk for retraumatization in these situations (in this study, nearly one-third), and it appears they may react differently and have poorer outcomes following a crisis. Based on our findings, we propose that retraumatization should be recognized as a risk factor in mass trauma situations. Programs and services must be truly trauma-informed to meet the needs of this vulnerable group. Second, mass traumatization can be influenced, in part, by processes of psychological contagion (30), with negative psychological impacts occurring through

interactions with others who have experienced trauma. Stress contagion has been described as the presence of "behavioral (e.g., anxiety-like symptoms) and/or physiological (e.g., HPA-axis activation) sequelae of stress exposure… in those individuals who are not directly exposed to the stressor" (31). Our previous research on the impacts of the wildfire, which saw the evacuation of all 88,000 residents of Fort McMurray, demonstrated that a number of adolescents who were only "minimally impacted" (e.g., were not present in the town for the wildfire, and did not suffer impacts such as the loss of their home) still showed symptomatology consistent with PTSD (32). Stress contagion is comprised of the psychological (e.g., anxiety) and physiological changes that occur in response to exposure to stress, but it occurs in individuals not directly exposed to the stressor—only other affected individuals. A review of the contagion phenomenon (31) has reported instances between mother-infant dyads (33, 34) and in married couples (35, 36) but we believe our work represents the first reported instance of stress contagion occurring *en masse* as a result of collective trauma resulting form natural disaster. Research has attempted to identify potential neurochemical mechanisms that might act as proximal signals of distress (37), although, evidence of this kind of signaling taking place remotely [e.g., *via* videotape; (38)] potentially suggests a concomitant role for media exposure in mass trauma circumstances. Our results support the idea that spending time in that environment in the company of others who were significantly affected was, in itself, enough to increase trauma symptoms in some individuals.

Experience of mass trauma may also differ in terms of increased levels of social and family support (social buffering, rather than contagion). In situations of mass trauma, there is a collective experience and response, which often results in increased levels of empathy, and sharing of physical resources. This was witnessed during the evacuation in Fort McMurray, where individuals fleeing the town were met on the highway by others providing bottles of water and gasoline to those in need. In other words, being surrounded by other empathetic parties who have experienced the same trauma may actually carry some protective effect. These suppositions highlight the critical role of community support in building and strengthening resilience following mass crises such as natural disasters. If it is true that one of the main characteristics of trauma is that it is "fundamentally decontextualizing" with disconnection from others being a foregone result (39), then shared experience may be a key to improved coping skills amongst survivors. This is another way in which mass trauma differs from individual-level trauma, which is often characterized by feelings of isolation, loneliness, and exclusion. It is possible that the prior trauma group differed in terms of symptoms such as depression because they were not expecting those around them to understand or sympathize with their anxieties, as was likely their experience with their past individual-level trauma. At the same time, their prior trauma experience may have resulted in alterations in the likelihood of turning to others for support or assistance. In this context, it makes sense that the subgroup that suffered sexual abuse (as opposed to injury or death of a loved one) would experience the greatest coping difficulties, because sexual abuse consequences are often hidden and processed alone; it is possible

these individuals had never learned to share their early feelings of grief and pain with others, and so did not see this as a potential coping response in the face of collective trauma. Interestingly, another paper examining retraumatization in veterans also found that sexual assault was the most robust predictor of increased risk for depression, PTSD, and suicidality (7). This is an issue worthy of continued investigation.

Finally, our results carry implications for educators and clinicians. This is particularly important in working with adolescents, as it has been suggested that the full effects of trauma may not be evident until adulthood (5). In the context of mass trauma, we should be sensitive to the fact that some individuals with a history of trauma may be more vulnerable to retraumatization. This reaffirms the need for services to be trauma-informed. However, in social situations where a mass trauma has occurred, it also suggests a need to treat the group as an ensemble, rather than reacting to specific individuals who are showing distress. Contagion studies suggest that those impacted react as a group and relationship should be central to therapeutic approaches (31, 40). In group settings, adolescents may work together to start finding ways to share the things they have found helpful, cognitively reframing the event, and incorporating what they have learned from the experience into a new worldview. This group dynamic therefore underscores the importance of leadership, with a role for teachers and therapists (who may themselves have also experienced the trauma) in helping adolescents develop the self-regulation skills promoting empathy among group members, as well as emotional maturity to recognize their own internal emotional distress signals.

LIMITATIONS

There are several limitations of this study, which reduce its potential replicability and generalizability. One is that we were not able to collect information regarding the trajectory of the recovery post-wildfire. Data utilized for this analysis were collected 3.5 years after the 2016 wildfire; data gathered during or shortly after the wildfire might have looked quite different, as many factors likely changed in the interim. Being prepared for research in disaster situations of all types, in terms of readiness with a set of potential study tools to broadly measure physical and mental health, and a potential schedule of when this information might be gathered, would be useful so that deployment in these situations can be efficient and well-planned. Additionally, our decision not to track individual IDs (a tradeoff between reduced complexity/increased participation and ability to capture individual-level changes over time) was a definite limitation complicating our analysis.

Relatedly, while details of the difficult social and economic circumstances in Fort McMurray are well-documented (41)[1], these variables were not measured directly. This represents another limitation in this study. It would have been useful to have an indication of how socioeconomic variables affected the overall recovery of the region post-wildfire, but at the time our

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[1] https://financialpost.com/commodities/energy/from-binge-to-bust-a-canadian-oil-town-lines-up-at-the-food-bank

focus was specifically on mental health, and there was little reason to believe at the time that the economic uncertainty was going to be long-term. The fact that nearly half of the adolescents surveyed reported that their greatest stressor had occurred in the years since the wildfire supports the supposition that this trauma was related to parental job loss, leading to financial instability, bankruptcy, mortgage foreclosure, etc., and other related issues, such as domestic conflict, including violence and marital breakdown, as reported anecdotally by local residents. Future studies should consider inclusion of direct measures of familial impacts, including economic well-being, and related mental health sequelae.

Another limitation of this study surrounds which adolescents were unavailable to take part in the study, and the fact that those taking part may not have been representative of the overall sample. Children who had left school (e.g., dropped out) or were simply not present that day would have missed it. This is noteworthy, as their absence could actually be indicative of poorer mental health. Children with a history of skipping school or leaving altogether may do so due to problems with handling the content, the social situation, or both. It is possible that these results represent an underestimate of difficulties. Additionally, because the survey was limited to students attending school within the Fort McMurray townsite, other adolescents living in nearby rural areas were excluded. Because this group of individuals includes Indigenous youth living on reserve, a significant segment of the local demographic, this dataset may not properly generalize to their experience.

There are other limits to the generalizability of this study, given the specific attributes of the townsite. Fort McMurray is a relatively small town (fewer than 100,000 residents) situated in a fairly remote, northern location. The nearest large city is over 4 h drive away, accessible by only one road—which held ramifications for the evacuation of the townsite. This means that residents are somewhat isolated and must be self-sufficient. It is also a very industrial, resource-dependent town. Prior to the fire and economic crisis, Fort McMurray was a net attractor for immigrants and internal migrants from other parts of Canada, due primarily to the potential for young people of making a very good income in the oil industry. For example, according to the 2016 Census[2], the median total income for a family in Fort McMurray was $195,656 CAD; compare this to the median income in the neighboring province of Saskatchewan (which has a similar population density) at $75,412 CAD. This has resulted in a fairly young population (median age 33.1 years, compared to 37.8 years for Saskatchewan), with a bias toward males (54.0% compared to Saskatchewan's 49.7%). Finally, it is noteworthy, as discussed above, that the town went through a drastic reversal in fortunes in the years following the wildfire. All of these factors potentially limit the generalizability of these results to other populations.

There were also limitations in terms of the level of detail of the data gathered. For example, while we were able to ascertain which adolescents had experienced prior trauma, for the most part we grouped these types of trauma together due to sample size limitations. It should be recognized that different types of trauma (e.g., loss vs. abuse) are likely to have different impacts, as we note in our subanalysis. Similarly, it is also worth considering that chronicity of trauma (e.g., childhood abuse vs. a single-episode traumas) could similarly affect the degree or expression of retraumatization (5). To that end, it is worth considering that some of the prior trauma group may have had poorer mental health and been functioning at a lower overall level prior to the wildfire. Again, due to the design of this study, such data could not be collected. Ideally, a prospective study having baseline measures of functioning for individuals with these types of underlying trauma would be useful in the future.

Finally, because social effects appear central to coping with a mass trauma (for both better and worse), future investigations should try to capture not only the perceptions of the affected individual, but his or her impressions of how those around them are coping. Our study did not attempt to capture this type of information. In mass trauma events, where the common understanding is that "everyone is going through the same thing," discrepancies in terms of resources and attitudes may in fact cause some individuals to feel more isolated, which could have broader mental health repercussions.

CONCLUSION

Retraumatization needs to be identified as an underlying, often unrecognized vulnerability that may worsen health outcomes for some individuals in the event of a mass trauma. In this study, nearly one-third of the population fell into this group. For this reason, it is important that those offering healthcare and social services in mass crisis situations ensure that the services they deliver are truly trauma-informed, to provide the best possible outcomes for those most vulnerable to retraumatization. Based on the limitations of this study, we would suggest that, in the event of a mass trauma, it is important for research teams to be prepared and proactive to evaluate these needs. Although, early measurements can be challenging as individuals actively deal with a crisis, these data may be invaluable in understanding the trajectory of change in recovery. Measurements should include basic indicators of physical and mental health, but also track socioeconomic factors, which can themselves affect group functioning. Finally, this study underscores the value of assessing individuals for prior trauma, to help identify which individuals may be in need of additional assistance in disaster situations. That said, mass trauma events also offer an opportunity for community members to support one another in ways that individual-level traumas may not, because there is a sense that everyone is in it together, and individuals may be able to lean on one another for support. Until we better understand the scope and overall effects of undiagnosed trauma in the population, we will fail to meet the needs of this vulnerable group.

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[2]https://www12.statcan.gc.ca/census-recensement/2016/dp-pd/prof/details/page.cfm?Lang=E&Geo1=POPC&Code1=0292&Geo2=PR&Code2=47&Data=Count&SearchText=FortMcMurray&SearchType=Begins&SearchPR=01&B1=All&wbdisable=true

DATA AVAILABILITY STATEMENT

The data analyzed in this study is subject to the following licenses/restrictions: data for this study is the property of the Fort McMurray Public and Catholic School Districts. Requests to access these datasets should be directed to Matthew R. G. Brown, mrbrown23@gmail.com.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by Health Research Ethics Board, University of Alberta. Written informed consent to participate in this study was provided by the participants' legal guardian/next of kin.

AUTHOR CONTRIBUTIONS

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Nurturing Spiritual Resilience to Promote Post-disaster Community Recovery: The 2016 Alberta Wildfire in Canada

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The 2016 Alberta wildfire, the largest insured natural disaster in Canada, led to a mass evacuation of residents of Fort McMurray, a small city in northern Alberta. The wildfire resulted in significant damages to housing and community infrastructure. The entire community was displaced for several weeks. Post-disaster, community members experienced individual and collective trauma, and other negative mental health impacts in response to the significant losses and grief they endured. Spirituality has been found to be a major protective factor in facilitating resiliency and recovery following the experience of disaster. Nonetheless, little focus has been directed toward how spirituality can strengthen and empower community capacity and growth during post-disaster recovery. Our study explored various meanings and concerns, along with tools and strategies that helped to nurture spiritual resilience and well-being among residents of Fort McMurray following the Alberta wildfire. Data were collected through interviews and focus group discussions with community influencers working to support long-term recovery efforts in the city. Participants identified a number of spiritual resources such as a strong sense of belonging, a shared positive outlook, faith and hope, compassion, and sense of gratitude, which contributed to increased resilience and positive health and well-being and helped them to support families and communities in the post disaster recovery period. Our findings indicate that spiritual values and beliefs can play a significant role in building resilience and promoting individual and communal healing and recovery post-disaster. These findings have important implications for post-disaster recovery strategies, as they highlight the need to ensure supports for interventions and initiatives that strengthen a collective sense of identity and social cohesion, informed by communal norms and beliefs, including programs and resources which support opportunities for reflexivity to foster shared healing and ongoing recovery processes.

Keywords: spirituality, resilience, post disaster recovery, community, service providers, meaning making

INTRODUCTION

"How we are able to weather the storm, how we're able to endure the challenges and complications of life that are thrown at us is a sign of our resilience. It's [pause] if we can't handle those, well then, we usually crumble and fall apart. But if we are still able to stand after experiencing trauma or tragedies like the wildfire and still stand on our feet that is a sign of resilience." (Interview participant)

The above quote describes a painful yet meaningful and self-enduring experience of an individual who experienced the Alberta wildfire disaster in 2016. The Alberta Wildfire which occurred in May 2016 is the costliest disaster and mass evacuation in Canadian history, resulting in damages totaling ~C$9.9 billion dollars (1). Over 88,000 residents were evacuated and displaced from Fort McMurray, Alberta, and ~2,600 homes and 589,995 hectares of land and other infrastructure were damaged (2). Shortly after the wildfire, the Wood Buffalo Ministerial Recovery Task Force was established to ensure safety and security in disaster affected areas, to support the community, to plan for the timely re-entry and settlement of residents, and to resume municipal, social, economic, and business activities (3). Voluntary re-entry was initiated in June 2016 in Fort McMurray, and the community rebuilding and recovery efforts are still ongoing today. The community as a whole experienced significant trauma, suffering, and difficulties as a result of this mass incident. 4 years later, many individuals in the community of Fort McMurray are still struggling to fully recover from the significant losses and prolonged distress that occurred as a result of the wildfire (4). In addition, other challenges which have occurred post-wildfire, including a prolonged economic downturn, particularly in the oil and gas industry which Fort McMurray is largely dependent on, a damaging flood in 2020, and more globally, the COVID-19 pandemic have compounded the challenges experienced in Fort McMurray and further complicate the recovery process. The recovery efforts are still going on in the community and various programs and activities are targeted to help the families and community in their post disaster recovery efforts. This article aims to discuss some of these enabling experiences along with spiritual tools and resources that helped community influencers and service providers to help families and community in post-disaster recovery and healing efforts.

Fort McMurray Context

Multiple geographical, social, economic, and cultural influences shape the resilience and wellbeing of a community especially in the post disaster recovery context, therefore it is important to recognize the unique context of the Fort McMurray community. Fort McMurray is the urban service area that lies within the Regional Municipality of Wood Buffalo (RMWB) in Northeastern Alberta on Treaty 8 land and serves as the municipal center for several multi-nationally owned oilsands projects that surround it. Prior to the wildfire, the municipality was home to a total of 111,687 residents, of which two-thirds resided within Fort McMurray itself. It is a diverse community

in that approximately one-third of the entire population is non-permanent/temporary resident, also referred to as the "shadow population." These temporary residents include both regional and international mobile workers who are mostly employed by oil companies in the region. Ninety percent of these workers resides and works within the active work camps near oilsands projects sites (4). Dorow and O'Shaughnessy (5) describes FMM as a uniquely diverse community comprised of mobile workers, permanent residents and aboriginal communities having varied social, cultural, and economic ties with the place they live. As per the RMWB census report, 2018, there are more males 54.9% as compared to 45.1% female population. Due to steep housing costs and transient population, homeowners account for 63% of the population within Fort McMurray, Alberta (~10% lower than the provincial average). Prior to wildfire, in 2015, FMM also faced an economic downturn due to lowered oil prices, further worsened by the disastrous wildfire in May 2016 resulting in a mass evacuation, with physical infrastructure destroyed and other damages in the Town (4). As per the census reports from Regional Municipality Wood Buffalo (2015–2018), there has been a 10.67% decline in the total population and a 14.9% decline in the shadow population within these 3 years nonetheless the age, ethnicity, and gender structures remained more or less the same within the region. Nearly 19.3% of residents have relocated within the Municipality due to wildfire and other social and economic reasons (4).

Spirituality, Resilience, and Post-disaster Recovery

Disaster impacts physical, economic, spiritual, and psychosocial well-being, inducing traumatic responses among those affected, particularly those who are most vulnerable, including the poor, children and youth, immigrants and refugees, and disenfranchised groups (6). Along with the trauma of experiencing a disaster, individuals and families often experience the loss of homes and community infrastructure, which makes the basic tasks of everyday life challenging, as well as loss of a sense of identity, meaning, and purpose—all of which impact overall health and well-being (7). Benson et al. (8) note that following a disaster event people often enter into helping relationships with feelings of helplessness, loss of personal control and doubt about their relationships, environment, and their cultural and belief systems. The struggle to find meaning in their losses and trauma can result in various mental, psychological, and spiritual issues, and delayed recovery. A complex process, post-disaster recovery requires a shared sense of solidarity that develops through collective expression of grief and empathy, communal commitment, and sense of public duty directed to uniting communities, building resilience, and fostering overall well-being (9). Shared values leading to emergence of social cohesion motivates and enhances the ability of the local population to adapt, respond, and cope in the aftermath of disaster (10).

Ungar (11) has described resilience as a set interdependent processes that "reflect the positive adaptations that individuals, families, and communities make" (p. 255) following exposure to

trauma. He characterizes resilience as the co-occurring capacity of individuals to navigate their way to the psychological, social, cultural, spiritual, and physical resources that sustain their well-being, and individual and collective capacity to create or obtain culturally meaningful resources needed to support such efforts (11). More specifically, spiritual resiliency is defined as the ability to sustain one's sense of self and purpose through a set of beliefs, principles, or values while encountering adversity, stress, and trauma by using internal and external spiritual resources (12). The literature indicates a positive relationship between resilience and spirituality both at the individual and the community level.

Spirtuality is defined as an aspect of humanity that refers to the way individuals seek and express meaning and purpose, the way they experience their connectedness to the moment, to self, to others, to nature and to the significant or sacred (13). Individuals often identify as being spiritual, regardless of whether they are religious or not. Wattis et al. (14) asserts that spirituality can be viewed both in secular and religious terms and is no longer confined to religion. Most authors now view spirituality and religion as separate and distinct constructs whereas some may them as overlapping concepts (15). Spirituality can be expressed in religious and non-religious forms and values, some people express their spirituality through their religion such as prayers and meditation; others may express through non-religious forms such as showing love, being present, community participation, listening, and communication in forms of art, drama, and music etc. (16). Individuals often seek spirituality or find spiritual resources when suffering as it helps them to find meaning, endure hardships and adversities, and supports healing and recovery during periods of loss and grief; experiencing a disaster and the associated recovery processes post-disaster (17–19). Spiritual needs or resources may include need to find meaning, love, sense of belonging, hope, peace, and gratitude (20).

Given this, it is clear that spirituality can be an important aspect of resiliency as it contributes to adaptive coping as well as personal growth and transformation following exposure to traumatic events and stressors, including disasters (10). Spirtuality strengthens family relationships and promotes healing and resilience through coping, inner peace, self-esteem, perseverance, and helping others (20). Additionally, it assists people in adapting and transitioning to, or constructing a new normal following disaster by providing a positive worldview, meaning and purpose, psychological integration, hope and motivation, personal empowerment, a sense of control, answers to ultimate questions, or meaning, and social support (21). Despite the significant role that spirituality plays in resiliency processes, limited research has been directed toward identifying the various means, approaches, and tools related to spiritual resilience which help strengthen and empower community capacity and growth during post-disaster recovery.

According to Walsh (20), spiritual values and beliefs influence the ways individuals and families deal with adversity and suffering, through the meanings they associate with these experiences. Walsh (20) outlines how these values influence the ways individuals and families communicate about their pain and struggles, as well as their attitudes toward mental health and health care, and their preferred pathways to recovery.

Spiritual values and resources—such as meaning making, hope, self-efficacy, strong sense of community identity, relationship building, and belongingness—have been found to be powerful resources in fostering the resilience of communities. These values and resources serve as important protective factors in helping individuals cope with unimaginable losses, resulting in reduced impact on mental and psychological health (10, 21). Thus, it is important to address spirituality as a means of making meaning of, and recovering from, adverse events like disasters, and explore ways to build community resilience through this dimension as part of post-disaster recovery processes.

Disasters often pose threats to individual's meaning making experiences, as they can remind individuals of their mortality, threaten the predictability and safety of the natural world, and cause existential anxiety leading individuals to question the larger meaning of life (22). Park's meaning making model has been increasingly used as a framework to conceptualize resilience and coping abilities among individuals and communities, particularly in the context of disaster and the disaster recovery process (10). Park states that survivors' ability to engage in, and approach meaning making is greatly influenced by their religious and spiritual values and beliefs. In the aftermath of disaster, families often experience a strong sense of helplessness and lack of security due to major threats to their physical and psychological resources. These experiences often result in feelings of meaninglessness and lack of purpose, resulting in mental health challenges such as depression, and psychological and spiritual distress. Building on Park's (10) meaning making model, how individuals understand, interpret, and reappraise the guiding meanings that direct their lives, and plan to adjust their life goals and actions, influences their resiliency, overall recovery process, and future outcomes. Understanding those meanings, behaviors, and actions can guide professionals in planning appropriate community interventions to foster community resilience in the post-disaster recovery phase.

Multiple studies have found that spiritual meanings and resources have shown positive impacts on post-disaster recovery outcomes among families and communities. Haynes et al. (22) found that spiritual meaning and sense of peace buffered the deleterious relationship between resource loss and symptoms of spiritual distress among survivors of Hurricane Katrina. Survivors who reported experiencing higher spiritual meaning following the disaster reported significantly less severe post-traumatic stress in response to resource loss, relative to survivors who reported lower spiritual meaning and peace. Similarly, Alawiyah (21) found that spirituality and religious practices provided the motivational force that supported resilience among African American survivors of Hurricane Katrina. Other studies have also reported that spirituality was an important resource that contributed to enhanced community resilience, and also helped to reduce post-traumatic mental health impacts and promote healing, through improved social support and enhanced self-efficacy during post-disaster recovery periods (23–25).

Study Context
The findings of the following analyses draw from a larger study on the "Health Effects of the 2016 Alberta Wildfire: Pediatric

Resilience" that primarily focused on examining the effects of the Alberta wildfires on children, youth, and families to better understand the social, economic, spiritual, and cultural factors that contributed to overall well-being and resilience. Individual characteristics and social-environmental factors in the lives of children and youth were considered in the recovery context to gain a holistic understanding of their health, functioning, and overall well-being. Brown et al.'s (26) population survey in a similar context showed that there was a significant negative impact of the wildfire disaster on many aspects of adolescent (grade 7–12) mental health and a significant increase in symptoms related to depression and suicidal thinking. To gain further insight into community resilience and the impacts of disaster, qualitative interviews and focus groups were conducted with community influencers in Fort McMurray. "Community influencers" is a term used in Alberta, Canada, that refers to direct service providers, community leaders, social work practitioners, educators, and individuals delivering services and programs to children, youth and families in a variety of organizations (6, 27). Drawing from the collective narratives gathered from community influencers, this article discusses the role of spirituality and spiritual values in fostering community resilience during the post-disaster recovery period.

METHODS

A qualitative descriptive study design was adopted using a community-based research approach. A research partnership was created with the Public and Catholic School Boards of Fort McMurray, Alberta, and other local community partners for the study (4). Qualitative interviews and focus groups were used to gather the perspectives and experiences of community influencers engaged in the delivery of services and programs for children, youth, and families, post-wildfire. Using a purposive, snowball sampling approach, participants were recruited from: (1) social service agencies and community organizations based in Edmonton and Calgary (the other two largest cities in Alberta) which played an important role in addressing the immediate needs of Fort McMurray residents following evacuation (housing, food, clothing, wildfire response updates, mental health support, etc.), and later supported their return home; and (2) social service agencies and community organizations based in Fort McMurray that actively supported the re-entry of residents, and have continued to support ongoing recovery efforts. These social services agencies and community organizations include but not limited to municipalities and regional services, schools, faith based organizations, recreation/wellness centers, child and youth crisis support services, culturally focused services, and mental health support services (For sample demographic information, see **Table 1**) For recruitment, phone calls and separate email invitations were sent to the agencies along with the study information letters by the principal investigator (PI) of the larger grant study with the post-doctoral fellow and four research assistants who were also part of the study. Semi-structured individual in-depth interviews were conducted by both PI and research fellow in the study whereas all the focus group

TABLE 1 | Demographic information for interview participants in Fort McMurray.

Community Agencies/Service Providers	# of Participants
Community Schools (Public/Catholic)	10
Non-Governmental Organizations (NGOs)	4
Wood Buffalo Municipality District Offices	5
Youth Elder (Aboriginal Organization)	1
Faith Ministries (Church Services)	2
Mental health/Wellness Services/YMCA	6
Alberta Health Services	2
Total	30

discussions were held by the PI along with a note taker in the study (4). The interview transcriptions were done by the research assistants and then analyzed by the research fellow along with the PI and Co-I of the study.

All the individual interviews and focus groups were held in person. Thirty interviews and 12 focus groups were conducted, yielding a sample of $n = 30$ and $n = 35$ participants, respectively. The small number of participants in each focus group session allowed for a rich and descriptive discussion of key questions and issues. The average duration for interviews and focus groups was 1–2 h. Interviews and focus group discussions focused on examining the perspectives and experiences of community influencers with respect to their roles in supporting children, youth, and families during the wildfire evacuation, response, and re-entry and recovery stages post-disaster. Focus groups were conducted in person with the objective of presenting preliminary interview findings to the participants and eliciting their feedback on identified themes, and further exploring their perspectives about the challenges the community faced, and how these could be addressed more appropriately. Research ethics approval was obtained from the Ethics Review Board at the University of Calgary. Participants' written consent was obtained prior to data collection; all data collected were audio-recorded and transcribed for analysis by the research team.

Data analysis was informed by the interpretive constructivist paradigm, recognizing the multiple, shared socially constructed realities of people's lived experiences (28). Using constructivist grounded theory concepts (29, 30), this paradigm was used to identify and explore multiple, subjective perspectives regarding ways spirituality can strengthen and empower community capacity and growth during post-disaster recovery processes. Grounded theory moves beyond individual perspectives to understand the meanings that groups of individuals attach to their experiences and the world around them, capturing patterns revealed across individuals and groups, including those that might not be obvious to participants (31). The emergent, inductive, and comparative nature of Grounded Theory research rendered it particularly well-suited for analysis of the qualitative data that was collected in this study. Individual in-depth interviews and focus group discussions were transcribed for coding and analysis by the research team. Separate memos and contextual details gathered during the interviews and discussions

were also added to the data. NVivo 12.0 was used to support qualitative data analysis of the transcripts. The PI and Co-I along with the graduate research assistants analyzed transcripts to identify emerging themes, links, and associations embedded in the data. Coded quotes were extracted for preliminary analysis, compared within and between cases, and grouped according to key themes and sub-themes. To maintain validity and reliability, a penultimate thematic listing was shared among research team members for review. Following minor clarifications, the final thematic listing was determined based on consensus.

FINDINGS

Analysis of data gathered from the diverse group of community influencers who participated in individual interviews and focus group discussions provided a vivid description of their experience of the 2016 wildfire, the chaotic city-wide evacuation, response and early and ongoing recovery processes since residents have returned to Fort McMurray. The narratives shared by the participants demonstrate several meaning making and spiritual perspectives, inner resources, and tools that helped families and communities in their post disaster recovery and healing processes. It is significant to note that participants were not asked directly to identify themselves as spiritual or not spiritual during the interviews or focus groups, nonetheless the narratives provided by the participants and extracted themes indicated various spiritual perspectives, attributes and inner resources that fostered resiliency and helped community to cope and adapt to the new normal in the post disaster recovery and healing process. These perspectives were organized into several themes under the study. The major themes included: a strong sense of belonging and social connection, fostering a shared positive outlook, hope and faith, sense of gratitude, compassion, and altruistic values, as well as strategies and programs used to foster spiritual resiliency among different groups.

Strong Sense of Belonging and Social Connection

Participants highlighted a strong sense of belonging and relational connectedness that Fort McMurray residents shared, which helped them to work collectively toward recovery and healing efforts. Although, participants also shared that they still feel a vacuum for those residents could never come back to the community due to various social and economic reasons and wished that they would never have to lose those connections. Most participants view the community connectedness and togetherness as a strength and an important resource to motivate and boost their efforts in post-disaster recovery period. Participants described the importance of maintaining and strengthening a sense of community post-disaster by reinforcing social bonds and continuing to grow together as a community. One focus group participant shared:

Fort McMurray is so much more than the fire. I think the outside community thinks it's the place of the fire. Although it's a big part of our story it's not who we are. I encourage all people that once we get to a place of help, that this is an opportunity for us as a community

to grow our character. We would be stronger, more loving, caring, and noticeable of the world around us. (Focus group participant)

The above finding was surprising yet significant in the study knowing that Fort Mc Murray is quite a diverse community comprised of temporary residents/mobile workers which make up one third of the community. Despite this unique aspect of the community, the participants expressed values of strong social ties, connections, and respect for each other. Such a unique population demographic of Fort McMurray was identified as a key consideration by participants in the study, which is evident in the following statement by one of the focus group participants:

The other strength is that because you had people that came from all around Canada and the world to live there [in Fort McMurray], they have some very strong bonds … that aren't necessarily the traditional bonds that we see with our own families and extended families. (Focus group participant)

Many service providers agreed that community connections were disrupted by the wildfire during the evacuation and it was important to re-establish those connections and relationships after the wildfire. For example, one focus group participant stated:

But the bigger picture was connecting, because after the evacuation everybody felt like we were isolated in our own little silos, because we were all going through different (things), we were all impacted differently but, we were nonetheless impacted in what happened.… We are a relational community here. We publicly teach the importance of community and relationship all the time. Other than being in close relationship with other people, it's hard to support and help people. (Interview participant)

Most of the participants discussed the wildfire recovery in relation to strengthening social connections and social capital in the community. This is evident in the following statement shared by a focus group participant:

[Recovery] is really about those social connections and building that social capital (Focus group participant)

Participants expressed that a successful post-disaster recovery meant moving forward together, understanding and respecting the needs and concerns of affected individuals and families, and ensuring a strong sense of community by sharing love and care, providing timely and adequate support, and pursuing communal growth. They strongly believed that it was necessary to help each other build their individual and collective capacity for realizing the future promise and potential of the community. Individual failure was viewed as a community failure. Participants emphasized the need to care for, and support everyone on their respective journeys through loss, grief, and trauma as they moved forward toward healing and recovery. As one interview participant stated:

Success to us is, are people coming together to move people along in their journey. For us, real success is often deemed by are we being an

encouraging family to one another. Are we loving one another? To the point of seeing others move and grow. Growth can look different for different people and be at different paces for different people, but if somebody can't get to the next step because they don't feel love or supported; that's a failure to me. Not every person can meet every goal, not everyone can be the Prime Minister. That would be awful if we had 32 million Prime Ministers, right? Not every person is going to reach the same end goal, but if every person is not able to reach the potential in them, then we failed as a community. (Interview participant)

Community connections were also perceived by participants as an important element of fostering a sense of belonging, particularly among immigrant newcomers. One of the focus group participants stated:

We deal with families that are newcomers to Canada and they have no idea what they are going through, how to deal with it and where to go, and that is very important for us to give the family a sense of belonging and that would help them a lot, you know … so it depends about who they are and where they come from because this is a multicultural society, so something, having a sense of belonging, guiding them to where people speak their own language so they felt they belong, that helps them really significantly with these situations. (Focus group participant)

Participants also discussed how mental health is strengthened through social and community connections.

Mental health is not created in isolation; it is created through connections. (Focus group participant)

Events such as community dinners were purposefully organized by community organizations and service providers to foster relationship building and a sense of belonging among community members. According to one interview participant, such events helped to promote a sense of togetherness, that generated a sense of cohesion and unity.

We did community dinners which brought people in the community together, and they didn't have to talk about the evacuation, the fire if they didn't want to, it was just for the dinner to sit. And we would go into different communities who were mostly impacted by the fire and would sit with them. Sometimes we would show them like a little film, and talk about mental health. But sometimes it was just about offering support, listening to music and talking, and socializing. (Interview participant)

In discussing post-wildfire resilience, some participants discussed the importance of keeping the needs of children and youth in view. Participants recognized the importance of children having a stable adult in their lives to provide support and reassurance and be a positive guiding influence. This is evident in the following quote from a focus group participant.

I think relationship building is probably the number one thing we have witnessed. We have some children that just really need an adult in their corner, a stable adult in their corner. (Focus group participant)

In addition to relational connections and mutual support, participants also mentioned strategies that fostered a shared positive outlook.

Need to Foster a Shared Positive Outlook

Study participants identified that a shared positive outlook was integral to helping community members cope with the impact of the wildfire. While this was recognized as important, participants shared that maintaining a positive outlook was a challenge for many community members given the scale and devastating impact of the wildfire. Participants shared that most families are still experiencing post-traumatic and anxiety symptoms along with other mental health issues and were finding it challenging to cope with multiple psychosocial and other stressors caused by the disaster. In most instances, mental health was not given an immediate priority among other various physical needs such as loss of homes, clothing, food, insurance, and loss of jobs. According to one focus group participant:

This is an entire community that is facing PTSD, and facing trauma, and facing a lot of challenges. (Focus group participant)

Participants also noted multiple associated, intersecting stresses and pressures, such as waiting for reconstruction of homes, coping with other physical and social losses, and loss of employment and income associated with the ongoing economic downturn. In addition to making it difficult to maintain an optimistic outlook, these challenges negatively impacted the mental health and spiritual well-being of community members. As one of participant shared:

The challenges have been multifaceted because not only is it the fire, it is the slowdown, the layoffs, the change in hours at work, so families that were well-to-do are maybe just trying to get by on one pay cheque. (Focus group participant)

Many participants also explained that disaster-affected residents were focused on meeting their basic needs, and the need for mental health support emerged later in the long-term recovery process.

It is hard to focus on your mental health when you are in survival mode and you are trying to meet your basic needs. (Focus group participant)

Another interview participant pointed to the complexity and challenge of fostering a shared positive attitude, given the unique experiences and array of challenges facing everyone:

… My story is that 88,000 people left that day, and there's 88,000 stories, and 88,000 ways people were impacted. Even for myself, my husband started smoking again, and I put on 20 pounds. Everybody has a different way of coping and trying to find ways to recover from that is difficult. Once you're in that, it's hard to pull yourself out. As time goes on, you just kind of throw your hands up and say OK, I'm done. (Interview participant)

Service providers strongly advocated for the need to draw on the inner strength of individuals that could contribute to empowering the collective effort of community members in rising to address ongoing challenges and working toward creating a more positive future. One service provider shared:

> Despite multiple challenges, you can find the inner strength to pick yourself up and move on. Knowing that when you move on it may not look like what it looked like in the past, but you can still make positive choices for yourself. You don't have to be defined by the event that happened. … Life continues to present some challenges, but hopefully you can give people the tools and skills to actually learn forward and cope better. (Interview participant)

In the midst of the above challenges, hope and faith emerged as major resources for building spiritual resiliency in the post-disaster context.

Hope and Faith

Participants in the focus group discussions reported that instilling hope and faith was expressed as "believing that something good is coming along the way." Faith and hope emerged as major resources in the provision of a collective sense of empowerment and growth, as well as courage to cope with all the losses and hardships experienced post-disaster. Community dinners and other congressional activities were held monthly in community spaces such as schools and playgrounds. These programs created space for community members to share their experiences, discuss their grievances, express their emotions and feelings, and build hope for a better future. This is evident in the following statement by one of the interview participants:

> Our resiliency is centered on hope. In a sense that, in order to be resilient, we need to know that there's hope for better and something different. The hope comes through our faith. We believe that God can bring us to better ends and has good plans for us. It's difficult to be resilient if you don't think there's a good place to get to. Why put in all this effort, get out of bed and fight through for all these things, to end up in somewhere you don't want to be. For us, a lot of it is reminding and teaching people there's always hope. The importance of being the voice in each other's life, of being hope, when someone can't see it themselves. (Interview participant)

Participants working with children and youth in elementary and secondary schools highlighted the importance of hope in their work. One interview participant shared:

> What I want to see is students thrive, have hope, and believe that we can have a better life before. That's where I'm trying to get … The core of our being, our faith, is having hope that we can actually do better. (Interview participant).

Some participants identified churches as a spiritual place where community members could meet.

> You need to go to your church and hang out with a friend, to go for coffee. (Focus group participant)

Similarly, hope was also expressed as pride in the community's rebuilding efforts post-wildfire. A focus group participant explained:

> It's a kind of community pride that I think a lot of youth had, especially the ones who came back, they love their community. And now, it seems maybe in their mind something else is now threatening their community, that they have worked so hard to recover from the fire. (Focus group participant)

Instilling hope through community rebuilding, as well as other opportunities for gathering together to discuss their fears and anxieties, along with their hopes, commitment, and resolve, and sharing their faith practices, helped to foster a positive and supportive environment that facilitated post-disaster recovery for many in the community.

Sense of Gratitude

Participants explained that despite needing to grieve and adjust to difficult losses, the major strength of the community was found in the gratitude they experienced, the connections they built and the inner courage shown to help themselves and others in the midst of several challenges and adversities. One interview participant stated:

> We need to acknowledge that our life isn't just about possessions, it should be about community, love, life, hope, and joy. All the things that can't be measured by what's lost in a fire… Be thankful to the Creator for giving us the day, look positively, and try to carry on with your work. At the end of the day, you'll be happy. (Interview participant)

Many participants expressed a sense of gratitude to people across Alberta, and the entire country, for all they did to support wildfire recovery and rebuilding efforts in the community.

> I think Albertans worked well. I think they were generous; they were conscious of what was happening, and there is that ethos in most of our communities that says 'We will help. Let us know how to help and we will help'. (Focus group participant)

One participant described how the generosity of people from across Canada helped to instill hope and foster a positive outlook among community members.

> But, there's a whole lot of generosity within our whole country and helping our community get back on its feet with welcoming 80,000 people into households into—so I think it's really, I think the community has a lot of hope in it. Like, I think people feel pretty good about (it), even if they're going through a hard time, they're wanting to keep working toward it. (Interview participant)

In addition to the sense of gratitude, community members were willing to help each other to develop a stronger and resilient community.

Compassion and Altruistic Values

Compassion and being of service to others were also identified as inherent values held within the community which were viewed

as essential in "building back better" as part of Fort McMurray's post-wildfire recovery. Participants felt a sense of responsibility to serve their communities and found joy in helping each other. One participant shared that despite her house being completely destroyed by the fire, she felt compelled to return to support the rebuilding of schools in the community. She explained:

I couldn't move away or walk away from it. We were in crisis. I felt a significant responsibility to make sure things were put back in place. My biggest motivation is just working with the families, the children, the positives, the negatives, the challenges, the successes. It's … no day is ever the same … I really look forward to being able to help shape the lives of those little children and help them grow. (Interview participant)

Altruism was expressed by participants as a concern for the well-being of others in the community who they felt closely connected through a sense of kinship given a shared attachment to Fort McMurray as being their "home."

This is my home. My family is here. My son is here. This is where I live. This is where I want to be. I think it's important that we take care of each other. I think it's important that everybody has a role to play in it. I feel like this is my place to help. (Interview participant)

The development of relational connections through altruistic and compassionate commitment to helping others led to a sense of self-efficacy and positive future orientation. As one participant shared:

… And I mean, with families you build those positive relationships, it's such a small community that everybody kind of knows everybody, and I can't see me doing anything else, you know! It's just, I love the people… If families did need support then it was having communication with the families, asking if they need help with anything, and being there to listen to them. It made us a lot closer with the family that we helped support. It was something we all went through together. It was a learning process when we came back. (Interview participant)

Another participant described the remarkable efforts and practices that took place after the wildfire, and expressed a sense of pride which suggested a positive future outlook.

It's good to promote the positive stories that happen when disasters happen. (Focus group participant)

The development of a greater sense of self-efficacy, inspired by compassion, and motivation to be of service to others and the community, was described by many participants as a milestone in the post-disaster context.

Strategies and Programs Used to Foster Resiliency

Several community-based, trauma-informed programs and strategies were implemented by community-based organizations to support post-disaster recovery in Fort McMurray. Efforts were made to engage new, often unanticipated individuals and

groups in taking leadership to initiate resilience efforts. This stimulated innovative approaches to integrating resilience into different aspects of the community, and led to recognition and appreciation of strengths-based approaches to post-disaster recovery. One focus group participant stated:

We certainly heard from community organizations around really sort of focusing more on a strengths-based approach. (Focus group participant)

Designed for service providers as well as community members across all age groups, including children, youth, and families, these programs focused on improving mental, psychosocial, and spiritual health, and enhancing overall individual well-being. Participants highlighted several examples of initiatives that were introduced to support community members, which are described below.

Wellness Grant
The "Wellness Grant" enabled service providers to access funding for specific initiatives that aimed to help them cope with trauma and enhance their sense of self-efficacy, while providing support to individuals and families in the community. Several participants discussed how this program helped them cope, and maintain a sense of self-efficacy, post-disaster period. One participant shared:

… The 'Wellness Grant' … allows staff to do things like, coffee break. Where they bring in Tim Hortons coffee and muffins and donuts and everyone kind of gets to have a minute to sit, chat, catch up, and be together. So, it's not just an entire day of hustle and bustle, and running around, and making sure all the kids are okay, but making sure they're okay. (Interview Participant)

Journey of Hope
The "Journey of Hope" program was developed to (1) support families experiencing complex challenges, such as grief and loss associated with separation and divorce, and domestic violence, that made reintegration into the community difficult; and (2) support children who were severely traumatized by the wildfire. The program aimed at helping vulnerable members of the community overcome fear and anxiety due to family disruption, and also those experiencing a heightened sense of anxiety and/ or isolation, post-disaster. The following quote by a participant speaks to the efficacy of the program:

We have a partnership with a non-profit agency who runs a separate program for family separation, (and) divorce groups. Their providers also come into our school and do grief and loss groups as well. So any time and grief and loss is very, very you know it could be loss of a house, loss of a park, loss of a friend who's moved to a different community because of the fire. Their expert providers would come in and do grief and loss work with our kids as well as work with our families. (Interview Participant)

Peer Mentorship
Peer mentorship and other mental health counseling programs were offered to children and youth in elementary and secondary

school settings to help them cope with the trauma they experienced and promote positive socialization and community integration post-wildfire.

I think our 'Friendly Peer' program which is the substance prevention program would be huge. A lot of …, especially teens, when teens hit like Grade 7, and that's what the program is for. We can do it with Grade 6, but it's for Grade 6 up to Grade 12. I think talking about substances, turning [to] them when you're stressed out, or peer pressure, those types of topics. We spend about 3 to 4 weeks on stress, what stress is, and how to deal with it. It's okay to feel stress. Stress is never going to go away in your life. Especially when you get old as an adult, but here's a healthy way to deal with it, and why you shouldn't turn to drinking and those types of things. I love that program. It's a really great program for Grade 7 when they hit that age. (Interview Participant)

Mindfulness and Psycho-Education

Mindfulness and psycho-educational programs introduced in the community focused on emotional regulation to facilitate the psychological, emotional, and social well-being of children, youth, and families affected by the wildfire. The following quotes attest to the value the participants placed on these programs. This participant endorsed mindfulness as an important approach for promoting healing and recovery:

I feel that's a huge strategy, anxiety is a huge piece to work on because, whether it be in children, or in adults, we all suffer from anxiety to some degree, and having that psycho-education, and learning some of those strategies, those coping strategies of grounding, and you know, learning about ways of regulating yourself, and how connecting it to your body, and understanding what's happening within your body is helpful (Interview Participant)

Participants also recognized how important it was to provide reassurance and support to families and children, especially when parents were still struggling with their own trauma post-disaster. One participant shared:

We have 'Circle Security', so that's working with families, and that's helping them understand the attachment piece, cause, often times, when you are working with families who have been traumatized, they forget, or they …, sometimes, it goes on the back burner how important attachment is with children, and … they're detaching because they are working through their own trauma, and they forget about how it's impacting their children. So 'Circle Security' helps them understand, it gives them psycho-education about attachment, and then gives them strategies to work with their children, and their teenagers. (Interview Participant)

Participants also pointed to the benefit of introducing specific emotional regulation approaches to students as a means of reaching their parents. One participant shared:

This year we're doing 'Heart Math', which is deep breathing and using a heart monitor to help regulate themselves. … We had the students teach the parents how to use 'Heart Math'. One of the things we've learnt with this process is, it's very difficult to help the parents. They don't want help. They won't show up for sessions, but if we teach the kids, the kids will teach their parents. It's an effective way to impact them in a positive way. That would be true with 'Leader in Me' too. For 'Leader in Me', we trained all our teachers to look at their own '7 habits', like to 'be proactive', and 'begin with the end in mind'. That was the first step, now it's about how do we teach students to be leaders. Teachers support them in their leadership, and that seems to be working. (Interview participant)

Overall, recognizing the diversity of needs, participants pointed to the need for a continuum of mental health support at the community level as part of an overall strategy directed to promoting resilience and enhancing well-being:

There needs to be a whole range of supports … we have heard about peer support work … there just needs to be a whole range to meet people where they are at because of the uniqueness of people's needs. (Focus group participant)

Participants shared that individual and collective efforts that had been committed to rebuilding the community–through these programs and other initiatives–had provided important opportunities for learning and growing, and enhancing collective resiliency by building upon each other's strengths, which had contributed to supporting the resilience, well-being, and long-term recovery of the community.

DISCUSSION

The challenges experienced by service providers and community influencers, as well as the community efforts that were implemented to rebuild the community during the post-disaster recovery phases were perceived by participants as an opportunity to learn, grow and build upon each other's strengths and experiences, thus increasing resilience. Participants identified a number of spiritual resources which contributed to enhancing resilience and promoting health and well-being post-wildfire, such as a strong sense of belonging, a need to demonstrate a shared positive outlook, faith and hope, compassion, and a sense of gratitude. The wildfire resulted in significant physical, psychological, and spiritual distress among families, children, and youth in the community.

Findings suggest that the strengths-based, spiritually informed programs and practices served as both protective factors and interventions that helped children, youth, and families cope with the challenges faced following the Alberta wildfire. This likely helped prevent ongoing spiritual and psychological distress, build resiliency, and facilitate a path toward long-term recovery. Community members were displaced for several weeks following the chaotic mass evacuation, and upon their return to Fort McMurray, they continued to be impacted by ongoing social and economic crises. Some residents left and were unable to return back to the community due to the socio-economic and other crises related to the disaster. Despite several challenges, the community strived to be united and demonstrate faith, compassion, hope and a strong sense of altruism and service to others. Building on their collective sense, meaning-making, and

continued persistence and work, the community established and offered various services and programs to support and sustain recovery and resilience post-disaster. A range of spiritually relevant values and strong sense of community enabled residents of Fort McMurray to endure and make meaning out of the ongoing painful realities and hardships that often result from disaster. For some of those who believed in facing their fears together found increased ability to restore the strength and determination working together for the community recovery and healing efforts. O'Grady et al. (32) support a similar view that multiple traumatic life events including disasters result in an existential quest, and a broadened view of life, leading to an increase in spirituality. Our findings also support Park's (10) meaning making model, in that adverse events enhance the individual's or community's ability to develop positive meanings out of tragedy and help build a sense of inner strength and purpose in life, leading to potential growth and transformation. The spiritual resources and values identified in this study enhanced the community's ability to cope with loss and grief, and generated a sense of self-efficacy, which are major pillars supporting post-disaster resiliency and recovery (17, 33).

Post-disaster resilience and recovery is a long-term process, not the outcome of a specific program or policy. The study findings suggested a strong sense of social connectedness, unity, and shared values contributing to enhanced support and resilience among wildfire-affected community members, further amplified by a wide range of community-based strategies and approaches. Considering FMM as a unique diverse and mobile community, the demonstrated shared values and strong social cohesion carries a considerable significance in the study. Social relations and community interactions play a meaningful role in promoting coping and recovery, often resulting from the supportive efforts of friends, family, and community agencies, as well as a sense of community connectedness and care (24, 34, 35). Multiple authors indicate the importance of social cohesion, community governance, and communal identities in promoting collective efficacy and resilience as helpful in addressing collective trauma post-disaster (25, 34). Further, collective efforts and social connectedness increase opportunities for knowledge and resource sharing, and provision of improved social support mechanisms within the disaster-affected communities (25, 34, 36).

During periods of any disaster or crisis people frequently seek spirituality or spiritual resources in order to find meaning, sense of belongingness, find love, hope, compassion, a sense of gratitude and peace to support healing and recovery (10). These spiritual values and resources have all been associated with increased resiliency and improved mental and psychological outcomes in crisis and disaster situations. Haynes et al. (22) examined whether spiritual meaning can buffer the effect of disaster-related resource loss on posttraumatic stress among Hurricane Katrina survivors ($N = 485$). Their study found that the survivors experiencing higher spiritual meaning following the disaster reported significantly less severe posttraumatic stress as compared to survivors who reported lower spiritual meaning and peace. Similar other studies also found that people who exhibited high spiritual values and resources such

as meaning making, finding connections, hope, and gratitude demonstrated a stronger adaptive coping and resilience (21, 23). Glass et al. (23) in their study found hope to be a critical spiritual resource that enhanced coping mechanisms and minimized general psychological distress among disaster-affected families and communities. Similarly, Kulig et al. (37) in their study examining post-traumatic stress among with young children post wildfire disaster also found that both internal and external protective factors such as self-regulation, encouraging supportive and caring relationships, fostering values of cooperation, positivity, and sense of security can buffer, ameliorate, and mitigate the effects of trauma and stress and thus, bring positive behavioral outcomes and enhanced coping. Similarly, our findings also indicated that programs like "Journey of Hope," peer mentoring, mindfulness, and other psycho-educational approaches offered supportive opportunities for reflexivity that helped individuals and families make sense of and process their experiences post-disaster. This helped many community members develop sense of belongingness, find spiritual meaning, hope for the future during the post-disaster recovery process. Programs and approaches provided a sense of connection, as well as opportunities for shared meaning-making, both of which promoted a sense of security that helped engender self-efficacy and a more positive outlook. Additionally, psycho-spiritual transformation and collective growth and healing in the community post-wildfire helped build and strengthen resilience. The findings point to the importance of recognizing that those supporting community resiliency and recovery efforts, such as community influencers, can only do so if they themselves are supported.

Moreover, since the start of the COVID-19 pandemic, various virtual tools have been found useful to maintain and enhance individual's spirituality and build community resiliency (38). For example, video conferencing was used to connect family and community members when physical distancing was mandated by national or regional lockdown measures post disaster. Facilitated online group programs were used by community members as well as text message programs such as Text4Mood and Text4Hope Coronavirus Disease 2019 Pandemic: Health System and Community Response to a Text Message (Text4Hope) had been used to quickly distribute information on spirituality and resiliency as well as provide psychological support to residents affected by disasters (38).

In summary, findings from this study suggest that spirituality and spiritual values are integral in fostering resiliency among families and communities in a long-term post-disaster recovery context. Spiritual values and resources such as meaning making and belongingness, a deeper sense of gratitude, compassion and altruism were reflected in the collective actions of the community and were found to be integral to building spiritual resiliency among the disaster-affected communities. These spiritual resources generated hope, a sense of collective efficacy, empowerment, social cohesion, and resulted in psychosocial recovery, personal and social transformation, and growth at a communal level. Potential future studies are needed to generate further empirical evidence in understanding the role and relationship between spirituality, post traumatic growth, and

collective resilience specifically in a disaster context. The unique demographics of FMM community raises several questions and insights for the researchers in understanding the unique sense of belongingness, bonding and commitment found among the community members, and could be further examined and studied. Future quantitative studies are recommended to examine associations among spirituality/meaning making, psychosocial recovery, and resilience promoting healing and recovery in post disaster related settings. There were also future calls for expanding programs like mentorship, counseling, psychoeducation and mindfulness to improve the spiritual resiliency among the families and community members. Funding for these programs should be considered. More studies can be conducted to examine the feasibility and effectiveness of these programs in improving spiritual resiliency and post disaster recovery and healing are also recommended.

STUDY LIMITATIONS

Findings generated in the study are limited to the Fort McMurray area post wildfire.

A detailed audit trail was kept ensuring rigor, credibility, and trust worthiness in the study. There is of a possibility of socially desirable responses from the participants. The study did not ask directly from the participants if they identify themselves as spiritual or not and therefore, there is also a possibility of differences in spiritual perspectives among participants who identify themselves as spiritual or those who did not. The rich findings generated provide lessons and insights to consider and develop programs enhancing spiritual resiliency in preparing for disaster recovery efforts in other similar communities.

CONCLUSION

This study contributes to a growing literature that supports the role of spirituality and meaning-making in community-led resiliency efforts following disaster. The study demonstrates that spiritually informed resiliency programs and approaches play a role in helping individuals' and communities in the post disaster recovery process and can reinforce post traumatic growth experiences, compassion, and healing. Such strategies and tools foster deeper connections and provide a stronger sense of community engagement and empowerment. Disaster recovery efforts should consider the value of adopting a multi-systemic, collective approach that draws on a shared sense of community identity, engagement, shared norms and beliefs, and spiritual values as essential to promote community resilience and recovery over time. Such resources and values can deepen the community's capacity to take control over their own process of healing, adaptation, and psychosocial restoration and advance for a sustainable recovery process post-disaster. The article signifies that spirituality is an important characteristic of resilience and suggests various tools and strategies for nurturing spiritual resilience among families and communities in post-disaster recovery.

DATA AVAILABILITY STATEMENT

The original contributions presented in this study are included in the article/supplementary material, further inquiries can be directed to the corresponding author/s.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by Human Research Ethics Review Board, University of Calgary. The patients/participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

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Social-Ecological Factors Associated With Higher Levels of Resilience in Children and Youth After Disaster: The Importance of Caregiver and Peer Support

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Children and youth are among the most vulnerable to the devastating effects of disaster due to the physical, cognitive, and social factors related to their developmental life stage. Yet children and youth also have the capacity to be resilient and act as powerful catalysts for change in their own lives and wider communities following disaster. Specific factors that contribute to resilience in children and youth, however, remain relatively unexplored. This article examines factors associated with high levels of resilience in 100 children and youth aged 5- to 18-years old who experienced the 2016 Fort McMurray, Alberta wildfire. A mixed-methods design was employed combining quantitative and qualitative data. Quantitative data was obtained from the Children and Youth Resilience Measure (CYRM-28) which measured individual, caregiver, and context factors influencing resilience processes among the participants. Qualitative data was collected through semi-structured interviews to gain further insight into the disaster experiences of children and youth. Quantitative findings reveal higher than average levels of resilience among the participants compared to normative scores. Qualitative findings suggest high levels of resilience were associated with both caregiver factors (specifically physical caregiving), and individual factors (primarily peer support). We discuss how physical caregiving and peer support during and after the wildfire helped mitigate the negative effects of disaster, thus bolstering children and youth's resilience. Implications for understanding the specific social-ecological factors that facilitate and support resiliency processes and overall recovery of children and youth following disaster are also discussed.

Keywords: disaster, children, youth, mental health, resilience

INTRODUCTION

Resilience among children and youth following traumatic life events is increasingly being examined in various disciplinary fields, including psychiatry, social work, psychology, and sociology. Traumatic life events include, but are not limited to, abuse, death, war and conflict, health pandemics, and natural disasters. Natural disasters, including hurricanes, tornadoes, tsunamis,

floods, and wildfires are increasing in both frequency and severity, often exacerbated by population growth, environmental degradation, and changes in global climate systems (1). Experiencing a natural disaster produces significant trauma for children and youth given the wide range of stressors involved, including "threat to one's own life and physical integrity, exposure to death and dying, bereavement, profound loss, social and community disruption, and ongoing hardship" (2). Due to their developmental life stage, dependence on adults, and limited access to child/youth-centered resources post-disaster, children and youth often are vulnerable to the devastating effects of disaster (3). After experiencing disaster, children and youth often experience increased behavioral problems, including insomnia, anxiety, depression, and post-traumatic stress disorder (PTSD) (2, 4–9).

The limited literature that has examined the experiences of children and youth post-disaster has largely focused on risk factors associated with negative outcomes rather than protective factors, resulting in a deficit-based approach (10–12). While understanding the risk factors and vulnerabilities of children and youth post-disaster is important, the need to understand the protective factors and strengths they possess is equally pressing as they can serve to mediate resiliency processes following the adverse experience of disaster (13, 14). Resilience is increasingly being viewed as involving not only individual characteristics, but also broader social-ecological factors such as family, peer, and community factors (13–16). Recent research which focuses on protective factors reveals that children and youth have the capacity to demonstrate resilience and act as powerful catalysts for change, recovery, and rebuilding within their families and communities following a disaster (17–19). This recent focus on resilience in disaster research is particularly relevant given that disasters are expected to rise globally in coming years due to the effects of climate change (20). While child and youth resilience research within the context of disasters has made significant gains, little is known about the specific factors that contribute to resilience in children and youth, and effective ways to support their overall health and well-being. Moreover, few studies have explored child and youth resilience from their own experiences, perspectives, and voices (11, 14, 17, 18, 21).

This article fills an important gap in the literature by exploring the lived experiences and voices of children and youth who experienced the 2016 Fort McMurray wildfire. The following analyses explores various factors associated with high levels of resilience among children and youth post-wildfire, including individual, caregiver, and context factors. Findings reveal that high levels of resilience among children and youth were associated with caregiver factors, specifically physical caregiving, and individual factors, namely peer support. This article discusses the implications these findings have for better understanding the social-ecological factors that facilitate and support the resiliency processes of children and youth post-disaster.

The 2016 Fort McMurray Wildfire

Fort McMurray, Alberta is located in the Regional Municipality of Wood Buffalo (RMWB) in the Northeastern area of Alberta. Fort McMurray is home to numerous multi-nationally owned oil-sands projects directed by various oil and gas companies.

Due to the resource-based industry of Fort McMurray, 35% of the population at the time of the wildfire was non-permanent/transient, referred to as the "shadow population" (22). The majority of this population resides within the active work camps near oilsands project sites. The gender distribution of the population is male-dominated, consisting of 55.4% males compared to 44.6% females. The population between the ages of 25 and 44 account for 43% of the total population, with the highest concentration (25%) being 25- to 34-years of age. The proportion of children and young adolescents 0- to 19-years of age constitute 23.9% of the overall population (22). On May 1st, 2016, the town of Fort McMurray experienced a devastating major wildfire coined "The Beast" (23). Over 88,000 people were evacuated as the wildfire threatened to engulf their homes and communities (23). Within just days, the wildfire spread across 590,000 hectares of land before firefighters and emergency crews could contain it (24). It is estimated that the wildfire caused $3.6 billion Canadian dollars in insured losses, the most catastrophic and costly disaster in Canadian history (25). Homes, schools, daycares, businesses, and entire communities were destroyed due to the wildfire. In addition to ongoing rebuilding and restoration efforts, individuals are continuing to recover from the many social emotional, and psychological impacts of the wildfire. Children and youth were particularly affected by the wildfire as the effects of both evacuation and destruction from the wildfire persisted for an extended duration of time, disrupting children and youth's day-to-day routines, functioning, and access to resources and supports.

LITERATURE REVIEW

The Impact of Disasters on Children and Youth

Much of the research which has examined the impact of disasters on children and youth has focused on the risk factors associated with negative outcomes, such as the prevalence of anxiety, depression, PTSD, and other mental health issues (26, 27). This research largely finds that children and youth are impacted by the disruption of routine, experiences of displacement, and limited or ineffective societal or familial response to disaster (17, 18, 21). Experiences of disruption and loss contribute to feelings of stress, sadness, loneliness, and worry among children and youth populations (17, 18). While understanding the risk factors and vulnerabilities of children and youth post-disaster is necessary to address their needs, the need to develop an understanding of the protective factors and strengths they possess is equally pressing as they can serve to mediate resiliency processes following adversity or trauma, such as experiencing a disaster. Research which focuses on protective factors has shown that even in the context of adverse circumstances like disaster, when provided with the proper support systems, children and youth often demonstrate resilience (17, 19, 28).

Resilience Among Children and Youth

Resilience, from a social-ecological perspective, is defined as "the capacity to navigate to health-enhancing resources that nurture individual, relational, and community assets, as well as the capacity of individuals to negotiate with others for these

resources to be provided to them in culturally meaningful ways" (29). This understanding of resilience highlights the multiple factors that contribute to producing positive developmental outcomes among children and youth who experience adversity, including individual, family, relationship, community, and cultural factors (30, 31). Despite the vulnerability of children and youth to the impacts of disaster, recent research reveals that children and youth can and do act as powerful catalysts for recovery and change in their families, peer groups, and wider communities post-disaster (17–19, 21). A number of influencing factors have been associated with child and youth resilience, including individual, family/caregiver, peer, and larger systems.

Individual Factors

Individual factors refer to internal capacities which influence how children and youth respond to traumatic experiences (32). Among the many individual factors that have been examined, locus of control—that is, the degree to which an individual believes they are in control or not of the situations they find themselves in—has a strong influence on child and youth resilience (33, 34). Having strong sense of internal locus of control is associated with self-efficacy, emotional regulation, and self-control, which significantly influence attitudes toward difficult circumstances, and choice of coping strategies which are, of course, critical to children and youth building resilience in adverse contexts (33–35). Self-control enables children and youth to make decisions and respond in times of crisis (33). For example, Terranova et al. (36) found that children who were able to exert self-control in adverse situations were less likely to develop PTSD symptoms following Hurricane Katrina in 2005 in Louisiana, New Orleans.

The research also indicates that children and youth who experience disasters fare better when they are proficient problem-solvers and adept at learning (37). For example, Nelson (37) found that following Hurricane Katrina, youth who believed that they could positively respond to adverse events in their lives, or asked for help in doing so, fared much better that those who did not. Many post-disaster interventions are in fact based on providing children and youth with a greater sense of control over their environment, more opportunities to think critically and solve problems, and means to make choices for themselves (38). This is often seen as an opportunity to recognize the individual strengths that children and youth possess, and their ability to influence their families, peers, and their wider communities (39).

Having an optimistic outlook has also been associated with resilience among children and youth post-disaster (40, 41). Children and youth who view challenges as learning opportunities rather than obstacles, and are able to maintain a positive and hopeful attitude have increased resilience (21, 37). For example, Walker et al. (21) found that children who experienced the 2007 flood in Hull, England, who engaged in opportunities to reframe their situation and focus on positive outcomes through play and other home and school activities, fared better.

The Role of Caregivers

Having supportive relationships with one or more caregivers has also been identified to be a consistent predictor of resilience among children and youth who have experienced traumatic events, such as a disaster (13, 42). The psychological support provided by caregivers serves to protect and bolster the resilience capacities of children and youth. Having a close and supportive relationship with caregivers helps children and youth build and strengthen their resilience. Re-establishing a sense of safety, resuming normal roles and routines, and ongoing open communication with their children are some of the ways caregivers have helped children to navigate and cope with the experience of disaster (43). A number of researchers have identified that sense of family cohesiveness (44, 45), positive family communication styles (44), effective conflict resolution skills within the family (46), and related positive coping skills (47) are all associated with child and youth resiliency. For example, Hafstad et al. (43) found that children who experienced the 2004 tsunami in Southeast Asia benefitted from parents who engaged in watchful waiting, careful monitoring of reactions, and sensitive timing as ways to monitor and determine the needs of their children.

Serving as a buffer to the trauma caused by disaster, physical proximity and physical affection between caregivers and children/youth post-disaster has also been found to be an important predictor of child and youth resilience (45, 48). By spending time comforting, reassuring and caring for the physical needs of children and youth, caregivers contributed to the sense of safety and security the family experienced post-disaster. Close contact and communication enables caregivers to teach children and youth specific skills, use their strengths, and encourage open communication, all of which are essential to shoring up resiliency (32, 49).

Peer Influence

A more recent predictor of resilience among children and youth following experiences of adverse events such as disaster is the presence and role of peer groups (50–52). A limited but growing body of research has found that maintaining friendships during and after disaster, despite evacuation and displacement, provides children and youth with social support that is helpful to them during early recovery and ongoing rebuilding stages (14, 31). Connecting and communicating with peers helps children and youth re-establish a sense of normalcy and security, and provides mutual ongoing support and assistance among peer groups (14, 50). Peer-to-peer relationships post-disaster provide children and youth with age-appropriate connections, which encourages and facilitates the sharing of experiences and needs. Often, children and youth also rely on peers as a form of distraction from the day-to-day stressors of post-disaster life (53).

Schools as Support Systems

Larger systems, such as schools, can also contribute to the resiliency of children and youth who experience a traumatic event like a disaster. Given that disasters often impact a large number of children and youth in communities, post-disaster recovery efforts are often implemented within schools as a

way to address the collective trauma of disaster (54). Group-based school interventions focused on routines, group problem-solving, as well as strategies directed to learning and enhancing protective factors of childhood development increase resiliency capacities (54). Schools often serve as a facilitator of recovery not only for children and youth themselves, but also for their families and the wider communities (3, 14). Within the school system, teachers and other school personnel (such as counselors and support workers) serve as a critical support systems for children and youth following disaster (14). School-based intervention programs aimed at reducing PTSD symptoms are often effective in helping children and youth recover from disaster (55). Likewise, teachers are often able to significantly reduce the post-traumatic symptoms of children and youth following disaster, thus enhancing their overall functioning within the school setting (56).

It is important to note that much of this research relies on data that is not obtained from children and youth themselves, but rather from the adults in their lives such as parents, teachers, doctors, and counselors. While information obtained from adult caregivers and allies is important, it neglects the experiences and insights of children and youth informed by their own unique perspectives which are key to understanding the factors that contribute to their resilience. In order to fully understand children and youth's resiliency post-disaster, it is crucial to include children and youth as informants, recognizing them as knowledge holders of their own experiences (19). This article aims to fill this gap in the literature by discussing findings that are based on data collected from children and youth themselves, and thus reflects their unique lived realities, experiences, perspectives, and voices.

METHODS

A mixed-methods approach was used to explore factors associated with resiliency among children and youth who experienced the 2016 Fort McMurray, Alberta wildfire. The study was conducted 1-year after the wildfire, and over a 3-month period from July to September 2017.

Recruitment

Informed consent from parents/legal guardians and assent from child/youth participants was obtained. A total of 100 school-aged children and youth between the ages of 5- to 18-years participated in the study. The participants had a mean age of 11.01 (SD = 3.89), and slightly more than half of the participants were female ($n = 55$) compared to male ($n = 45$). All of the participants directly experienced the wildfire, and therefore faced the numerous physical, economic, psychological, and social difficulties that often occur in the aftermath of disaster.

It is important to note the large age range (5- to 18-years) of the child/youth participants. Despite variations in age differences, all of the child/youth participants demonstrated a notable recall ability and reflexive capacity. The quotes selected from the data and discussed in the qualitative findings section are drawn from participants with varying ages, gender, and community of residence, so as to represent the diverse experiences of the

participants. Younger participants were more likely to discuss immediate issues and concerns, whereas older participants were more likely to move beyond current contexts and discuss long-term effects and consequences related to their disaster experience and resiliency capacities.

Measure

The Child and Youth Resilience Measure (CYRM-28) was first administered to child and youth participants to assess factors contributing to their resilience post-disaster. Completion of the CYRM-28 ranged in length from 15 to 20 min. Informed by a social-ecological perspective, the CYRM-28 assesses three dimensions, or factors, associated with resiliency, including: (1) Individual (comprised of individual personal skills, individual peer support, and individual social skills), (2) Relationship with Primary Caregivers (caregivers physical caregiving, and caregivers psychological caregiving), and (3) Context (context spiritual, context educational, and context cultural) (57). A 5-point response scale is used for all 28 items (1 = not at all; 2 = a little; 3 = somewhat; 4 = quite a bit; 5 = a lot). Scores on the overall CYRM-28 range from 28 to 140, with higher scores reflecting higher levels of factors associated with resilience. Higher scores on each of the three CYRM-28 subscales (individual, caregivers, and contextual) also reflect higher levels of factors specific to each of these dimensions. Participants responses to the CYRM-28 measure were input, calculated, and analyzed using SPSS.

Semi-structured Interviews

Qualitative semi-structured interviews were then conducted with child and youth participants to contextualize the CYRM-28 resiliency factors and further assess the specific ways in which individual, caregiver, and contextual factors contribute to rates of resilience among children and youth. The interview guide consisted of numerous open-ended questions which further examined children/youth's overall wildfire experience in relation to numerous factors related to resilience, such as personal skills, social skills, peer interactions, parent/caregiver availability and support, spiritual beliefs, cultural values, and educational supports. Art-based activities were utilized during the interviews to keep child/youth participants engaged, particularly younger participants. These art-based activities included clay modeling, drawing, coloring, and painting. Interviews were recorded with the participants' permission using digital voice recorders, and ranged in length from 1.5 to 2.5 h. Interviews were transcribed verbatim for analysis, and interview transcripts were uploaded and coded in NVivo. Comparisons were drawn across interviews to identify themes and meanings grounded within the data. The data were analyzed using Maxwell's (58) and Miles and Huberman's (59) qualitative analysis technique referred to as "descriptive" and "pattern" coding. Child/youth participants' responses were open-coded to identify descriptive explanations of the individual, caregiver, and contextual factors. In-depth analysis of these open categories was then conducted to identify patterned relationships across these categories and determine similarities and differences in the themes. Responses were coded and examined by the authors to ensure coding reliability. In

order to interpret the coded data, we utilized Burawoy et al.'s (60) approach where arguments were constructed by creating an ongoing exchange between the data categories and existing disaster and resiliency theory in order to build upon and expand the existing theory. The quotes selected from the data and discussed in this article are drawn from child/youth participants with varying age, gender, and race/ethnicity, so as to represent diverse experiences among the participants. Ungar's (31, 57) social-ecological theory of resilience informed how we made sense of relationships between social factors that contributed to the resilience of the children and youth who participated in our study.

Ethical considerations and measures were applied throughout the study to prevent any harm to child/youth participants which may have arisen from recalling potential traumatic memories of the wildfire. A total of 6 student research assistants on the research team collected the data. These research assistants were trained in quantitative and qualitative methodologies and ethical practices prior to conducting the interviews with the child and youth participants. Parents/legal guardians of the child/youth participants were provided with a list of local counseling services, should they feel the need to access such services after the interview. Moreover, participants were given a $50 gift card as an honorarium to recognize the time they contributed in participating in the study. Ethics approval for the study was obtained from the Human Research Ethics Board at Mount Royal University. All participant names have been replaced with pseudonyms to ensure anonymity.

FINDINGS

> I learned that we can be like, resilient. I learned that we are strong. We are strong together. That's what really cheered me up (Alonzo, 11-years old)

The findings reveal that the children and youth participants who experienced the 2016 Fort McMurray wildfire had higher than average levels of resilience. As illustrated in the quote above from one of the child/youth participants in our study, resilience is not just an individual characteristic that one is born with, but rather is a result of broader social-ecological factors such as family, peer, and community factors. The findings from our study reveal that higher levels of resilience among children and youth participants were associated with (1) caregiver factors, specifically physical caregiving; and (2) individual factors, namely peer support. We discuss below.

Quantitative Findings: CYRM-28 Resilience Scale and Subscale Scores

Total and mean CYRM-28 scores and total and mean scores on the three CYRM-28 subscales (individual, relationship with caregivers, and contextual), and total and mean scores on subscale question clusters were calculated (see **Table 1**).

The total mean CYRM-28 score was 118.65, with a standard deviation of 10.23. Normative data for the CYRM-28 with a 5-point scale indicates that for a total sample of Canadian youth the mean score is 108.60 with a standard deviation of 18.66 (for

TABLE 1 | Descriptive statistics for CYRM-28 total and subscale scores ($n = 100$).

Name	N	Mean	SD
CYRM-28 Normative Scores (Score out of 140)			
Total Sample	2,198	108.60	18.66
Complex Needs Youth	1,071	103.85	20.18
Low-Risk Youth	1,127	113.12	15.82
Total CYRM-28 SCORE (Score out of 140)			
	100	118.65	10.23
Mean Scores for 3 Sub-Scales (Scores out of 3)			
1) Individual	100	4.19	0.435
• Personal	100	4.15	0.476
• Peer Support	100	4.25	0.796
• Social Skills	100	4.21	0.519
2) Relationship with Primary Caregivers	100	4.41	0.418
• Physical Support	100	4.45	0.564
• Psychological Support	100	4.40	0.485
3) Context	100	4.17	0.454
• Spiritual	100	3.62	0.906
• Educational	100	4.41	0.748
• Cultural	100	4.41	0.436

complex needs youth the mean score is 103.85 with a standard deviation of 20.18, and for low-risk youth the mean score is 113.12 with a standard deviation of 15.82). As such, the total observed mean score of 118.65 is relatively high compared to normative scores, indicating that participants had higher than average levels of characteristics associated with resilience than a normative comparison sample.

The mean scores on the three CYRM-28 sub-scales indicated that the Relationship with Primary Caregivers sub-scale had the highest overall mean (4.41) with the Physical Support cluster having the highest mean of 4.45. This indicates that participants had high levels of characteristics associated with caregiving contributing to their overall resilience, such as having their psychological needs met but especially their physical needs met by the caregivers in their life. The second highest mean was for the Individual sub-scale (4.19), with the Peer Support cluster having the highest mean of 4.25. This indicates that participants had high levels of characteristics associated with individual factors when it comes to their overall resilience, such as social skills, and especially peer support. Both Relationship with Primary Caregivers and Individual characteristics are closely associated with children and youth's resilience. The Context sub-scale was found to have the lowest overall mean (4.17), with the Spiritual cluster having the lowest mean of 3.62. This indicates that participants had low levels of characteristics associated with context contributing to their overall resilience, such as educational, cultural, and especially spiritual support.

Qualitative Findings: Themes and Patters From Child and Youth Interviews

In-depth semi-structured qualitative interviews were conducted to contextualize participants' CYRM-28 resiliency scores and

further explore the specific ways in which individual, caregiver, and contextual factors contribute to rates of resilience among child/youth participants. Given that the CYRM subscale scores indicated that high levels of resilience among child/youth participants was associated with both caregiver factors (physical support having the highest mean score), and individual factors (peer support having the highest mean score), we focus on themes and patterns described by the child/youth participants in relation to these two factors.

Child/Youth Resilience Post-disaster and Caregiver Support

In discussing the caregivers in their lives, children and youth largely referred to their parents. Child/youth participants discussed how their parents provided physical support during and after the wildfire by (1) ensuring their safety during the evacuation; (2) providing basic needs such as shelter, food, and clothing; and (3) offering support and reassurance by being physically present. The physical support children and youth received from their parents during and after the wildfire played an important role in their recovery, thus strengthening their resilience.

Ensuring Safety During Evacuation

A disaster can severely impact children and youth's sense of safety due to the suddenness of such events, which often occur without much warning or preparation. Children and youth, due to their cognitive and developmental life stage, have limited understandings about disaster events, and therefore often feel as though they have little to no control over what is happening around them, particularly during an evacuation. With the threatened destruction of the physical spaces in which they live, such as their homes, schools, and community spaces, having physical support from a caregiver is critical for ensuring both the physical and psychological security and protection of children and youth. Many child/youth participants discussed how their parents' efforts to safely and quickly evacuate their families during the wildfire helped them feel a greater sense of physical safety and security during this stressful time. For example, Lainey, an 8-year-old, discusses how being able to physically evacuate with her parents, as opposed to someone else, provided her with a sense of safety and security: "It made me feel closer because we were all sticking together, like when we were evacuating were close together and like always having plans." Likewise, Hermione, a 14-year-old, describes how she recognized the great lengths her parents went to in order to leave their workplace and pick up both her and her siblings from their respective daycares/schools:

> Just getting us out safe I think was a huge impact because I know I wouldn't— If I had been in that situation trying to get out from site, and all the kids from the daycare, and plus me and my sister, plus everything from the house, I know I would have been probably crazy. It was so stressful and they held it together really well and they got us all out safe with everything that we needed, so I think that really impacted me a lot.

Child/youth participants also discussed how during the evacuation they worried about damage to their homes, belongings, schools, recreation centers, and other infrastructures they frequently used in their communities. Many children and youth spoke about how concerned they were about potentially losing their physical belongings, such as toys, clothing, and technology (computers, tablets, and video game consoles), which added to the stress of having to evacuate their homes and communities. These were items that children and youth valued and used daily. Child/youth participants discussed how, despite these concerns, their parents continued to remain a vital source of support, reassuring them that they would take care of their physical needs by finding a place to stay, and when permitted to return home, replacing and rebuilding anything that was damaged or lost in the wildfire. For example, Francine, an 8-year-old, discusses how her parents found a safe place for them to stay during the wildfire, and worked through financial and insurance issues without her having to feel the burden or stress:

> They made us feel safe by like finding us a place to stay and like, making sure we weren't worried about what was happening with like, our house or um, finances, or insurance, or anything. They took that under their belt so that we didn't have to worry about it as well. So I think like for them it was a lot harder to deal with things than for us because they didn't want us to go through that. So, I think they made it so much easier just for us in like, technical terms, not like emotionally but like, technically.

By providing physical safety and security during and post-disaster, parents helped bolster the overall health and well-being of their children, thus contributing to their recovery.

Providing Basic Needs

Child/youth participants frequently described the upheaval caused in their lives by displacement during and after the wildfire. Many children and youth had not anticipated that they would not be able to physically return to their homes and community for weeks, even months. As time went on, many children and youth became increasingly worried about how their basic needs would be met, including how they would access shelter, food, and clothing. Parents who took control, or sought to take control of these matters, such as planning for short- and long-term shelter for their families, ensuring their children had access to clothing and other basic necessities, helped children and youth to feel a greater sense of safety, stability, and control over the situation. For example, Veronica, an 18-year-old, discusses how she felt reassured because her parents had a plan for their family:

> If we had to like, um, we weren't able to go home, my dad already had a plan to rent out a basement. Like having a plan really helped me, like I didn't feel like I was lost, like, "what's going on?" and stuff like that. Even, like I said, when we came back my dad and my mom took an active role in making sure that the house was done and getting like, insurance and stuff like that, like having the side fixed, cleaning out the house. Just they were — it really helped like, having them like, take control like — like that.

Child/youth participants also worried about the financial implications of the wildfire for their family, both short- and long-term, which created significant stress for them. Parents who provided needed assurance not only through words, but also actions, helped alleviate some of these concerns that children and youth experienced about having their physical needs met. For example, Admir, a 16-year-old, describes how he felt he could rely on his father, despite the financial challenges their family faced, because his father took action to ensure the family's basic needs were met:

> My father…he was the one who went and got clothes for us and toiletries from the place where they distributed it. He was the one who talked to a lot of people, like especially our insurance about like the money that we were getting. And he was the one who worked — he's the one who works so hard for — for us.

Similarly, Franny, a 10-year-old, was concerned about the loss of her personal belongings, but reassured by her parents that they would be able to replace these items. This helped Franny gain greater perspective: "My dad would say like 'I can buy you lots of new stuff', and I'd be like 'It's okay.' Then my mom would say stuff like that, and then say 'It happened to all of us, it happened to me [too]' (crying)." The effects of having a dependable caregiver reflects children and youth's need to have a source of both physical and emotional stability during times of chaos and upheaval. The presence of a caregiver who is able to provide both a structured and stable environment reduces children and youth's fears and concerns following disaster, a key factor contributing to recovery among children and youth.

Physical Presence and Support

Child/youth participants also discussed the importance of having their parents physically close and present during and after the wildfire. Physical proximity facilitated parents' ability to provide psychological support to their children. Many child/youth participants stated that just having their parents physically close to them, and getting to spend additional time with them during and after the wildfire was a source of comfort, and also provided them with greater perspective. Undoubtedly, losing their home and belongings presented numerous challenges to children and youth, yet many of them were quick to recognize and articulate that material things like homes can be rebuilt and belongings repurchased after a wildfire, but non-material things like families cannot be replaced. For example, Jono, a 13-year-old, explains how having his parents with him and being together as a family after the wildfire provided him with a great sense of security during an unpredictable time:

> So, just the fact that they were — we were there for each other. I mean, isn't that all you need, is family? Just other people around you that you know, and that you love, and that you trust, you know? That's just — it just clicks in you. You don't really know why, it just — it makes you feel safe, secure.

Similarly, Anna, a 12-year-old female, describes how having her parents and family members physically close and spending time together helped her gain perspective about the wildfire

and realize that family, and not material items, is what matters most. She states: "We all like, I guess went everywhere together. Family's like the most important thing, so if they were all okay like everything was fine. Houses can like, be rebuilt if they're burnt." Like many others, Anna found solace in knowing her family members were safe despite the destruction caused by the wildfire.

Several child/youth participants described how the physical presence of their parents led to increased communication in the family, which helped them feel comforted and reassured. This underscores the importance of children and youth having not only their physical needs met, but also their emotional needs met through increased communication. Many child/youth participants described how communication with their parents provided a significant source of support both during and after the wildfire. Being able to speak freely about their wildfire experiences with their parents helped children and youth share their fears, concerns, and difficulties, which helped them process the event. Consequently, parents were better able to respond to the needs of their children when they were physically present, which aided in their recovery. For example, Hannah, a 15-year-old, asserts that the presence and availability of her parents provided assurance during tumultuous times: "They [parents] would always listen or always be there if I had to talk about something." Likewise, active listening among caregivers helped support children and youth who were struggling and needed to feel heard, as 11-year-old Natalee describes: "I don't know, they just… They [parents] listened to everything that I was saying by showing that they care and not being sad for me and with me. Tried everything they can to make me happier."

Increased communication often served as the basis for parents being able to assess where their children were at in terms of physical, as well as mental and emotional well-being. Some child/youth participants stated that they experienced mental health challenges after the wildfire, but were able to confide in their parents and receive support, which helped them to cope better. For example, 13-year-old Asher describes the emotional support his mother was able to provide him with after the wildfire:

> I think my mom, because my dad like he's very helpful because he was making money working, but my mom was like our caretaker. We did a bunch of stuff and it made it easy for us to have fun and like, take our minds off of it [wildfire]. She'd support us if uh, if like, one of us was down, which was pretty good. She was calm the whole time. Like it makes you feel good (laughs). It's like the oldest one that knows more is calm then you're most likely calm.

Evident in Asher's response is the ways in which his mother actively sought to support the children in their family, as well as model open communication and positive coping skills. These findings highlight how the physical support children and youth received from their parents during and after the wildfire played a significant role in their recovery, thus strengthening their resilience.

Child/Youth Resilience Post-disaster and Peer Support

Individual factors, specifically peer support, is another key determinant of resilience identified by child/youth participants. Child/youth participants discussed how their peers provided support during and after the wildfire by (1) communicating with them; and (2) providing a needed distraction from immediate stressors. The support children and youth received from their peers during and after the wildfire played an important role in their recovery, thus strengthening their resilience.

Communication

A disaster can disrupt children and youth's social connections. Peer relationships are often important sources of stability and support for children, particularly for youth. Yet displacement during an evacuation can present challenges to peer group contact and communication, often leading to feelings of isolation and loneliness among children and youth. For many children and youth being able to interact and openly and honestly communicate, not only with their parents, but also their peers during and after the wildfire provided a valuable source of support. The opportunity to express their feelings, share their concerns, and reciprocally obtain and offer support to their peers helped children and youth better process the trauma of the wildfire. In fact, for many children and youth, communication with their peers was perceived as therapeutic. Several child/youth participants discussed how the willingness and availability of their peers to talk with them helped them feel supported. For example, Lucy, a 15-year-old, describes how her peers' commitment to talking with her whenever she felt the need made her feel cared for: "They're just like, very caring people, like by their actions and stuff. So yeah, like they always made it clear that if I needed to talk to them about anything like they were there for me." Likewise Meredith, a 13-year-old, explains how simply knowing that her peers were available if she needed to talk helped her recover from the trauma of the wildfire:

> They weren't like, off doing their own thing, like worrying about all this stuff. Like if you needed to talk to them or they needed to talk to you, like we were all kind of there for each other. It didn't matter if you were going through something, you were also there to help them get through something.

Having the opportunity to communicate with peers provided children and youth with insight into how others, similar in age and experience, were processing the wildfire and navigating both the short- and long-term challenges that result from disaster. This served to legitimize and validate their own experiences. Many child/youth participants discussed how they felt comforted by the fact that they were all going through the same thing, and that they could be open and honest about their feelings with their peers, regardless of their circumstances. For example, Hugo, an 18-year old, describes how his peers never judged him but always supported him, despite the fact that his home was not damaged by the wildfire:

> There were a few times where I talked with them about it, just like what happened and all that kind of stuff, and they were always very supportive, you know. My house is fine and you know, still talking about it like it was a bad experience, there might be something [judgment] there. But nope, everyone was just like really supportive.

In addition to receiving support from their peers, children and youth also provided support to their peers, highlighting the reciprocal nature of peer support. Child/youth participants discussed how they also took an active role in supporting their peers after the wildfire, which strengthened their relationships with their peers. For example, Hannah, an 8-year-old states how her peer group supported one another when they were struggling, which served as a safety net of sorts for many of them:

> They [friends] cared about me because when I was really hurt and they were really hurt I cared for them and they cared for me... When I was really scared about the fire, I was telling my friends about it, and they told me "It's okay, the fire is gone. But it can come back. Just remember what to do if it comes back."

Likewise, Jamie, a 14-year-old, explains how she tried to create an open and non-judgmental space for her friends to reach out and share their feelings with her, which helped build and solidify their friendship:

> It makes me feel good cause then it's like they will always feel like I'm there for them to talk to. Like, I feel like if they can talk to me about like anything then like, we could build like our friendship.

Other child/youth participants discussed the importance of regularly checking-in on their friends, and providing them with informal supports, whether that be just sharing their feelings, or spending time with them. For example, Sara, an 18-year-old, discusses how she helped her friends process the loss and damage of their homes and belonging, which created significant distress for many of her peers:

> I did have a couple friends whose houses burnt down, but like yeah, I'm not a counselor, but like I did do my best to just talk to them, and be like, "hey like..."— I feel like you know, that helped a bit. Even just hanging out with them and stuff, and being like, "Okay, well whatever, like let's go to the mall," you know? Things like that or like catching up or whatever. I don't know, like that's how I feel.

Openly and honestly communicating with their peers, as well as reciprocally receiving and offering support to their peers helped many children and youth in the recovery phases of the wildfire. By communicating with their peers, children and youth felt supported and heard, which validated and legitimized their unique experiences.

Distraction From Stressors

Child/youth participants also discussed how their peers helped provide a needed distraction from the stressors of the wildfire. Child/youth participants frequently discussed how spending

time with their peers served as a useful distraction from the stresses associated with evacuation, rebuilding, and recovery. Time spent interacting with their peers, whether that be just visiting or playing/interacting with one another, provided a necessary respite from the trauma of the wildfire. For example, Kris, a 10-year-old, describes how talking on the phone with his friends after being evacuated, and then having his friends come over to his house to play once he was permitted to return to his home helped bolster his overall well-being: "During the wildfire we [friends] talked on the phone, so that made me feel better and more safe, just talking to them, hearing their voices. And after, they came to my house when I told them I came home right away and then we played." Similarly, Margaery, a 15-year-old, shares how the willingness of her peers to talk with her through text, or meet up in-person to discuss even mundane things provided a useful, temporary escape from the negative effects of the wildfire:

> They checked up on me, you know? They'd ask what was going on or like again, if I texted them and said like, "Hey, this happened." They'd be interested in it and they'd let me talk…or they'd be willing to meet up with me if I wanted to, if we could.

For some child/youth participants, spending time with their peers after the wildfire boosted their morale, and helped them regain a sense of happiness despite the challenges they continued to face in the rebuilding and recovery stages. Catherine, a 7-year-old, discusses how just spending time with her friends brought her a sense of joy, which in turn helped her to forget about the stressors of experiencing the wildfire: "My friends helped me because they like made me feel good about myself. When I'm with them [talking], they make me feel like happy, which helps me forget about the wildfire and helps me not to worry." Having their peers distract them helped many children and youth cope with the stressors of the wildfire. This reflects children and youth's need to sometimes take a step back from adverse situations to feel a sense of normalcy again, even if only temporarily.

Child/youth participants also discussed how their peers helped distract them from the negative impacts of the wildfire by helping change their mindset. Many child/youth participants expressed that their peers helped them focus on some of the positive outcomes that emerged from the wildfire. For example, Franny, a 10-year-old, states that her peers tried to cheer her up by reminding her of the new items she received at school which were bought to replace the ones that were damaged: "They would say stuff like, 'Look at all the gifts you get at school now, like you're really lucky,' and stuff like that. So, you know, that would make me feel better." Similarly, Allison, a 16-year-old, discusses how her peers helped take her mind off of the extensive damage in their community by sharing the new items they received, but also sharing humorous and amusing stories and experiences: "They just like kept my mind off of it. We were always talking about, 'Oh look, I got this new stuff, and I got this new stuff' (laughs). I'd tell them stories and jokes and whatever, we were just talking about random things that were happening." Humor was something that child/youth participants frequently cited as one way that their peers boosted their mood.

Some child/youth participants even shared that their peers helped distract them by recommending ways to keep themselves busy, like books to read, games to play, television series to watch, among others. For example, Astrid, a 12-year-old explains how his friends lightened his mood with their humor, but also by recommending a new book series which helped keep him busy:

> Most of my friends are a lot of jokers. So, I think they were making puns about it all throughout (laughs). So, that really lifted my spirits. I had a friend who got me into this like, series. I can't even remember what it was called. But this friend got me into this series, and I read that in like, a week (laughs). I guess, again, just being there was most of the big part.

Evident in Astrid's response is the various ways in which his peers actively sought to uplift him by helping him have a more positive mindset and encouraging him to pursue activities that brought him a sense of joy. These findings highlight how the support children and youth received from their peers during and after the wildfire played a significant role in their recovery, thus strengthening their resilience.

DISCUSSION

Quantitative Findings

The quantitative findings from the CYRM-28 measure revealed that child/youth participants who experienced the 2016 Fort McMurray wildfire had higher than average resilience scores compared to normative comparison samples. These findings indicate that wildfire-affected child/youth participants had significant strengths, capabilities, and supports at their disposal in the aftermath of the wildfire, which helped them in the face of adversity.

The findings revealed that child/youth participants with higher resilience scores had higher scores on the subscales Relationship with Primary Caregivers (specifically caregivers physical caregiving) and Individual (specifically individual peer support). These findings reveal that caregiver physical support and individual peer support were the most influential factors that contributed to the resiliency of wildfire-affected child/youth participants. It is important to note that the CYRM-28 measure of caregiver physical support relates almost exclusively to the behavior of caregivers (supervision provided by caregivers, and basic needs such as food provided by caregivers), whereas the measure of individual peer support relates not only to the behavior of peers, but also to the individual's perception of peer support (the presence of peers during challenges, and feeling supported by peers). Therefore, there is a possibility that children/youth's individual perception of support from peers is as important as actually having support from peers when it comes to resilience[1].

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[1]In the CYRM-28, the two questions in the sub-scale Caregiver: Physical Care Giving that measure caregiver physical support are: "My parent(s)/caregiver(s) watch me closely," and "If I am hungry, there is enough to eat." The two questions in the sub-scale "Individual: Individual Peer Support" that measure peer support are: "I feel supported by my friends," and "My friends stand by me during difficult times" (57).

Following disaster, children and youth experience disruption and instability in their lives as a result of the destruction or loss of physical structures and belongings which they rely on for their everyday functioning. Yet, having physical support from caregivers as well as individual support from peers post-disaster are important determinants that can mitigate the disruption and instability caused by disaster, thus contributing to higher levels of resilience among children and youth. These findings point to the importance and necessity of ensuring that children and youth's basic physical and peer needs are met post-disaster, in order to increase their resiliency and recovery.

Qualitative Findings

Child/Youth Resilience Post-disaster and Caregiver Support

The qualitative findings revealed that child/youth participants with higher levels of resilience had parents who provided physical support during and after the wildfire. Parents provided child/youth participants with physical support during and after the wildfire by (1) ensuring their safety during the evacuation; (2) providing basic needs such as shelter, food, and clothing; and (3) offering support and reassurance by being physically present. These findings illustrate that caregiver support, specifically physical support, during and after the wildfire was a significant source of support for child/youth participants and helped strengthen their resilience. The findings of this study are consistent with previous research which indicates the benefits of children and youth being physically and emotionally close to their caregivers following disaster (48, 61, 62). Children and youth are better able to build and strengthen their resilience when they have strong support systems that provide a sense of security and normalcy in their lives. Similar to Botey and Kulig's (45) findings, our findings reveal that children and youth cope better following disaster when parents attempt to provide stability for their children by focusing on their physical needs and attempting to provide a sense of normalcy. Similar to Hackbarth et al.'s (61) findings, our findings also support the link between physical support in terms of having basic needs met or sought after by caregivers, rather than material belongings, as a key factor in children and youth's ability to cope post-disaster.

Furthermore, our findings reveal that when parents are in close proximity to their children, they are able to not only offer physical support, but also psychological support due to their increased presence and availability. Similar to Salloum and Lewis' (47) findings, our findings also reveal that emotional processing, a common coping strategy used within the parent-child dynamic following disaster, helps children recover as it provides them with the opportunity to share and validate their unique experiences, as well as forge stronger bonds with their caregivers. These findings suggest that parental recognition of the care their children needed may play as important of a role as the actual care given to children. The findings of this study highlight the crucial role that

physical caregiving plays in strengthening children and youth's resilience post-disaster.

Child/Youth Resilience Post-disaster and Peer Support

The qualitative findings also revealed that child/youth participants with higher levels of resilience had peers who provided support during and after the wildfire. Peers provided child/youth participants with support by (1) communicating with them; and (2) providing a needed distraction from immediate stressors. These findings illustrate that individual factors, specifically peer support, during and after the wildfire was a significant source of support for child/youth participants and helped strengthen their resilience. The findings of this study lend support to previous research which finds that communication and comfort among peers is a significant source of support for many children and youth post-disaster, thus strengthening their resilience (19, 50). Similar to Prinstein et al.'s (50) findings, our findings reveal that peers can be among the most critical factors in helping children and youth cope post-disaster. By interacting with their peers, children and youth were able to undergo emotional processing and gain insight into the ways in which their peers were coping in the aftermath of the wildfire. While children understood the damages caused by the wildfire, they also kept a positive attitude which was reflected in the way in which peers encouraged each other to reflect and focus on the positive outcomes of the wildfire.

In addition, the findings of this study also remain consistent with previous research which indicates that peers play an important role in supporting children and youth post-disaster by helping them re-establish a sense of routine and normalcy (53). Similar to Fothergill and Peek's (14) findings, our findings indicate that spending time with peers serves as a useful distraction from the post-disaster challenges associated with rebuilding and recovery, helping children and youth better cope with the adversity of disaster. Children and youth displayed incredible agency and emotional awareness by recognizing when their friends needed to be distracted from wildfire-related worries. The findings of this study underscore how children and youth are capable of providing useful sources of support not only to their peer groups, but also their wider communities, thus strengthening individual and community resilience in the aftermath of disaster.

CONCLUSION

The current study was conducted following the 2016 Fort McMurray, Alberta wildfire in order to examine the factors associated with high levels of resilience among children and youth post-disaster. This study utilized a mixed-methods approach, which involved administering the CYRM-28 resilience measure and face-to-face qualitative interviews with 100 children and youth between the ages of 5- and 18-years.

This study found that despite the various challenges that children and youth experienced as a result of the wildfire, they had higher than average levels of resilience. The findings reveal that high levels of resilience among children and youth are associated with caregiver factors, namely caregiver physical support, as well as individual factors, specifically peer support.

The findings of this study build on and contribute to empirical knowledge and evidence related to the social-ecological factors that enhance resilience in children and youth who experience disaster. These findings demonstrate that when supported, children and youth are better able to cope with the negative effects of disaster, thus bolstering their resilience. These findings also support the need for additional research which takes a strength-based approach in order to unearth the protective factors that contribute to resilience among disaster-affected children and youth. Research, policy, and practice that recognizes the specific strengths and capacities of children and youth in the aftermath of disaster may facilitate the development and implementation of programs, services, and resources that can help children and youth learn and develop resilience skills. Understanding the determinant factors that contribute to high levels of resilience among children and youth is critical due to the increasing frequency and occurrence of disasters and other catastrophic events like the current COVID-19 health pandemic.

DATA AVAILABILITY STATEMENT

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author/s.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by Human Research Ethics Board, Mount Royal University. Written informed consent to participate in this study was provided by the participants' legal guardian/next of kin.

AUTHOR CONTRIBUTIONS

CM-H, JD, MB, and PS: study design. CM-H: data collection. CM-H, JD, and AS: analysis. CM-H, JD, AS, MB, PS, PB-M, and VA: manuscript preparation. All authors contributed to the article and approved the submitted version.

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Model of Post-traumatic Growth in Newly Traumatized vs. Retraumatized Adolescents

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Background: In our analysis of adolescents affected by the 2016 Fort McMurray wildfire, we observed many negative mental health effects in individuals with a prior history of psychological trauma. Elevated rates of depression and markers of post-traumatic stress disorder (PTSD) were observed, consistent with the hypothesis that prior trauma may reduce sensitivity thresholds for later psychopathology (stress sensitization). Surprisingly, levels of anxiety did not differ based on prior trauma history, nor were retraumatized individuals at increased risk for recent (past month) suicidal ideation. These results are more suggestive of inoculation by prior trauma than stress sensitization. This led us to consider whether individuals with a prior trauma history showed evidence of Post-Traumatic Growth (PTG), a condition in which the experience of a previous trauma leads to areas of sparing or even improvement.

Method: To investigate this issue, we generated a structural equation model (SEM) exploring the role of anxiety in previously traumatized ($n = 295$) and wildfire trauma alone ($n = 740$) groups. Specifically, models were estimated to explore the relationship between hopelessness, anxiety, PTSD symptoms, self-efficacy and potential protective factors such as friend and family support in both groups. The model was tested using a cross-sectional sample of affected youth, comparing effects between the two groups.

Results: While both models produced relatively good fit, differences in the effects and chi-squared values led us to conclude that the groups are subject to different causal specifications in a number of areas, although details warrant caution pending additional investigation.

Discussion: We found that adolescents with a prior trauma history appear to have a more realistic appraisal of potential difficulties associated with traumatic events, and seem less reactive to potentially unsettling PTSD symptoms. They also seemed less prone to overconfidence as they got older, an effect seen in the adolescents without a history of trauma.

Our findings provide preliminary evidence that the construct of anxiety may work differently in newly traumatized and retraumatized individuals, particularly in the context of mass trauma events.

INTRODUCTION

It is generally recognized that a history of trauma in childhood and adolescence has negative effects on long-term functioning (1, 2), a finding that large, early investigations of Adverse Childhood Events (ACEs) (3) made evident. While adaptive sympathetic nervous system responses play a role in how individuals deal with short bursts of acute trauma, current thinking contends that long-term stress decreases the efficiency of reactions to stressful events due to changes in stress-related brain circuitry (4). Animal evidence suggests mediation of such effects via changes in the immune response leading to increases in cell inflammation, which subsequently influences neural circuitry (5). Supporting this hypothesis, we have recently shown long-lasting changes in subregions of the amygdala in those exposed to stress as children (6).

Consequently, youth with previous trauma may be more at risk of sympathetic overload or exhaustion. In other words, it is hypothesized that prior trauma reduces the sensitivity threshold for these children and adolescents, such that presentation of a stressor later on makes them more reactive and therefore more likely to endure negative effects. This has been coined the stress sensitization hypothesis (7), and one implication of this theory is that exposure to prior trauma will make individuals more vulnerable to mental disorders in the wake of proximal stressors (8), perhaps by complicating their ability to adjust to negative events (9). This hypothesis has been borne out in number of studies. For example, it was demonstrated that in newly recruited soldiers there is an increased risk of past 30-day major depressive episode or generalized anxiety following a stressful incident in the past year, for those individuals with a history of childhood maltreatment (8). More broadly speaking, a population-level National Epidemiological Survey ($n = 34,653$) in which it was demonstrated that there was an increased risk of mental health problems in individuals with a history of childhood adversities, with number of events correlating with increased risk (10). Similarly, the degree of exposure to the original stressor also correlates with risk, with more extreme exposure resulting in worse outcomes; for example, residents whose home was destroyed following a fireworks disaster responded more strongly to subsequent stressful life events than those whose home was spared (11). It has been suggested that adversities may need to cross a "severity threshold" to impact later stress vulnerability (10). Linking such observations to functioning of the autonomic nervous system, individuals with histories of adverse events showed higher levels of destabilized autonomic reactivity, as well as symptoms of worry, depression, and PTSD, in the wake of Covid-19 (12). These results support autonomic reactivity as the mechanism linking adversity and psychological ill-health following mass trauma.

That said, it is also possible that individuals with a history of prior trauma may in some ways be able to use their past experience to better cope with later traumatic events. This idea is central to a competing hypothesis to the stress sensitization model, known as inoculation theory (13). Inoculation theory suggests that prior experience successfully coping with stressors actually increases resistance to subsequent stress, and so ultimately has a protective effect. In an early paper discussing this effect, Bonanno (14) noted that the tendency to infer that psychological harm generally follows loss is predicated on the observation that most of the individuals that therapists see are not coping well. In fact, individuals who have encountered past trauma may have learned cognitive management strategies such that they are actually less likely to experience negative involuntary reactions, and therefore better able to navigate difficult situations – a trait sometimes referred to as post-traumatic growth (PTG). In support, Tedeschi and Calhoun (15) cite stronger, more meaningful relationships and an increased appreciation for life as potential positive consequences of past trauma. PTG appears to be strongly related to factors such as social support (16, 17), and females may show more benefits in terms of PTG than males (15). Thus, PTG appears to lie at the heart of the inoculation effect. Previous support for the inoculation hypothesis has also been demonstrated. Prior earthquake experience was shown to be associated with lower depression scores in the wake of another earthquake, although rumination was apparently unaffected (18). Similarly, another study found that flood victims who had experienced a previous flood were less likely to experience trait anxiety or weather-related distress related to personal loss in a second flood (13). A more recent study (9), also looking at flooding, compared individuals who experienced no home or property damage to those who experienced it in either a recent flood (single disaster) or both a recent and a past flood (double disaster). That study also found evidence consistent with the inoculation hypothesis, although it was less compelling (non-significant); still, it found no support for the stress sensitization hypothesis; the double disaster group was no more vulnerable to mental health issues after the flood than the single disaster group. It should be noted that while most of these inoculation studies look at previous experience with the same event, it is possible that coping strategies and reactions learned by one event can generalize to an unrelated future trauma. Norris and Murrell (13) argue that increased resistance to a new stressor may represent a type of "cross tolerance", such that "exposure to one type of stressor prevents a different stressor from impairing performance". In support of this contention, one study found that previous exposure to the September 11 terrorist

attack moderated PTSD symptomatology in response to Shrira A et al. (19). Moreover, that study found that this effect only held for older adults who had high levels of previous trauma exposure, effectively ruling out simple maturation as a competing explanation for these findings.

Present Study

In May 2016, the northern town of Fort McMurray, Alberta suffered a devastating wildfire which engulfed almost 600,000 hectares of land, destroyed over 2,400 buildings, and caused the evacuation of all 88,000 inhabitants.[1] a remote northern settlement, there were only two vehicular routes out of town, and the nearest large city (Alberta's capital, Edmonton) was a 4.5 h drive away. Ironically, the only fatality of the fire was an automobile accident which occurred as a result of the mass exodus. The evacuation led to some individuals being stranded by the side of the road, although local communities stepped up with offers of water and gasoline to ensure safe passage. While the evacuees were generally greeted by hospitality from across Alberta and the rest of the country, it caused a massive amount of upheaval. As one teacher involved in the study described it, "we left for school in the morning, and didn't come home for 3 months". For the children especially, evacuation was associated with upheaval, marked by redistribution in schools across the province which made room for new students with scarcely 2 months left in the school year. Anecdotally, at least some of the children displayed signs of trauma in the months that followed. For instance, one child was described as fearing the setting sun during the drive out of town, because they believed the wildfire was "following them". As our statistics indicated that over 90% of the children in the groups surveyed were in or near Fort McMurray during the wildfire and forced to evacuate, it can be assumed the vast majority of our sample was affected in some way. Our study attempted to capture some of the broader psychological impacts of this event.

In a previous study on this disaster (20), which compared adolescents who had experienced a perceived psychological trauma prior to the wildfire ("prior trauma group") with those who reported that the wildfire was their worst trauma ("wildfire group"), we found clear evidence of mental health problems associated with retraumatization. Namely, the prior trauma group showed increased rates of both depression and post-traumatic stress disorder (PTSD) symptomatology, as would be expected according to the sensitization hypothesis. However, contrary to expectations, there was no concomitant increase in rates of anxiety, and these individuals were at no increased risk for 30-day suicidal ideation. Thus, the present study explored whether, despite our previous findings of stress sensitization in those with a history of prior trauma, there were areas of sparing or PTG, reflective of some degree of inoculation.

We chose the construct of hopelessness as the dependent variable in our model comparing newly traumatized adolescents with those with a trauma history, for two reasons. First, hopelessness shows a strong and consistent association with suicide risk (21–24). Thus, to the extent that PTG is presumed

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[1]https://www.cbc.ca/news/canada/edmonton/fort-mcmurray-fire-beast-extinguished-out-1.4271604

a protective factor in our model [at least in terms of anxiety and suicidal ideation, as suggested by our first study (20)], a decrease in hopelessness could suggest inoculation has occurred. Second, as Chang EC (21) points out, beyond suicidal ideation, hopelessness also mediates other indices of vulnerability such as emotional dysregulation, loneliness, and problem-solving deficits. Because, in our model, hopelessness represents a lack of faith in oneself or one's ability to assert a sense of agency over one's future, it bears relevance for both anxiety and suicidal ideation.

In this study, we set out to develop a structural equation model (SEM) examining how these factors affected the likelihood of someone becoming hopeless if they had or had not experienced a prior trauma. We wanted to examine whether the two groups showed a different pattern of associations in terms of their demographic characteristics, including factors such as the support of friends or family, and markers of PTSD. Because previous research has suggested that an individual's response to trauma may, in part, depend on how manageable the stress is perceived to be (4), we also incorporated the concept of self-efficacy (feeling one could effectively tackle challenges) as a potential mediating variable. We examined potential relationships amongst the attributes by generating and testing an SEM of their presumed relationships using the data gathered during the previous study. In line with the discussion on the competing theories of sensitization and inoculation, our research question generated two competing hypotheses: Hypothesis 1, which supports the sensitization model, was that the group with a history of prior trauma would show an increase in hopelessness. Hypothesis 2, which supports the inoculation theory, was that the prior trauma group would show a decrease in this measure. Conversely, the null hypothesis predicts that there will be no differences in the magnitudes of the effects between the groups.

METHODS

Description of Data Collection

Use of survey materials for this study was approved by the University of Alberta Health Research Ethics Boards (ethics protocol number Pro00072669). Surveys were administered to all adolescent children enrolled in junior and senior high schools in both Public and Catholic School Boards in Fort McMurray, Canada from 2017 to 2019, as part of the school system's evaluation of their post-wildfire mental health programming. Both parents and students were given the option to opt out of the study, and students could withdraw participation at any point. Data collected was online and anonymous. Information gathered from students included demographics, exposure to the wildfire, and a battery of mental health questionnaires (detailed elsewhere) (25).

Participants were excluded if they (a) fell outside of the pre-determined age range for the study (10–20 years of age); (b) if they gave inconsistent answers on the questionnaires (e.g., for positive and negative questions); and (c) if they did not answer more than 75% of the questionnaires overall. Of the 4,849 children enrolled in the 2019 school year, surveys were collected from 3,217, of which 3,041 met acceptability criteria yielding a 62.7% participation rate.

To examine the issue of retraumatization, respondents were classed into two groups the "prior trauma group" ($n = 295$) and the "wildfire group" ($n = 740$), described below, in the third year of data collection. The "prior trauma group" consisted of individuals that indicated they had experienced a more traumatizing event prior to the wildfire, while the "wildfire group" was made up of individuals that stated that the wildfire was the worst event they had sustained. This was assessed via the question: *Please select the most distressing event you have experienced* (to which the possible options were: *Fort McMurray wildfire*; *Death of someone close to you*; Injury that you suffered; *Physical assault against you*; *Sexual assault against you*.) A second question was used to determine whether that event actually happened prior to the wildfire (as several years had transpired since). This question read: *"How long has it been since the event from the previous question".* There were eight response options for the question, ranging from the past month to more than 11 years. This method led to the elimination of over 1,789 students, because they reported that their worst trauma had occurred following the wildfire. Of the remaining students, almost one-third (28.5%) reported a previous trauma history.

As has been reported previously (20), individuals with a previous history of trauma were significantly more likely to be older, male, and – not surprisingly – been exposed to less wildfire trauma. A detailed breakdown of all of the sample characteristics of the two groups, as well as the overall sample, are presented in **Table 1**.

Measures

A detailed description of all of the questionnaires administered and their methodological characteristics is available elsewhere (25). The next section focuses only on the variables and items used for the current SEM model.

Wildfire Trauma Exposure

This variable consisted of four yes/no questions, which were summed to calculate a scale from 0 to 4, with higher scores being reflective of greater exposure and closer proximity to the wildfire. These questions were: *Were you in or near Fort McMurray during any part of the 2016 wildfire?; Did you evacuate because of the fire?; Was your home destroyed by the fire?; Did you see the fire in person?*

Friend Support/Family Support

We did not use the overall score of the Child and Youth Resilience Measure - Youth 12-question version [CYRM-12 (26)] in this paper to measure resilience; instead, we extracted a few of the items to provide more precisely focused measurements. Two items from the were used to gauge support: *My family stands by me during difficult times* (Family Support), and *My friends stand by me during difficult times* (Friend Support). Responses were coded on a 1–5 scale, with higher scores indicating greater agreement with the supportive statements. Although, arguably, additional items in the CYRM could have been used as indicators, these single indicators were chosen because other items (e.g., *I enjoy my cultural and family traditions*) are open to varying interpretations which are difficult to tease apart given the limits

of our data collection, and so are less likely to demonstrate causal homogeneity, a precursor for structural equation modeling. For this reason, only these indicators were selected.

Anxiety

Anxiety was measured using the seven-item anxiety subscale of the Hospital Anxiety and Depression Scale [HADS (27)]. Items on the HADS are scored on a scale of 0–3. After recoding negatively keyed items, an overall score was calculated such that higher scores reflected a higher level of anxiety.

Self Efficacy

As we were specifically interested in the impact of anxiety on feelings of self-efficacy, we used the item *I am able to solve my problems without harming myself or others* from the CYRM-12 resilience scale, to measure self efficacy. This item was chosen not only because it reflected positive self-regard, but also because it was characteristic of an attitude of hope and optimism for the future. We considered using the entire resilience score, however closer inspection suggested that it was multifactorial. For example, some questions focus on an individual's values (e.g., *Getting an education is important to me*), some on interpersonal perceptions (e.g., *My parents know a lot about me*), some on knowledge (e.g., *I know where to go in the community to get help*), among others. In addition, we had already selected two of the items from this scale as indices of Friend Support and Family Support, which would have created specification issues.

PTSD

Post-traumatic stress disorder symptomatology was measured using the Child PTSD Symptom Scale [CPSS (28)]. This scale assigns a value of 1–4 for each question, based on the frequency with which each symptom is endorsed. However, while the CPSS scale generally breaks the items into three factor scores, we instead chose to represent all four categories of symptoms necessary for a diagnosis of PTSD, as defined by the DSM-V (29). Specifically, items were chosen to represent: (1) intrusive symptoms, (2) avoidance, (3) negative changes in thinking and mood, and (4) hypervigilance. Other reports have also called into question the existing three factor solution of the CPSS (30), one of which indicated a superior fit for a four factor solution (31). Choosing the best item to represent each concept allowed us to ensure that all items reflected use of effortful cognitive strategies in reducing trauma. The four items chosen were: *Having upsetting thoughts about the event that came into your head when you didn't want them to* (intrusive symptoms); *Trying not to think about, talk about, or having feelings about the event* (avoidance); *Feeling upset when you think about or hear about the event* (negative cognitions); *Being overly careful – for example, checking to see who is around you and what is around you* (hypervigilance).

Hopelessness

This variable was seen as central to, but distinct from, depression, in that it encompasses not only feelings of negative affect, but also a feeling of being unable to make things better going forward. One can be depressed about events that have occurred or present circumstances without necessarily feeling hopeless. Hopelessness expresses a lack of faith in oneself or one's ability to make things

TABLE 1 | Sample characteristics of the "*prior trauma group*", the "*wildfire group*", and the overall sample.

Variable	Prior trauma group (n = 295)	Wildfire group (n = 740)	Total (n = 1,035)
Sex (self-identified), n (%)			
Female	114 (38.6)	373 (50.4)	487 (47.1)
Male	159 (53.9)	335 (45.3)	494 (47.7)
Other	12 (4.1)	13 (1.8)	25 (2.4)
Prefer not to say	10 (3.4)	17 (2.3)	27 (2.6)
Age (years), n (%)			
11	4 (1.4)	27 (3.6)	31 (3.0)
12	43 (14.6)	152 (20.5)	195 (18.8)
13	49 (16.6)	144 (19.5)	193 (18.6)
14	48 (16.3)	132 (17.8)	180 (17.4)
15	59 (20.0)	110 (14.9)	169 (16.3)
16	40 (13.6)	82 (11.1)	122 (11.8)
17	47 (15.9)	85 (11.5)	132 (12.8)
18	4 (1.4)	6 (0.8)	10 (1.0)
19	1 (0.3)	1 (0.1)	2 (0.2)
Mean (SD)	14.52 (1.76)	14.04 (1.77)	14.17 (1.78)
Grade, n (%)			
7	44 (14.9)	169 (22.8)	213 (20.6)
8	46 (15.6)	140 (18.9)	186 (18.0)
9	52 (17.6)	128 (17.3)	180 (17.4)
10	58 (19.7)	121 (16.4)	179 (17.3)
11	46 (15.6)	84 (11.4)	130 (12.6)
12	48 (16.3)	97 (13.1)	145 (14.0)
Missing	1 (0.3)	1 (0.1)	2 (0.2)
Mean (SD)	9.48 (1.98)	9.11 (1.83)	9.22 (1.88)
Junior high (gr 7–9)	142 (48.1)	437 (59.1)	579 (55.9)
Senior high (gr 10–12)	152 (51.5)	302 (40.8)	454 (43.9)
Wildfire exposure (Y responses), n (%)			
Were you in or near Ft. McMurray during any part of the wildfire?	223 (75.6)	732 (98.9)	955 (92.3)
Did you evacuate because of the fire?	230 (78.0)	734 (99.2)	964 (93.1)
Was your home destroyed by the fire?			
Did you see the fire in person?	17 (5.8)	116 (15.7)	133 (12.9)
	189 (64.1)	641 (86.6)	830 (80.2)
Total exposure (/4 items, above), n (%)			
0	61 (20.7)	5 (0.7)	66 (6.4)
1	10 (3.4)	2 (0.3)	12 (1.2)
2	33 (11.2)	80 (10.8)	113 (10.9)
3	177 (60.0)	548 (74.1)	725 (70.0)
4	13 (4.4)	104 (14.1)	117 (11.3)
Missing	1 (0.3)	1 (0.1)	2 (0.2)
Mean (SD)	2.24 (1.26)	3.01 (0.57)	2.79 (0.90)
Trauma history (worst trauma), n (%)			
Fort McMurray wildfire	–	740 (100.0)	740 (71.5)
Death of someone close to you	107 (36.3)	–	107 (10.3)
Injury that you suffered	22 (7.5)	–	22 (2.1)
Physical assault against you	6 (2.0)	–	6 (0.6)
Sexual assault against you	36 (12.2)	–	36 (3.5)
Other (unidentified)	124 (42.0)	–	124 (12.0)

Values in parentheses are percentages, unless otherwise indicated.
SD, standard deviation.

better in the future. The indicator selected was from the Patient Health Questionnaire [PHQ-9 (32)]: *Feeling bad about yourself - or feeling that you are a failure or that you have let yourself or your family down.*

The covariance matrix of these indicators, for each group, is available in the **Supplementary Materials**.

Statistical Analysis

Structural equation modeling using maximum likelihood estimation in LISREL [linear structural relations software (33)] was employed to analyse the correlations between different concepts in our model. The primary variables of interest were Friend and Family Support, Anxiety, Self Efficacy, PTSD, and the

effect of these variables on our ultimate dependent variable, level of Hopelessness.

We developed a model relating these constructs, working under the assumption that relationships would function the same way in the prior trauma group and the wildfire group. Once the model was deemed to be acceptable, we ran a stacked model in which all β and γ effects were constrained to be equal between the groups. The stacked model locates the single set of effect estimates which best matches the variables' covariance matrices for the two groups (34). In essence, this permits testing of the null hypothesis, that the magnitudes of the effects connecting the concepts are the same in both groups. Thus, inconsistencies between effects in these models represent differences in causal functioning in the two groups.

Model Description

The current study focuses on the associations between Anxiety, Friend/Family Support, Self Efficacy, and PTSD symptoms on Hopelessness (despair in how one sees their ability to effectively manage the future). Because Anxiety did not differ between the two groups, our key question was whether it played the same role in mediating feelings of Hopelessness for those with prior trauma compared to those experiencing trauma for the first time. We were particularly interested in this relationship given the fact that the prior trauma group did not exhibit increases in recent suicidal ideation. The exogenous variables, which were posited as affecting Anxiety, were Sex (self-identified), Trauma Exposure, Friend Support, and Family Support. Age was not predicted to affect Anxiety directly, rather impacting Hopelessness via an indirect effect of altered Self Efficacy (i.e., as one ages, one feels more in control).

Our model also permits Anxiety to indirectly affect one's subjective levels of Hopelessness *via* alterations in Self Efficacy (feeling of control regarding one's future). The relationship between Anxiety and Self Efficacy was therefore modelled as a reciprocal effect, since it was predicted that Anxiety would tend to reduce Self Efficacy, while Self Efficacy could also affect Anxiety (anxious mood could undermine one's sense of self, while increased self efficacy would potentially decrease an anxious mood). The working hypothesis we adopted was that these concepts work together to determine one's level of Hopelessness. In other words, our model predicted that anxiety as a core feature of the stress response may be experienced as discomforting, but only becomes truly distressing when it begins to reflect a lack of control over one's future circumstances. Friend Support and Family Support were also predicted to impact Hopelessness via Self Efficacy, in that having others show confidence in one's ability to handle events is assumed to be key to whether one feels despair in difficult circumstances. Finally, Anxiety was also posited to affect Hopelessness indirectly via changes in PTSD. In other words, experiencing PTSD symptoms could lead the individual to feel that the future is bleak and that there is little to hope for.

In the model, measurement error variances for single indicators (described above) were held at 5%, while scale indicators (i.e., the HADS Anxiety scale, and the total score of the Trauma Exposure questions), were given 10% variance. The exogenous variables were allowed free variances and to freely covary, as were the residual variances of the individual PTSD latent variables, thereby acknowledging unmodeled sources of covariance between them.

RESULTS

Model Modifications and Fit

In the original iteration of our model, all the exogenous concepts were constrained so that their direct effects only impacted Anxiety. Then, Anxiety was constrained to effect Hopelessness only through Self Efficacy and PTSD symptoms. Anxiety and Self Efficacy were allowed a reciprocal effect. Changes to the model suggested by the modification indices included the following.

The first change involved freeing the effects of Age, Friend Support, and Family Support on Self Efficacy. These effects appeared reasonable, as increased maturity and social support should both be associated with feeling confidence in problem-solving. The next change suggested by the modification indices was freeing the direct effect from Anxiety to Hopelessness. As mentioned, the original model forced effects to go from Anxiety to Hopelessness only indirectly, *via* PTSD and Self Efficacy. Freeing this effect allowed that there may be other unmodeled mechanisms besides those concepts mediating the link between Anxiety and Hopelessness, which seemed theoretically plausible. Finally, the third change involved freeing the effect from Family Support to Hopelessness and the effect from Age to Hopelessness. Freeing the connection between Family Support and Hopelessness makes logical sense because having one's family stand by them clearly impacts whether a youth believes they have let their family down. Similarly, freeing the effect from Age to Hopelessness is defensible, because as an individual approaches adulthood, more is asked of them, and they likely feel a greater weight of responsibility.

In order for a change to be implemented, it was necessary for those changes to improve model fit considerably, and to be theoretically meaningful in the context of the full causal model. Importantly, all changes suggested by the diagnostics were applied to both groups, and so were made simultaneously, though each group was permitted a separate estimate. Permitting separate estimates in each group was important because a central test of our conceptualization involved constraining the two models to have the same magnitude of effects in the corresponding model locations. These changes led to an overall adequately-fitting model for the prior trauma group ($\chi^2 = 38.02$, df = 29, $p = 0.12$), but a slightly poorer fit for the wildfire group ($\chi^2 = 57.98$, df = 29, $p < 0.02$). The other goodness-of-fit statistics did not provide evidence of concerns (root mean square error of approximation [RMSEA] = 0.036 vs. 0.037; comparative fit index [CFI] = 0.992 vs. 0.985; standardized root mean squared residual [SRMR] = 0.034 vs. 0.033 for the prior trauma and wildfire groups, respectively). The lack of clear χ^2 fit indicated we must remain cognizant of possible misspecification in these models as well as possible mismatch in causal effects between the two groups (35). The effect estimates in these models are presented in **Tables 1**, **2**. We consider possible differences between the groups in more detail below. Note, only results from the final model for each group are reported below.
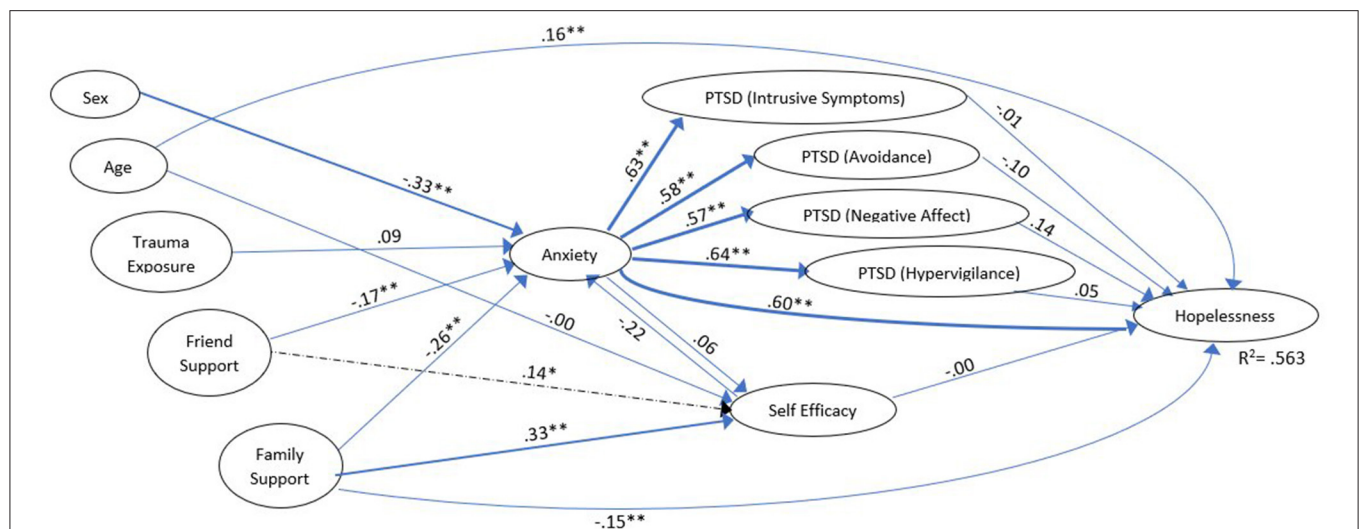
FIGURE 1 | Model of adolescents who said they had experienced worse trauma prior to the wildfire ("prior trauma group"). Dashed effects are significant for the *prior trauma group only*. Coefficients are standardized for ease of comparison; effect size (36) is reflected by line weight. For clarity, the following model features have not been depicted in this figure: exogenous variable covariances, residuals on the endogenous variables, correlations among the residuals on the PTSD variables, the indicators and measurement error variances for the indicators.*$p < 0.05$, **$p < 0.001$.
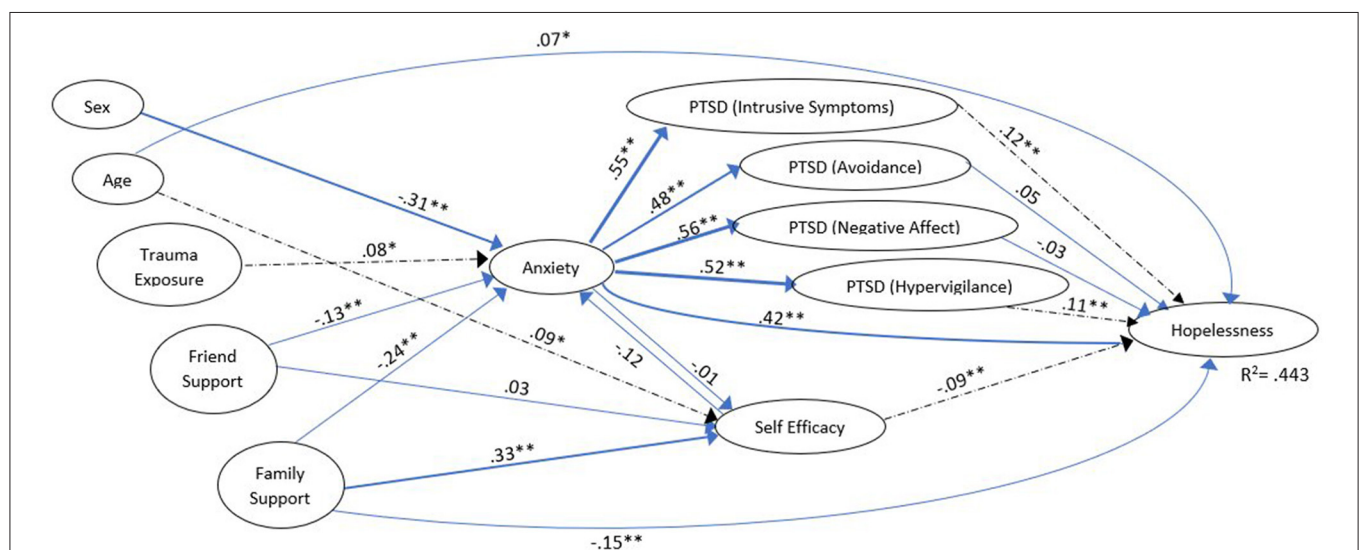
FIGURE 2 | Model of adolescents who reported the 2016 wildfire as their worst trauma ("wildfire group"). Dashed effects are significant for the *wildfire group only*. Coefficients are standardized for ease of comparison; effect size (36) is reflected by line weight. For clarity, the following model features have not been depicted in this figure: exogenous variable covariances, residuals on the endogenous variables,correlations among the residuals on the PTSD variables, the indicators and measurement error variances for the indicators.*$p < 0.05$, **$p < 0.001$.

Group Comparisons

As predicted, in both groups, Friend Support and Family Support showed a significant inverse effect on Anxiety ($\gamma = -0.166$, $z = -2.783$ vs. $\gamma = -0.125$, $z = -3.206$ for Friend Support and $\gamma = -0.260$, $z = -3.134$ vs. $\gamma = -0.241$, $z = -4.700$ for Family Support (standardized effects reported throughout the text and in **Figures 1**, **2** which show the model for the two group, while unstandardized effects are presented in **Tables 1**, **2**; all comparisons report prior trauma group vs. wildfire group,

respectively). Similarly, stronger Family Support seemed to directly reduce Hopelessness ($\gamma = -0148$, $z = -2.929$ vs. $\gamma = 0.148$, $z = -4.338$). In other words, as level of support increases, negative consequences decrease. Sex (scored 1 = female, 2 = male) also showed a similar effect in both groups, with females reporting more Anxiety than males ($\gamma = -0.325$, $z = -6.079$ vs. $\gamma = -0.307$, $z = -8.722$).

However, there were a number of areas where the two groups differed. The effect of Trauma Exposure on Anxiety was only

TABLE 2 | Parameter estimates of Anxiety and related variables on Hopelessness in students who said they had experienced worse trauma prior to the wildfire ("*prior trauma group*").

Variable	Estimate	Std error	95% Confidence interval		z-value
			Lower	Upper	
Sex → anxiety	−3.203	0.527	−4.23592	−2.17008	−6.079**
Trauma exposure → anxiety	0.347	0.217	−0.07832	0.77232	1.601
Friend support → anxiety	−0.632	0.227	−1.07692	−0.18708	−2.783**
Family support → anxiety	−1.050	0.297	−1.63212	−0.46788	−3.534**
Age → self efficacy	−0.003	0.044	−0.08924	0.08324	−0.074
Friend Support → Self Efficacy	0.142	0.070	0.0048	0.2792	2.018*
Family support → self efficacy	0.365	0.100	0.169	0.561	3.641**
Anxiety → self efficacy	0.017	0.049	−0.07904	0.11304	0.349
Anxiety → (PTSD1) intrusive symptoms	0.123	0.010	0.1034	0.1426	12.385**
Anxiety → (PTSD2) avoidance	0.131	0.012	0.10748	0.15452	10.945**
Anxiety → (PTSD3) negative affect	0.121	0.011	0.09944	0.14256	10.655**
Anxiety → (PTSD4) hypervigilance	0.152	0.012	0.12848	0.17552	12.617**
Age → hopelessness	0.105	0.028	0.05012	0.15988	3.706**
Family support → hopelessness	−0.140	0.048	−0.23408	−0.04592	−2.929**
Anxiety → hopelessness	0.140	0.018	0.10472	0.17528	7.781**
Self efficacy → hopelessness	0.004	0.041	−0.07636	0.08436	0.090
(PTSD1) Intrusive symptoms → hopelessness	−0.01	0.088	−0.18248	0.16248	−0.118
(PTSD2) Avoidance → hopelessness	−0.105	0.071	−0.24416	0.03416	−1.47
(PTSD3) Negative affect → hopelessness	0.153	0.090	−0.0234	0.3294	1.696
(PTSD4) Hypervigilance → hopelessness	0.048	0.064	−0.07744	0.17344	0.755

Coefficients are unstandardized; bold text indicates a significant relationship that is absent in the other group.
*p < 0.05.
**p < 0.01.

significant for the wildfire group ($\gamma = 0.087$, $z =$ ns vs. $\gamma = 0.078$, $z = 2.160$); while the standardized effects appear quite similar, the unstandardized effects differ more clearly (**Tables 2**, **3**). This may have been an artefact due to some of the prior trauma group having experienced relatively less exposure to the wildfire (see **Table 1**). However, there is no *a priori* reason to expect exposure to have a more pronounced effect on anxiety in one group compared to the other.

While both groups showed a fairly strong, significant effect of Family Support on feelings of Self Efficacy ($\gamma = 0.329$, $z = 3.641$, and $\gamma = 0.330$, $z = 6.159$), only the prior trauma group showed an effect of Friend Support on this variable ($\gamma = 0.136$, $z = 2.018$ vs. $\gamma = 0.034$, $z =$ ns). Thus, as Friend Support increased so did feelings of Self Efficacy. Age also had a direct effect on Self Efficacy, but only for the wildfire group ($\gamma = -0.004$, $z =$ ns vs. $\gamma = 0.088$, $z = 2.393$). Thus, in the newly traumatized group older adolescents felt more confidence in solving their problems, but this did not hold true for those with severe prior trauma.

The effect of Anxiety on Self Efficacy was, unexpectedly, small and not significant for either group ($\gamma = 0.062$, $z =$ ns vs. $\gamma = -0.012$, $z =$ ns). Taken together, these results suggest that one's unease had less of an impact on their perceived ability to deal with problems than the support they received from others. Interestingly, the effect of Self Efficacy on Hopelessness was only significant for the wildfire group, ($\beta = -0.004$, $z =$ ns vs. $\beta = -0.091$, $z = -2.786$). For this group, the more confident they felt

about handling challenges, the less they reported feeling hopeless. This effect did not hold for those with prior trauma.

For both groups, Anxiety led to significant increases in all four PTSD variables, which were of approximately the same magnitude (β's > 0.571 for the prior trauma group, and β's > 0.478 for the wildfire group, all z's > 10.0). Similarly, the direct effect of Anxiety on Hopelessness was significant for both groups ($\beta = 0.598$, $z = 7.781$ vs. $\beta = 0.415$, $z = 8.976$). For each of these, an increase in Anxiety meant corresponding increases in the downstream variable.

Finally, specifically examining the impact of PTSD on Hopelessness, an interesting effect emerged. For the prior trauma group, there was no effect of any of the four PTSD variables on Hopelessness (all β's < 0.138, all z's $=$ ns), while for the wildfire group, two of the four PTSD dimensions – Intrusive symptoms ($\beta = 0.120$, $z = 2.994$) and Hypervigilance ($\beta = 0.106$, $z = 2.840$) – showed a significant impact on Hopelessness.

This model was found to explain 56.3% of the variance of Hopelessness in the prior trauma group, but only 44.3% in the wildfire group.

Overall Stacked Model Comparison

Given these significant differences in the pattern of interactions between the groups, it was not surprising that the stacked model constraining the β and γ effects to be equal did not fit ($\chi^2 = 127.86$, df $= 79$, $p < 0.001$). The stacked model investigates

TABLE 3 | Parameter estimates of anxiety and related variables on hopelessness in students who reported the 2016 wildfire as their worst trauma ("wildfire group").

Variable	Estimate	Std error	95% Confidence interval		z-value
			Lower	Upper	
Sex → anxiety	−2.754	0.316	−3.37336	−2.13464	−8.722**
Trauma exposure → anxiety	0.633	0.293	0.05872	1.20728	2.16*
Friend support → anxiety	−0.512	0.160	−0.8256	−0.1984	−3.206**
Family support → anxiety	−1.000	0.213	−1.41748	−0.58252	−4.700**
Age → self efficacy	0.064	0.027	0.01108	0.11692	2.393*
Friend support → self efficacy	0.040	0.049	−0.05604	0.13604	0.807
Family support → self efficacy	0.392	0.064	0.26656	0.51744	6.159**
Anxiety → self efficacy	−0.003	0.032	−0.06572	0.05972	−0.109
Anxiety → (PTSD1) intrusive symptoms	0.093	0.006	0.08124	0.10476	15.879**
Anxiety → (PTSD2) avoidance	0.102	0.008	0.08632	0.11768	13.394**
Anxiety → (PTSD3) negative affect	0.105	0.006	0.09324	0.11676	16.398**
Anxiety → (PTSD4) hypervigilance	0.123	0.008	0.10732	0.13868	14.827**
Age → hopelessness	0.039	0.017	0.00568	0.07232	2.286*
Family support → hopelessness	−0.138	0.032	−0.20072	−0.07528	−4.338**
Anxiety → hopelessness	0.093	0.010	0.0734	0.1126	8.967
Self efficacy → hopelessness	−0.071	0.026	−0.12196	−0.02004	−2.786**
(PTSD1) Intrusive symptoms → hopelessness	0.157	0.052	0.05508	0.25892	2.994**
(PTSD2) Avoidance → hopelessness	0.051	0.044	−0.03524	0.13724	1.136
(PTSD3) Negative affect → hopelessness	−0.040	0.056	−0.14976	0.06976	−0.712
(PTSD4) Hypervigilance → hopelessness	0.101	0.035	0.0324	0.1696	2.84**

Coefficients are unstandardized; bold text indicates a significant relationship that is absent in the other group.
*p < 0.05.
**p < 0.01.

whether some "reasonable compromise" set of effect estimates can be found that makes the data from both groups consistent with the model. Again, older criteria for other fit statistics would suggest model acceptability (RMSEA = 0.035; CFI = 0.991; SRMR = 0.039), but this does not negate the evidence of significant mismatch between the constrained model and the available data. As such, it is difficult to dismiss differences between the data and what the models predict as being due to mere random sampling variation.

We attempted freeing those β and γ effects described above as differing between the groups, but this alone did not significantly improve the chi-squared fit ($\chi^2 = 123.570$, df = 74, $p < 0.001$). This mismatch indicates differences in just these five effects would be insufficient to produce a fitting model. Alternately, if the two groups had been stacked with *no* constraint on the β and γ effects, then the stacked model χ^2 would have been the sum of the individual model χ^2's or 96.00. That means constraining the 21 β and γ effects in the model to equality between the groups resulted in an χ^2 increase of 31.86 with 21 degrees of freedom, which is on the borderline of statistical significance. Since we would expect many of the 21 effects to be the same in both groups, this essentially reports that more than five but somewhat fewer than all 21 modeled effects differ between the two groups. This helps verify that there is in fact a different pattern of functioning amongst individuals who have experienced prior trauma, though it is difficult to determine precisely which effects differ, and how they differ. We suggest this provides preliminary

evidence that the construct of anxiety may work differently in the newly traumatized and retraumatized groups– partially due to stronger or weaker effects to or from anxiety, and partially due to somewhat different indirect effects of anxiety being transmitted though the PTSD variables as a consequence of the PTSD variables differential effects on hopelessness.

DISCUSSION

While our earlier research showed clear deficits in functioning in individuals who previously suffered trauma compared to the newly traumatized, a more complex analysis also suggested indications of learned skills and tendencies which may be protective. To explore this issue, we developed a structural equation model (SEM) to examine the nature of the relationship between anxiety and hopelessness in survivors of the 2,016 Fort McMurray wildfire. Fit indices suggested clear evidence of different effects between newly traumatized adolescents vs. those who had suffered an earlier trauma; however, because χ^2 seemed to detect some lack of fit in the base model for the wildfire group, and because of some uncertainty in which specific effects are involved, we would argue these require further investigation and verification.

The relationship between Friend Support and Self Efficacy in the prior trauma group suggests that there are differences in terms of the role friend relationships play in coping for these individuals. While one might be tempted to conclude on the basis

of these results that adolescents with prior trauma are more likely to seek out friends as a source of emotional support, examination of the means reveals the fact that those with a history of prior trauma are actually less likely to feel supported by friends. For example, there were over twice as many adolescents in the prior trauma group (9.6%) as compared to the wildfire group (4.1%) who responded, "*Not at all*" to the item "*My friends stand by me during difficult times*". This may reflect the fact that adolescents with a trauma history are less trusting and so less likely to seek out support, or perhaps that they are less willing to recognize or accept support when offered. Thus, it appears the relationship between the two concepts is mainly driven by the fact that the wildfire group reported higher levels of support across the board, effectively rendering this variable a constant. That said, for those kids with prior trauma who *do* feel they have supportive friendships, there was a strengthening in how much self-efficacy this resulted in. Thus, it would appear that some retraumatized individuals derive not only comradeship, but feelings of self-efficacy from their interactions with their peers. This fits with qualitative evidence suggesting that enhanced empathy and placing greater value on relationships are important factors in promoting PTG (37), thus lowering the risk of suicidality among disaster survivors (16). It is possible that the results we obtained are, however, specific to episodes of mass trauma — it may be that, in events such as the wildfire, retraumatized adolescents were able to see others going through the same challenges (likely in contrast to their prior trauma), leading them to lean on other youth in beneficial ways. Ironically, instances of mass trauma may therefore actually provide a unique window into the development of these skills — when individuals are impacted as a group, other community members can potentially provide empathy and support in meaningful ways. This is distinctly different from individual-level trauma, in which individuals experiencing the events often feel isolated. These data suggest a role for peer support training, particularly for newly traumatized individuals. Encouragement of supportive friendships in children with a history of trauma is also strongly indicated. That said, for both newly traumatized and retraumatized youth, the relationship between Family Support, and Self Efficacy was even stronger than that observed for Friend Support, pointing to the critical role of families in helping children feel a greater sense of control when coping with trauma.

Together, relationships between Age and Self Efficacy, and Self Efficacy and Hopelessness suggest that, for individuals experiencing trauma for the first time, there exists an age-related boost in confidence in their ability to handle things, which was negatively related to Hopelessness. For the wildfire group, the oldest adolescents showed higher mean levels of confidence; for the prior trauma group, these age-related improvements did not exist. One might conclude that, for individuals with little experience with trauma, there may be a sense of overconfidence in "being able to manage" anything life throws at them, which shields these individuals from experiencing hopelessness. In one sense, this is clearly a source of strength for the newly traumatized group. However, at times, a crisis might be greater than one's capacities allow, and the overconfident adolescent might feel more distress than one who has mentally prepared for

struggle. This overconfidence was not evident in the previously traumatized group, suggesting they may have developed a more realistic appraisal of trauma, given their prior experience. That said, it is worth noting that, particularly at the extremes of our age distribution, the *n*'s for these effects become quite small and represent only a few individuals; our interpretation would benefit from systematic investigation across this age range.

One possible explanation to why this overconfidence might begin to break down may be offered by the inconsistencies in how PTSD symptoms affected Hopelessness for the two groups in our model. Specifically, the two markers which differed between the groups — Hypervigilance and Intrusive Symptoms — are linked by their role in the sympathetic response. The former is associated with an increased startle reflex and exaggerated threat response, while the latter is marked by flashbacks, involuntary imagery, and dissociative reactions. Reasonably, the exhaustion that results from hypervigilance could feasibly result in an increase in intrusive thoughts. Following from this, we suggest the more this system feels out of control, the greater the feelings of perceived Hopelessness. Indeed, being on constant alert for possible dangers has the effect of leaving the individual exhausted, and ironically *more* prey to frightening, intrusive thoughts. Although rebound effects have been reported after individuals attempt to suppress negative thoughts (38) and it is also possible to interpret hypervigilance as increasing one's sense of agency via feeling as though they are "doing something" about their symptoms, our findings suggest exhaustion as a result of prolonged sympathetic activation. Importantly, this effect was observed only for the newly traumatized group in our study, and was *not* observed for those in the prior trauma group, who seem to have learned to adapt to or cope with these symptoms, lessening their ultimate impact on hopelessness. As noted by Bonanno (2004) "even among resilient individuals... virtually all participants reported intrusive cognitions and rumination at some point early after the loss" (14), which suggests the prior trauma group would have previously confronted such symptoms. In fact, individuals at risk for PTSD are often counselled to anticipate and mitigate intrusive thoughts (39).[2] Previous experience with trauma may have taught these individuals that intrusive symptoms are to be expected — unpleasant but not necessarily threatening — and that hypervigilance is both distressing and ultimately counter-productive. That intrusive thoughts are specifically linked to sympathetic activation has been demonstrated using an analog trauma paradigm, which found that increased skin conductance (a marker of sympathetic activity) during presentation of a distressing film clip was associated with greater frequency of intrusions afterward (40). A prospective, longitudinal emergency department study in which skin conductance response (SCR) data was gathered within h of a real-life trauma event demonstrated that SCR magnitude significantly predicted which individuals would go on to develop chronic PTSD, lasting at least 1 year (41). The authors argued that their results supported the idea of sympathetic hyperactivity, perhaps leading to "overconsolidation" of distressing memories

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[2]https://www.verywellmind.com/ways-to-manage-your-ptsd-symptoms-2797613

in the development of PTSD. Taken together, these findings corroborate that what we are witnessing is nervous system exhaustion in the wildfire group, with repetitive attempts (and failures) in blocking negative thoughts and feelings resulting in a sense of defeat. Thus, contrary to expectations of the sensitization model, it appears that sympathetic overactivity was most pronounced in the group newly experiencing trauma, not in retraumatized individuals. For individuals undergoing significant trauma for the first time, increased psychoeducation regarding the nature of the sympathetic response is indicated, specifically that intrusive symptoms should be anticipated, and will dissipate; that constant vigilance is not healthy; and that sympathetic overload can be effectively managed (e.g., using deep breathing, systematic relaxation, and mindfulness techniques).

For the prior trauma group, as an unfortunate consequence of resignation that intrusive thoughts are forthcoming, depression may be the unfortunate, perhaps predictable, consequence. Perhaps it is to be expected that children and adolescents who have undergone previous trauma show the expected increases in some negative variables (specifically, depression), while at the same time their previous experience has also allowed them to adapt, such that intrusive thoughts do not ultimately determine whether or not they feel like a failure. This "decoupling" could account for why these individuals do not show the expected increases in suicidal ideation that relatively often accompany depression and PTSD symptomatology. For situations of mass disaster, it may in fact be helpful to have peer support from others who have undergone significant prior trauma to discuss how some of those cognitive skills can be helpful in coping, something which the newly traumatized may not yet appreciate. In the prescient words of Norris and Murrell (13), " 'experienced' victims could be a valuable resource in [mental illness] prevention efforts."

The idea of cognitive changes being important in resilience supports the work of Huang and Gan (42), who found a relationship between PTG and positive mental associations in adolescents who had survived the Sichuan earthquake in 2008. Beyond reappraisal, researchers have also found a positive role for distraction, as supported by previous studies using negative mood induction to study the effect of either expressive or distracting creative tasks (43, 44). But how is it possible that both cognitive reappraisal and distraction can be effective in decreasing stress? It is conceivable that, as Pat-Horenczyk and Brom (45) suggest, it is "through the *oscillation between remembering and avoiding* memories of their experience [that survivors] are able to integrate the memory, find meaning in the event, and resume a balance in their functioning" (italics added). If this is the case, it may be this oscillation to which retraumatized individuals have become accustomed, which proves at least somewhat protective.

However, this interpretation should be considered in light of the fact we did not see good model fit for the wildfire group, according to χ^2 criteria. This finding implies that, for newly traumatized adolescents, there is a need to explore the contributions of additional variables and relationships. One possibility suggested by our interpretation is that

PTSD symptoms (particularly those involved in sympathetic activation) feed back to concepts of anxiety and self efficacy — an effect we posit is absent for the prior trauma group. Additionally, the incorporation of constructs such as self-esteem (self-enhancement is associated with better trauma outcomes) (14); cognitive reappraisal strategies (46); use of creative outlets, which improve positive mood (43, 44), or self-medication strategies such as alcohol or drug use, is warranted. Research is underway to examine these potential avenues.

Finally, it is worth considering why our earlier line of investigation appeared to support the stress sensitization model, while this analysis points to inoculation effects indicative of PTG. In describing inoculation theory, Norris and Murrell (13) noted that such discrepancies were evident in the literature, and suggested that prior trauma experience may be helpful in cushioning the reaction to acute traumatic events, but prove less effective in helping to manage chronic stress. However, that explanation does not seem to adequately address why we have witnessed evidence for both sensitization and inoculation in the same group of subjects in response to the same event. We speculate that it could be our use of the Hopelessness concept that has allowed us to capture elements of PTG in this data. Our conceptualization of Hopelessness focused on "lack of faith in oneself or one's ability to assert one's sense of agency", which supports recent research finding that "hope agency" — confidence in being able to attain one's goals — accounted for additional variance in their model of suicide, over and above trauma history (47). Similarly, research has suggested that problem solving appraisal, the belief in one's capacity to effectively tackle problems, is independent of life stress in predicting suicidality (48). It is also consistent with recent research demonstrating a significant effect of both hope and trauma history, as well as their interaction, on anxiety and depression in college students (49). To this end, Clement et al. (50) note that optimism and a focus on goal-directed activity appear to be protective against suicide-related outcomes. It could be that developing a sense of hope and control over one's ability to effect positive change is an important lesson one can take away from past trauma.

In summary, differences between the prior trauma group and the wildfire group, as suggested by our model, point to some areas of PTG amongst individuals who have a prior trauma history. First, those in the prior trauma group appear more likely to benefit from a boost to self efficacy from peer support. Second, they seem less overconfident than those without a trauma history, which may be reflective of a more realistic appraisal of the challenges that accompany trauma. Third, having had firsthand experience, they may be less surprised or alarmed by symptoms of sympathetic reactivity that are associated with PTSD, such as hypervigilance or intrusive thoughts, and so may not experience the same level of anxiety as those who are newly traumatized. However, this wisdom may (quite reasonably) be accompanied by symptoms of depression. Still, the realization that one has tackled traumatic incidents before and made it through may be one of the most potent lessons that characterizes PTG in the midst of retraumatization.

LIMITATIONS

With respect to the model itself, it should be noted that model fit is dependent on the specific indicators chosen. For example, the indicator we chose for our concept of Hopelessness primarily reflected agency, which one could argue ties it closely to conceptions of self efficacy; a different choice of indicator could relate it more closely to depression. These different indicator choices would potentially then be subject to different interpretations by the respondent. Similarly, different indicator(s) could have been chosen for each of the four PTSD variables, again with various ramifications for interpretation and response. Moreover, because relationships between these different concepts (i.e., Hopelessness and PTSD) rest on such assumptions, the overall fit of the model could theoretically differ based on these modeling decisions.

As a related issue, we noted potential issues with the use of multiple indicator scales; in particular, model specification indices suggested problems with the items comprising the concept of Anxiety. This appeared to be due to their potential overlap with some of the symptom indicators of PTSD. Such issues are commonly associated with grouping indicators based on factor analytic techniques, as has been described elsewhere (51, 52). Thus, to maximize theoretical precision, we elected to use single indicators where we determined that one item best reflected the concept of interest. That said, the reader should be aware that this method is controversial, as it can be argued that these are less reliable and more open to potential bias than validated scales. For example, if a subject misreads or misunderstands the item in question, it will produce greater modeling variability than would a scale comprised of several items. On the other hand, using a scale which is multifactorial creates a different set of problems. This is reflected in the findings described earlier by Meyer et al. (31) where a four factor solution was found to fit the PTSD data better than the three factor one suggested by the publisher. It is problematic because one may find potentially conflicting concepts driving responses to different items. So, in the questions comprising the Anxiety scale, the item *worrying thoughts go through my mind* is representative of cognitive control, while the item *I feel restless and have to be on the move* is better representative of behavioral activation. While both of these items are associated with anxiety, there is no *de facto* reason to expect them to co-occur. As we noted above, other Anxiety items (such as *I get sudden feelings of panic*) are tied fairly closely to the concept of PTSD. This overlap makes the model less clear. Hence, even this scale, which we felt was significantly robust in terms of having items that well-represented the concept, still showed evidence of modeling difficulties. Conversely, using single indicators allowed us to hone in on specific questionnaire items that we thought best captured our concepts of interest. Moreover, picking the single item best aligned with each of the four DSM-V symptom categories of PTSD allowed us to identify that a different process appeared to be at work for those symptoms mediated by sympathetic activity. This would not have been possible had we simply used the factor scores. The reader is urged to consider such implications of item selection when making modeling choices.

Individual differences are another issue which need to be considered in light of our findings. With regard to prior trauma, we did not ask individuals to rate the extent to which they felt traumatized. That is, two individuals experiencing the same event (e.g., the death of a loved one), or even experiencing the same type of event at different times or under different circumstances, can experience very different subjective events. This is important given the postulated importance of a sense of control in one's response to events (4). This would have been a useful metric to include in the model. Similarly, our findings are not meant to imply that every individual with a trauma history will show improvement, nor that it will occur in all individuals to the same extent. Indeed, it is possible that only a significant minority of patients experience PTG.

It is also a limitation that individuals were asked about prior trauma retrospectively, as recall bias may be a factor. In other words, individuals experiencing difficulty may be more likely to attribute their feelings to past negative events, while those not experiencing psychological distress may be less likely to remember such events.

Finally, while the model implications suggest some degree of inoculation and PTG in our subjects with previous trauma, our measures did not attempt to examine indicators of PTG directly. We did gather information on resilience [see Brown et al. (25) for further details], but while these two concepts are similar, they are functionally distinct. Because resilience is a considered complex and dynamic, there is no agreed-upon definition for the construct (4, 53); that said, resilience could be conceived of as an ongoing, stable dimension of human experience, with some people showing higher levels than others. Conversely, PTG occurs only in the aftermath of, and in response to, a traumatic incident, and may not happen in everyone. Future studies should consider such distinctions specifically.

CONCLUSION

Between this study and our previous publication on the Fort McMurray wildfire (20), we show evidence of both sensitization and inoculation effects in the same subjects. Taken together, these papers contribute to the literature by demonstrating that both processes are likely at work at the same time. While it may be intuitive to think of individuals who have suffered previous loss and trauma primarily as victims due to their high rates of mental ill-health, this study demonstrates that, for some individuals, PTG may occur and act as a source of inoculation from the negative effects of trauma. The past experience of those with prior trauma appears to result in an improved capacity to draw personal strength from supportive peer relationships, even if those relationships are harder to come by. It may also grant these individuals the foresight to expect negative effects such as intrusive thoughts, while being able to ignore or discount the distressing hypervigilance that often attends trauma; this effectively "decouples" symptoms of sympathetic activation from emotional overreaction in those with a history of traumatic events. A trauma history may also protect individuals from overconfidence in thinking that the next distressing event will

be easy to manage. While such knowledge may be inherently depressing, it is also a source of potential source of strength.

Thus, to the extent that it is hopelessness that may drive individuals to acts of desperation like self-abuse and suicide, it may be that having endured past trauma can potentially have some benefits as a protective factor, *via* the knowledge that one can withstand and overcome other difficult events in the future — a phenomenon that has been described as hope agency. This knowledge may in fact be most useful for individuals experiencing trauma for the first time, who may be particularly sensitive to the disorienting effects of sympathetic activation that occur hand-in-hand with trauma, least cognizant of the value of experienced peers, and unaware of the potential for growth that trauma provides.

DATA AVAILABILITY STATEMENT

The data analyzed in this study is subject to the following licenses/restrictions: Data for this study is the property of the Fort McMurray Public and Catholic School Boards. Requests to access these datasets should be directed to Dr. Matthew Brown, mrbrown23@gmail.com.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by Health Research Ethics Board, University of Alberta. Written informed consent to participate in this study was provided by the participants' legal guardian/next of kin.

AUTHOR CONTRIBUTIONS

HP, MB, LH, and PS: study design. HP, MB, SN, MM, and DK: data collection. HP, MB, and LH: analysis. HP, MB, LH, CM-H, AG, VA, BL, JO, PB-M, and PS: manuscript preparation. All authors listed have made a substantial, direct and intellectual contribution to the work, and approved it for publication.

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SUPPLEMENTARY MATERIAL

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Physical and Mental Health Effects of Bushfire and Smoke in the Australian Capital Territory 2019–20

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The 2019–20 bushfire season in south-eastern Australia was one of the most severe in recorded history. Bushfire smoke-related air pollution reached hazardous levels in major metropolitan areas, including the Australian Capital Territory (ACT), for prolonged periods of time. Bushfire smoke directly challenges human health through effects on respiratory and cardiac function, but can also indirectly affect health, wellbeing and quality of life. Few studies have examined the specific health effects of bushfire smoke, separate from direct effects of fire, and looked beyond physical health symptoms to consider effects on mental health and lifestyle in Australian communities. This paper describes an assessment of the health impacts of this prolonged exposure to hazardous levels of bushfire smoke in the ACT and surrounding area during the 2019–20 bushfire season. An online survey captured information on demographics, health (physical and mental health, sleep) and medical advice seeking from 2,084 adult participants (40% male, median age 45 years). Almost all participants (97%) experienced at least one physical health symptom that they attributed to smoke, most commonly eye or throat irritation, and cough. Over half of responders self-reported symptoms of anxiety and/or feeling depressed and approximately half reported poorer sleep. Women reported all symptoms more frequently than men. Participants with existing medical conditions or poorer self-rated health, parents and those directly affected by fire (in either the current or previous fire seasons) also experienced poorer physical, mental health and/or sleep symptoms. Approximately 17% of people sought advice from a medical health practitioner, most commonly a general practitioner, to manage their symptoms. This study demonstrated that prolonged exposure to bushfire smoke can have substantial effects on health. Holistic approaches to understanding, preventing and mitigating the effects of smoke, not just on physical health but on mental health, and the intersection of these, is important. Improved public health messaging is needed to address uncertainty about how individuals can protect their and their families health for future events. This should be informed by identifying subgroups of the population, such as those with existing health conditions, parents, or those directly exposed to fire who may be at a greater risk.

Keywords: bushfire, wildfire, natural disaster, biomass smoke, respiratory health, mental health, Australia

INTRODUCTION

During the summer of late 2019 and early 2020, extensive areas of south-eastern Australia experienced one of the most severe bushfire seasons in recorded history. Over 10 million hectares of land were burnt, and over 2,400 homes were destroyed in New South Wales (NSW) alone. Bushfire smoke-related air pollution reached hazardous levels in major metropolitan areas including Canberra, Australia's capital, in the Australian Capital Territory (ACT). Between 15 December and 15 February in the ACT, 27% of days ($n = 17/63$ days) had air quality levels that were considered extremely poor (≥ 300 PM$_{2.5}$ μg/m^3) and on three quarters of days ($n = 47/63$ days), air quality was classified as poor or worse (≥ 50 PM$_{2.5}$ μg/m^3) at one or more of Canberra's three air quality monitoring stations (1) [using thresholds defined by NSW Department of Planning, Industry and Environment (2)]. On the worst days, hourly levels reached well over 1000 PM$_{2.5}$ μg/m^3.

Bushfire is an inevitable and essential part of natural Australian ecosystems; however, the severity and duration of fire seasons are projected to increase globally with climate change (3). A recent study concluded that as a result of anthropogenic climate change, the prevalence of days of high-risk bushfire weather has increased, conservatively, by at least 30% since 1900 (4). As a result of predicted changes to bushfire patterns, the health and community impacts of bushfire are likely to increase unless effective adaptation measures are implemented. The public health impacts of bushfire extend beyond direct exposure to the fire itself, with increasing awareness of the effects of bushfire smoke-related air pollution (5). Smoke can travel long distances and affect large populations, even in urban areas geographically separated from fire (6). Bushfire smoke can have considerable impacts on health; it is estimated 340,000 deaths can be attributed to bushfire smoke globally each year (7). Fine particulate matter, i.e., particles <2.5 micrometers in diameter (PM$_{2.5}$), can adversely affect health via impaired respiratory and cardiac functioning, promotion of inflammation, and alteration of immune function (8, 9). Bushfire-related air pollution has also been associated with increases in mortality (10–12) and the effects of smoke can be more severe in populations with particular vulnerability, such as those with pre-existing medical conditions including cardiovascular disease or respiratory conditions (13, 14).

In bushfire events, it can be difficult to separate the health effects associated with direct displacement, loss, or exposure to fire from those of bushfire smoke. Most studies examining the effects of bushfire smoke on health have used routinely collected health data such as emergency department presentations, hospital admissions and mortality (5), which are very likely to underestimate the effects on the population by capturing only those affected severely enough to require seeking secondary or tertiary-level health care. Prior studies have also focused primarily on physical health concerns, with few studies taking a holistic approach to the assessment of health by including measures of mental health and lifestyle in addition to physical health.

The 2019–20 bushfire season affecting south-eastern Australia elicited widespread public concern due to its duration, and uncertainty about potential immediate and long-lasting health effects of prolonged smoke exposure. In addition, individuals experienced considerable uncertainty about how to protect the health and wellbeing of themselves and their families during this period (15). A preliminary evaluation of the air pollution health burden in eastern Australia estimated that bushfire smoke was responsible for 417 (95% CI, 153–680) excess deaths, over 3,000 excess hospitalizations for cardiovascular (1,124; 95% CI, 211–2,047) and respiratory (2,027; 95% CI, 0–4,252) problems, and 1,305 (95% CI, 705–1,908) presentations to emergency departments with asthma (16). The total smoke-related physical health costs during the 2019–20 bushfire period have been estimated at AU\$1.95 billion (17). The 2019–20 bushfires were of particular interest in the Canberra and surrounding community, as this area experienced a severe bushfire in January 2003. During this earlier disaster, almost 160,000 hectares of land were burnt, 448 houses were destroyed (and a much greater number damaged), over 5,000 people were evacuated, four people died and hundreds of people received medical care (18).

This paper presents the findings of a cross-sectional study examining the effects of prolonged exposure to hazardous levels of bushfire smoke-related air pollution on the physical health, mental health, and sleep patterns of residents of the ACT region during the 2019–20 bushfire season and how these vary by demographic and lifestyle factors.

MATERIALS AND METHODS

Study Design

This cross-sectional survey asked participants about their experiences during a "period of interest" defined as 15 December 2019 to 15 February 2020, as this was the period during which the most significant levels of bushfire smoke-related air pollution (hereafter referred to as "smoke") affected the Canberra region.

Participant Recruitment

The survey was conducted over a six-week period in March and April 2020. The sampling frame included all adult residents of the ACT and immediately adjacent regions of NSW. Inclusion criteria were: aged 18 years or older, able to understand an online questionnaire in English, and a residential address defined by specific postcode areas constituting the ACT and immediately surrounding postcodes (2600–2612, 2614–2620, 2626, 2900–2906, 2911–2914).

Participants were recruited using three methods: (i) Letter–An invitation to complete the online survey was posted to a random selection of 10 000 addresses, selected from the ACTmapi database ("ACT Addressing" from ACTmapi ©Australian Capital Territory). Any addresses identified as non-residential (e.g., businesses, schools) were removed and replaced prior to the mail out; (ii) Panel–A representative population sample of participants recruited by an external company; (iii) General–A convenience sample of the population was recruited via social media, radio advertisements and word of mouth, including interest from local media.

Data Collection

Potential participants were invited to complete the online survey via REDCap electronic data capture tools hosted at Australian National University (19). The survey was available in English and in an online format only. Participants provided consent by submitting a completed survey. Two participants that received a letter mailout invitation and who did not have internet access completed the survey by phone with a study team member recording their responses.

The survey collected: postcode of residence, age (years), highest level of education achieved (no school qualification/school or intermediate/ HSC or leaving certificate/ trade or apprenticeship/ certificate or diploma/ university or higher), tobacco smoking (never/past/current), rental status (renter/owner-occupier/other), pregnancy status (self/partner/none/not applicable), parental (yes/no and age of youngest child) or carer status (yes/no); previous medical diagnoses [asthma/chronic obstructive pulmonary disease (COPD–including emphysema and chronic bronchitis)]/allergies or hay fever/other respiratory disease (e.g., pleurisy, bronchiectasis, pulmonary fibrosis)/multiple sclerosis/arthritis/diabetes/other), engagement with a professional for a mental health concern during the last 12 months (yes/no) and self-rated health (poor/fair/good/very good/excellent); prior exposure to bushfire (no previous exposure to bushfire/been in an area with fire nearby/evacuated due to bushfire/experienced loss of or damage to property/had direct contact with bushfire (e.g.,firefighter or protecting property)/other) including whether this was during the 2003 Canberra bushfire (yes/no); direct exposure to bushfire in the current season (not affected/voluntarily relocated/forced to evacuate/damage to or loss of property/family or close friend affected/had to cancel or alter travel or holiday plans/firefighter or first responder/other); effects of smoke on physical health (eye irritation or watery eyes/throat irritation or dry throat/cough/wheeze or whistling chest/sneezing/chest tightness or pain/breathlessness/headache/diarrhea or gastroenterological symptoms/other condition not listed), sleep (disrupted or poor sleep/fatigue or feeling tired) and mental health (anxiety/feeling depressed) symptoms and whether these were attributed to smoke (yes/no/unsure); health advice sought as a result of symptoms (yes/no, hospital inpatient/emergency department/general practitioner/specialist/24 h health advice hotline/pharmacist/mental health professional e.g., psychologist/other health professional).

Data Analysis

Data Management

Summary statistics were used to describe the study's participants (**Table 1**) using demographic, health and lifestyle variables as described in **Table 2**. To explore physical health outcomes, data were divided into quartiles based on the cumulative number of physical health symptoms reported. A mental health outcome variable was created by including those who self-reported anxiety and/or feeling depressed as a result of smoke. Similarly, a sleep outcome variable was created by combining those who reported

TABLE 1 | Description of sample characteristics.

Factor	n (%)
Gender	
Male	831 (40.2)
Female	1,231 (59.6)
Other	4 (0.2)
Age (years)	45 (SD 16.8) min 18, max 85
18–24	128 (6.1)
25–34	396 (19.0)
35–44	328 (15.7)
45–54	310 (14.9)
55–64	427 (20.5)
65-74	381 (18.3)
75+	113 (5.4)
Education	
No school qualification, school or intermediate, HSC or leaving	266 (12.9)
Trade, apprenticeship, certificate or diploma	346 (16.8)
University	1,451 (70.3)
Parent (Yes)	548 (26.5)
Age of youngest child	
0–18 month	113 (20.8)
>18 month−4 years	123 (22.7)
5–11 years	176 (32.4)
12–17 years	131 (24.1)
Carer (Yes)	317 (15.4)
Pregnant (Self)	43 (2.1)
Self-rated health	
Poor-Fair	205 (10.6)
Good-Excellent	1,730 (89.4)
Previous diagnosis of a physical health condition (Yes)	1,241 (62.5)
Previous diagnosis of a mental health condition (Yes)	441 (29.4)
Renter (Yes)	295 (22.2)
Smoker	
Never	1,490 (72.3)
Past	512 (24.9)
Current	58 (2.8)
Direct fire exposure—current season	
None	859 (41.7)
Mild	1,032 (50.1)
Severe	168 (8.2)
Cumulative direct fire exposure in current season (number of experiences)	
0	880 (42.2)
1	787 (37.8)
2	315 (15.1)
3	88 (4.2)
4	13 (0.6)
5	1 (0.1)

(Continued)

Factor	n (%)
Previous Fire Exposure	
None	686 (33.0)
Mild	1,173 (56.5)
Severe	217 (10.5)
Exposure to 2003 Canberra bushfires (Yes)	905 (43.4)
Cumulative previous fire exposure (number of experiences)	
0	689 (33.1)
1	1,271 (61.0)
2	98 (4.7)
3	24 (1.2)
4	2 (0.1)

disrupted or poor sleep and/or fatigue or feeling tired. Although scaled, validated measures, especially of mental and physical health status, are generally preferable, this paper reports results of a rapid research response developed during the bushfire crisis, with the intention of reporting responses during or soon after the emergency in a way that would be helpful for future researchers and public health officials. Accordingly, our outcomes measures are brief assessments. They were developed from the research team's expertise in different contexts, and are based on our previous research (13, 15, 20).

Statistical Analysis

All analyses were conducted in Stata (v15.1, College Station, TX StataCorp LLC). Summary statistics were used to describe the study sample as detailed in **Table 1**. Number (%) were used to describe categorical variables and mean (SD) to describe continuous data. Descriptive statistics were calculated to examine the prevalence of self-reported physical health, sleep and mental health symptoms, overall and for men and women which were compared using Chi^2 analyses. Ordinal logistic regression was used to identify factors (as per **Table 2**) that were associated with higher physical health symptoms. Bivariate analyses including age, gender and age*gender interaction were then conducted for factors for which $p \le 0.1$. Logistic regression was used to determine factors that were associated with either disrupted sleep or mental health symptoms. Similar bivariate analyses were conducted to develop sleep and mental health models. Summary statistics [n (%)] were used to describe sources of health advice sought, overall and separately for males and females, which were compared using Chi^2 analyses.

RESULTS

Population

A total of 2,095 completed responses to the survey were received; 644 (30.7%), 639 (30.5%), and 812 (38.8%) people recruited via the panel, letter and general recruitment methods respectively. This was a response rate of approximately 6.4% to the letter invitations, although many were returned to sender so it was unclear how many were undelivered. Eleven responses were excluded as the participant resided outside of the target area or did not provide a valid postcode. This resulted in a total sample of 2,084 responses that were included in subsequent analyses.

Participant characteristics are summarized in **Table 1**. Of the study participants, 40.2% were male, 59.6% were female, and 0.2% identified as being of another gender. The mean age of respondents was 45 years (median 45, range 18–85 years), approximately 10 years older than the median age of ACT residents. Approximately 13% of the sample had completed a high school certificate or less, 17% a trade, apprenticeship, certificate or diploma, and 70% had completed a University degree. This suggests that the sample included a greater proportion of women, was on average older, and more highly educated than the ACT population compared with data from the Australian Bureau of Statistics (21).

Approximately a quarter of respondents were parents, 15.4% were carers for one or more non-child dependents and 22% of participants rented their place of residence. Forty-three respondents (2.1%) were pregnant during the period of interest, 11% rated their own health as poor-fair (vs 89% good-excellent), 3% were current smokers, 25% were ex-smokers and 72% had never smoked. Over half of the sample (58%) had been directly affected by fire (not just smoke) during the 2019–20 bushfire season, with 8% of the total sample reporting being affected severely. Previous direct exposure to bushfire had been reported by 67% of the sample, 10.5% severely. For most participants (43% of the total sample), this exposure had been during the 2003 Canberra bushfire event.

Physical Health

Most participants (97.1%) reported experiencing at least one specified physical health symptom during the period of interest that they attributed to the smoke (**Table 3**). The most common symptoms were eye irritation or watery eyes (73.1%), throat irritation or dry throat (70.4%) and cough (50.6%). A considerable proportion of people also reported experiencing headaches (38.2%), breathlessness (21.9%), sneezing (21%) or wheeze/whistling chest (19.9%). A small number of people (3.2%) also reported experiencing other (non-itemized) physical or mental health impacts of the smoke including asthma, bronchitis, itchy skin/rash, runny nose, sinusitis and mental trauma. Women reported all physical symptoms more frequently than men ($p < 0.001$ for all other than sneeze $p < 0.05$) and had almost three times the odds of men of experiencing a greater number of physical health conditions as a result of exposure to smoke (2.92 ± 0.344, $p < 0.001$) (**Table 4**). After accounting for age and gender, those participants with poorer self-rated health (2.13 ± 0.344, $p < 0.001$), a previous diagnosis of either a physical (2.18 ± 0.266, $p < 0.001$) or mental health condition (1.64 ± 0.206, $p < 0.001$), or were a past (but not current) smoker (1.83 ± 0.226; $p < 0.001$), had greater odds of experiencing more physical symptoms. Any direct exposure with fire this season increased odds of experiencing a greater number of health symptoms (1.64 ± 0.186, $p < 0.001$). The effect was strongest in those who had experienced more severe effects of bushfire compared to those

Variable	Description
Gender	Due to the small number of "other" responses, gender was included in regression models as binary variable (male vs. female)
Age	Explored as either continuous (years) or categorical (18–24, then 10 year bins (e.g., 25–34) up to 75+ years) variables
Parent	No vs. yes (parent of one or more children under 18 years)
Parent age	Age of youngest child grouped into 0–18 months, under 5 years, 5–11 years, 12–17 years
Carer	No vs. yes (carer of one or more non-child dependents)
Pregnant	No vs. yes (self-pregnant)
Self-rated health	Grouped into two groups; fair and poor vs. excellent, very good and good
Previous physical health diagnosis	No vs. yes (one or more previous diagnoses)
Previous mental health diagnosis	No vs. yes (engagement with a professional for a mental health concern during the last 12 months)
Renter	Two categories–owner-occupier vs. renter
Smokers	Three categories–never, past, current
Education	The level of education completed was grouped into: no school qualification, school or intermediate, HSC or leaving; vs. Trade or apprenticeship, certificate or diploma; vs. university or higher
Direct fire exposure	Direct exposure to fire in the current season was measured as: 1. Any exposure—yes/no if any direct exposures to fire were indicated; 2. Scale—a scale was created consisting of three levels of exposure—none (none or indirect), mild (classified as responses limited to being in an area with fire nearby, evacuation due to bushfire, area of significance lost other than home, family member was affected, home was affected while away), and severe (if experience included loss of or damage to property or direct contact with fire e.g., firefighter or protecting property); 3. Cumulative—the number of ways in which the participant has previously been exposed for fire were added
Previous fire exposure	Previous exposure to fire was measured as: 1. Any exposure—yes/no if any previous exposures were indicated; 2. Scale—a scale was created with three levels of exposure—None (not affected, effects were limited to health and/or smoke effects), mild (responses limited to voluntary evacuation, family or close friend affected, cancellation or alteration of holiday plans/events, business or work affected), and severe (if experience included forced evacuation, damage to or loss of property, firefighter, first responder, volunteer, protected property, alert to evacuate, worry about property or risk);Cumulative—The number of ways in which the participant has previously been exposed for fire were added
2003 fires	For those that indicated previous exposure to fire, no (exposure was a result of another fire event) vs. yes (experience was as a result of 2003 fire in Canberra)

who reported mild exposure to fire (2.47 ± 0.465 vs. 1.52 ± 0.178; $p < 0.001$). Previous fire exposure increased the odds of experiencing more physical health symptoms, whether this was defined as any previous exposure (1.55 ± 0.182, $p < 0.001$), mild or severe exposure (1.51 ± 0.181; $p = 0.001$, 1.82 ± 0.345; $p = 0.001$, for mild and severe respectively) or as a cumulative measure (1.40 ± 0.121; $p < 0.001$). Having experienced the 2003 Canberra bushfires did not statistically increase the odds of experiencing a greater number of negative physical health symptoms (1.56 ± 0.447; $p = 0.124$). Parental, carer, pregnancy or education status were not associated with an increase in physical health symptoms.

Mental Health

Over 55% of responders self-reported symptoms of anxiety (45.3%) and/or feeling depressed (21.4%) as a result of the smoke (**Table 3**). Women were more likely than men to report negative mental health outcomes (1.99 ± 0.192, $p < 0.001$) which reflected increased symptoms of both anxiety (54.5 vs. 31.8%) and feelings of depression (25.5 vs. 15.5%). Poor mental health outcomes were associated with younger age groups (25–54 years groups). Bivariate models (**Table 5**) identified parents (1.27 ± 0.142; $p = 0.029$), individuals with an existing physical (1.35 ± 0.138; $p = 0.004$) or mental health diagnosis (1.30 ± 0.164; $p = 0.038$), and those who had obtained a higher level of education (high school or lower vs. trade/diploma: 1.46 ± 0.257, $p = 0.032$ vs university:

1.42 ± 0.208; $p = 0.015$) had greater odds of experiencing negative mental health outcomes (**Table 5**). Direct exposure to fire in the current season was associated with increased reported symptoms of anxiety and feeling depressed, according to all measures used ($p \leq 0.001$). Of note, severe bushfire exposure had a stronger effect on mental health than mild exposure (1.87 ± 0.344 and 1.46 ± 0.148 for severe and mild, respectively). Exposure to fire in a previous season, including during the 2003 Canberra fires, was not associated with mental health outcomes.

Sleep

Half of survey respondents reported poorer sleep as a result of exposure to smoke (**Table 3**). This was defined as either disrupted or poor sleep (37.2%) and/or fatigue or feeling tired (32.5%). Females were more likely to experience poorer sleep outcomes than men (1.75 ± 0.168, $p < 0.001$). Odds of poor sleep outcomes were increased in younger age groups. When age and gender were accounted for, those with poorer self-rated health (2.01 ± 0.339; $p < 0.001$), or a previous diagnosis of a physical health condition (1.34 ± 0.136; $p < 0.01$) all had greater odds of experiencing smoke-attributed impairments in sleep (**Table 6**). Direct exposure to fire in the current fire season increased the odds of poor sleep outcomes, irrespective of the measure used ($p < 0.001$). This effect was more pronounced in those who had experienced more severe exposure (1.81 ± 0.326 vs. 1.34 ± 0.135 for mild vs. severe exposure, respectively). The

TABLE 3 | Proportion of surveyed ACT region residents that experienced health-related symptoms attributed to bushfire smoke during the 2019–20 bushfire season.

Symptom	Number experiencing the symptom n (%)		
	All	**Male**	**Female**
	$n = 2,084$	$n = 832$	$n = 1,231$
Physical symptoms			
Eye irritation or watery eyes	1,525 (73.1)	544 (65.3)	967 (78.6)
Throat irritation or dry throat	1,469 (70.4)	506 (60.8)	950 (77.2)
Cough	1,056 (50.6)	346 (41.5)	702 (57.0)
Headache	797 (38.2)	184 (22.1)	607 (49.3)
Breathlessness	457 (21.9)	126 (15.0)	326 (26.5)
Sneezing	437 (21.0)	153 (18.4)	278 (22.6)
Wheeze or whistling chest	416 (19.9)	103 (12.3)	307 (24.9)
Chest tightness or pain	314 (15.1)	71 (8.5)	242 (19.7)
Diarrhea or gastroenterological symptoms	51 (2.4)	6 (0.7)	44 (3.6)
Other condition not listed	67 (3.2)	19 (2.3)	47 (3.8)
Mental health symptoms			
Anxiety	945 (45.3)	265 (31.9)	670 (54.4)
Depression	447 (21.4)	129 (15.5)	314 (25.5)
Sleep-related symptoms			
Disrupted or poor sleep	776 (37.2)	234 (28.1)	535 (43.5)
Fatigue or feeling tired	677 (32.5)	187 (22.5)	482 (39.2)

Difference between gender $P < 0.001$ for all other than sneeze $P = 0.022$, and other $P = 0.05$.

odds of poor sleep outcomes were increased in the group who had experienced more severe exposures to fire in a previous season (1.82 ± 0.312; $p < 0.001$), and tended to be increased to a lesser extent in the group who had more mild experiences (1.29 ± 0.135; p = 0.014).

Medical Advice

Approximately 17% of people reported they sought advice from a health professional or medical facility in relation to their smoke-attributed symptoms (**Table 7**). The most commonly accessed source was a general practitioner (13.2%), followed by pharmacist (3.6%) and mental health professional (2%). Females were more likely to have sought health advice than males (21 vs. 11%, p <0.001).

DISCUSSION

The extreme 2019–20 Australian bushfire season increased the burden on the health system (22). The current study indicates substantial self-reported effects of bushfire smoke on the ACT community's physical, mental health and sleep patterns, with almost all respondents reporting at least one negative health effect during this time. The most common symptoms (eye and throat irritation, cough) were consistent with other studies (23) and the known short-term effects of exposure to very high levels of $PM_{2.5}$. Bushfire smoke-related air pollution reached hazardous levels in the ACT over a longer period and to higher levels than previously reported in other areas of south eastern Australia (23, 24). In the current ACT study, 97% of the sample reported at least one smoke-related health symptom, whereas prevalence of similar health conditions was 65.1% in the Hunter-New England area (25, 26), and 16.1% in a control population located in Hobart, Tasmania that was not affected by smoke.

The smoke-attributable health burden experienced in the ACT region is higher than other studies of the health effects of smoke (23). Other studies have relied on emergency presentations or hospital records to identify those experiencing negative health outcomes (8, 27–30), but the current study drew on self-reported effects from community members, only ~1% of whom presented at a hospital. Presentation measures only capture medical conditions severe enough for individuals to seek clinical care, therefore underestimating the total health burden. These measures may also miss mental health conditions, for which support may be sought elsewhere. The extent to which this study documents smoke effects is significant and concerning. The prevalence of health conditions for which formal medical advice was not sought highlights the importance of interventions to better prepare people on ways to reduce exposure during periods of hazardous air pollution and when to seek help. Barriers to accessing medical and psychological care were not investigated in this study, but future studies should examine this. Further epidemiological studies that accurately measure individual smoke exposure will be able to better characterize specific health impacts of severe smoke, or thresholds for these, and give more accurate advice about how and when individuals should protect their health.

Smoke exposure is known to exacerbate existing health conditions (14). Our finding that participants with an existing

TABLE 4 | Ordinal logistic regression examining factors associated with odds of greater number of self-reported physical health symptoms attributed to bushfire smoke exposure.

	Univariate			Bivariate[a]		
	OR (SE)	95%CI	*P*-value	OR (SE)	95%CI	*P*-value
Gender	2.92 (0.344)	2.31–3.68	<0.001			
Age (years)	0.99 (0.003)	0.98–1.00	0.001			
18–24	1.00					
25–34	0.23 (0.245)	0.03–1.81	0.165			
35–44	0.26 (0.275)	0.03–2.06	0.203			
45–54	0.35 (0.379)	0.04–2.89	0.332			
55–64	0.41 (0.439)	0.05–3.33	0.405			
65–74	0.32 (0.336)	0.04–2.53	0.278			
75+	0.10 (0.106)	0.01–0.82	0.032			
Parent	1.14 (0.130)	0.91–1.42	0.257			
Age of youngest child						
0–18m	1.00					
>18 month−4 years	1.42 (0.433)	0.78–2.58	0.255			
5–11 years	1.43 (0.408)	0.82–2.50	0.209			
12–17 years	1.41 (0.424)	0.78–2.54	0.260			
Carer	1.17 (0.160)	0.89–1.53	0.266			
Pregnant	1.20 (0.412)	0.61–2.35	0.598			
Self-rated health	2.05 (0.317)	1.51–2.77	<0.001	2.13 (0.344)	1.56–2.93	<0.001
Previous physical health diagnosis	2.20 (0.257)	1.75–2.76	<0.001	2.18 (0.266)	1.72–2.77	<0.001
Previous mental health diagnosis	1.73 (0.209)	1.36–2.19	<0.001	1.64 (0.206)	1.28–2.09	<0.001
Renter	1.32 (0.187)	1.00–1.75	0.046	1.24 (0.194)	0.92–1.69	0.163
Smoker						
Never	1.00					
Past	1.54 (0.170)	1.23–1.93	<0.001	1.83 (0.226)	1.44–2.33	<0.001
Current	1.34 (0.402)	0.74–2.41	0.331	1.50 (0.463)	0.82–2.74	0.193
Education						
No school qualification, school or intermediate, HSC or leaving	1.00					
Trade, apprentership, certificate or diploma	1.20 (0.229)	0.84–1.75	0.314			
University	1.05 (0.165)	0.77–1.43	0.757			
Direct fire[b]						
Any exposure	1.85 (0.202)	1.49–2.29	<0.001	1.64 (0.186)	1.31–2.04	<0.001
2. Scale–None	1.00					
Mild	1.72 (0.195)	1.38–2.15	<0.001	1.52 (0.178)	1.21–1.91	<0.001
Severe	2.73 (0.497)	1.91–3.90	<0.001	2.47 (0.465)	1.71–3.58	<0.001
3. Cumulative	1.44 (0.080)	1.29–1.60	<0.001	1.35 (0.079)	1.21–1.51	<0.001
Previous Fire[c]						
1. Any exposure	1.36 (0.153)	1.09–1.69	0.006	1.55 (0.182)	1.23–1.95	<0.001
2. Scale – none	1.00					
Mild	1.35 (0.156)	1.08–1.70	0.009	1.51 (0.181)	1.19–1.91	0.001
Severe	1.40 (0.252)	0.98–1.99	0.063	1.82 (0.345)	1.26–2.64	0.001
3. Cumulative	1.31 (0.108)	1.11–1.54	0.001	1.40 (0.121)	1.19–1.66	<0.001
Canberra bushfires 2003	1.56 (0.447)	0.89–2.73	0.124			

[a]Bivariate models included factors along with gender, age and gender*age interaction; [b]Direct exposure to fire in the current season was measured as: 1. Any exposure – yes/no if any direct exposures to fire were indicated; 2. Scale—a scale was created consisting of three levels of exposure—none (none or indirect), mild (classified as responses limited to being in an area with fire nearby, evacuation due to bushfire, area of significance lost other than home, family member was affected, home was affected while away), and severe (if experience included loss of or damage to property or direct contact with fire e.g., firefighter or protecting property); 3. Cumulative—the number of ways in which the participant has previously been exposed for fire were added; [c]Previous exposure to fire was measured as: 1. Any exposure–yes/no if any previous exposures were indicated; 2. Scale–a scale was created with three levels of exposure—None (not affected, effects were limited to health and/or smoke effects), mild (responses limited to voluntary evacuation, family or close friend affected, cancellation or alteration of holiday plans/events, business or work affected), and severe (if experience included forced evacuation, damage to or loss of property, firefighter, first responder, volunteer, protected property, alert to evacuate, worry about property or risk); 3. Cumulative–The number of ways in which the participant has previously been exposed for fire were added.

TABLE 5 | Logistic regression examining factors associated with self-reported negative mental health outcomes attributed to bushfire smoke exposure.

	Univariate			Bivariate[a]		
	OR (SE)	95%CI	P-value	OR (SE)	95%CI	P-value
Gender	1.99 (0.192)	1.65–2.40	<0.001			
Age (years)	0.99 (0.003)	0.98–0.99	<0.001			
18–24	1.00					
25–34	1.71 (0.365)	1.12–2.59	0.012			
35–44	2.07 (0.455)	1.34–2.18	0.001			
45–54	1.59 (0.350)	1.03–2.45	0.034			
55–64	1.13 (0.239)	0.75–1.72	0.549			
65–74	0.96 (0.205)	0.63–1.46	0.837			
75+	0.70 (0.201)	0.40–1.23	0.212			
Parent	1.43 (0.150)	1.16–1.75	0.001	1.27 (0.142)	1.02–1.59	0.029
Age of youngest child						
0–18m	1.00			1.00		
>18 month−4 years	1.25 (0.354)	0.72–2.18	0.423	1.26 (0.364)	0.71–2.22	0.426
5–11 years	0.95 (0.242)	0.58–1.57	0.848	0.96 (0.257)	0.57–1.62	0.885
12–17 years	0.60 (0.162)	0.35–1.02	0.058	0.60 (0.173)	0.34–1.06	0.078
Carer	0.89 (0.114)	0.69–1.15	0.367			
Pregnant	1.51 (0.526)	0.77–2.99	0.234			
Self-rated health	1.17 (0.186)	0.86–1.60	0.323			
Previous physical health diagnosis	1.32 (0.130)	1.09–1.60	0.004	1.35 (0.138)	1.10–1.64	0.004
Previous mental health diagnosis	1.45 (0.178)	1.14–1.85	0.002	1.30 (0.164)	1.01–1.66	0.038
Renter	1.12 (0.157)	0.85–1.48	0.409			
Smoker						
Never	1.00					
Past	1.06 (0.115)	0.86–1.31	0.592			
Current	0.86 (0.240)	0.49–1.48	0.579			
Education						
No school qualification, school or intermediate, HSC or leaving	1.00					
Trade, apprentership, certificate or diploma	1.40 (0.243)	1.00–1.97	0.050	1.46 (0.257)	1.03–2.06	0.032
University	1.37 (0.196)	1.04–1.82	0.026	1.42 (0.208)	1.07–1.90	0.015
Direct fire[b]						
1. Any exposure	1.65 (0.157)	1.37–1.99	<0.001	1.51 (0.149)	1.25–1.83	<0.001
2. Scale–None	1.00			1.00		
Mild	1.60 (0.157)	1.32–1.94	<0.001	1.46 (0.148)	1.20–1.78	<0.001
Severe	2.02 (0.365)	1.42–2.88	<0.001	1.87 (0.344)	1.31–2.69	0.001
3. Cumulative	1.41 (0.077)	1.26–1.57	<0.001	1.34 (0.076)	1.20–1.50	<0.001
Previous Fire[c]						
1. Any exposure	0.96 (0.095)	0.79–1.17	0.683			
2. Scale -None	1.00					
Mild	0.92 (0.094)	0.75–1.12	0.412			
Severe	1.23 (0.205)	0.88–1.70	0.223			
3. Cumulative	1.08 (0.082)	0.93–1.25	0.346			
Canberra bushfires 2003	1.05 (0.097)	0.87–1.26	0.621			

[a]Bivariate models included factors along with gender, age and gender*age interaction; [b]Direct exposure to fire in the current season was measured as: 1. Any exposure—yes/no if any direct exposures to fire were indicated; 2. Scale—a scale was created consisting of three levels of exposure—none (none or indirect), mild (classified as responses limited to being in an area with fire nearby, evacuation due to bushfire, area of significance lost other than home, family member was affected, home was affected while away), and severe (if experience included loss of or damage to property or direct contact with fire e.g., firefighter or protecting property); 3. Cumulative—the number of ways in which the participant has previously been exposed for fire were added; [c]Previous exposure to fire was measured as: 1. Any exposure–yes/no if any previous exposures were indicated; 2. Scale–a scale was created with three levels of exposure—None (not affected, effects were limited to health and/or smoke effects), mild (responses limited to voluntary evacuation, family or close friend affected, cancellation or alteration of holiday plans/events, business or work affected), and severe (if experience included forced evacuation, damage to or loss of property, firefighter, first responder, volunteer, protected property, alert to evacuate, worry about property or risk); Cumulative–The number of ways in which the participant has previously been exposed for fire were added.

TABLE 6 | Logistic regression examining factors associated with negative self-reported sleep outcomes attributed to bushfire smoke exposure.

	Univariate			Bivariate[a]		
	OR (SE)	95%CI	*P*-value	OR (SE)	95%CI	*P*-value
Gender	1.75 (0.168)	1.45–2.11	<0.001			
Age (years)	0.99 (0.003)	0.98–0.99	<0.001			
18–24	1.00					
25–34	1.69 (0.361)	1.11–2.57	0.014			
35–44	1.47 (0.321)	0.96–2.26	0.075			
45–54	1.51 (0.333)	0.98–2.33	0.059			
55–64	1.15 (0.243)	0.76–1.74	0.516			
65–74	0.89 (0.191)	0.58–1.35	0.579			
75+	0.81 (0.233)	0.46–1.43	0.470			
Parent	1.29 (0.133)	1.05–1.58	0.015	1.18 (0.129)	0.96–1.47	0.121
Age of youngest child						
0–18 months	1.00					
>18 month-4 years	1.67 (0.451)	0.99–2.84	0.056	1.63 (0.448)	0.95–2.79	0.077
5–11 years	1.68 (0.416)	1.03–2.73	0.036	1.66 (0.430)	0.996–2.76	0.052
12–17 years	1.25 (0.330)	0.75–2.10	0.394	1.29 (0.364)	0.74–2.25	0.363
Carer	0.96 (0.123)	0.74–1.23	0.733			
Pregnant	1.42 (0.481)	0.73–2.76	0.298			
Self-rated health	1.97 (0.324)	1.43–2.72	<0.001	2.01 (0.339)	1.45–2.80	<0.001
Previous physical health diagnosis	1.32 (0.129)	1.09–1.60	0.005	1.34 (0.136)	1.10–1.63	0.004
Previous mental health diagnosis	1.19 (0.140)	0.95–1.50	0.133			
Renter	1.23 (0.169)	0.94–1.61	0.135			
Smoker						
Never	1.00					
Past	1.08 (0.116)	0.88–1.33	0.472			
Current	1.28 (0.362)	0.74–2.23	0.379			
Education						
No school qualification, school or intermediate, HSC or leaving	1.00					
Trade, apprentership, certificate or diploma	1.12 (0.193)	0.80–1.57	0.522			
University	0.88 (0.125)	0.66–1.16	0.357			
Direct fire[b]						
1.Any exposure	1.54 (0.146)	1.28–1.85	<0.001	1.40 (0.137)	1.15–1.69	0.001
2. Scale–None	1.00					
Mild	1.48 (0.144)	1.22–1.79	<0.001	1.34 (0.135)	1.10–1.63	0.004
Severe	1.98 (0.351)	1.40–2.80	<0.001	1.81 (0.326)	1.27–2.58	0.001
3. Cumulative	1.29 (0.068)	1.16–1.43	<0.001	1.22 (0.067)	1.10–1.36	<0.001
Previous Fire[c]						
1. Any exposure	1.22 (0.121)	1.01–1.49	0.039	1.36 (0.139)	1.11–1.66	0.003
2. Scale–None	1.00					
Mild	1.18 (0.120)	0.97–1.44	0.095	1.29 (0.135)	1.05–1.59	0.014
Severe	1.48 (0.245)	1.07–2.05	0.018	1.82 (0.312)	1.30–2.55	<0.001
3. Cumulative	1.16 (0.088)	0.999–1.35	0.051	1.24 (0.098)	1.06–1.45	0.006
Canberra bushfires 2003	1.07 (0.099)	0.89–1.28	0.452			

[a]Bivariate models included factors along with gender, age and gender*age interaction; [b]Direct exposure to fire in the current season was measured as: 1. Any exposure—yes/no if any direct exposures to fire were indicated; 2. Scale—a scale was created consisting of three levels of exposure—none (none or indirect), mild (classified as responses limited to being in an area with fire nearby, evacuation due to bushfire, area of significance lost other than home, family member was affected, home was affected while away), and severe (if experience included loss of or damage to property or direct contact with fire e.g., firefighter or protecting property); 3. Cumulative—the number of ways in which the participant has previously been exposed for fire were added.; [c]Previous exposure to fire was measured as: 1. Any exposure–yes/no if any previous exposures were indicated; 2. Scale–a scale was created with three levels of exposure—None (not affected, effects were limited to health and/or smoke effects), mild (responses limited to voluntary evacuation, family or close friend affected, cancellation or alteration of holiday plans/events, business or work affected), and severe (if experience included forced evacuation, damage to or loss of property, firefighter, first responder, volunteer, protected property, alert to evacuate, worry about property or risk); 3. Cumulative–The number of ways in which the participant has previously been exposed for fire were added.

TABLE 7 | Proportion of surveyed ACT region residents that sought medical advice in relation to bushfire smoke attributed health conditions during the 2019–20 bushfire season.

	Number seeking medical advice n (%)		
	Overall	**Male**	**Female**
Medical advice from any source	332 (17.1)	80 (10.9)	251 (21.1)
General practitioner	275 (13.2)	65 (7.8)	209 (17.0)
Pharmacist	75 (3.6)	17 (2.1)	58 (4.7)
Mental health professional (e.g., psychologist)	42 (2.0)	6 (0.7)	36 (2.9)
Specialist	22 (1.1)	4 (0.5)	18 (1.5)
Other health professional	16 (0.8)	3 (0.4)	13 (1.1)
Emergency department	14 (0.7)	2 (0.2)	12 (1.0)
Hospital inpatient	8 (0.4)	3 (0.4)	5 (0.4)
24 h health advice hotline	6 (0.3)	3 (0.4)	3 (0.2)

Females were more likely to have sought health advice than males (p <0.001).

health condition had greater odds of experiencing more smoke-related health issues is consistent with this. Similarly, poorer self-rated health was associated with increases in both physical health and sleep-related symptoms. Sleep problems have been associated with both physical and mental health problems (31, 32) and physical and mental health are also strongly linked (33, 34). Future studies ought to examine the inter-relatedness of these health outcomes (14).

Several studies demonstrate the lasting psychological effects of bushfire exposure, including increased rates of depression, post-traumatic stress disorder (PTSD), and increased drug and alcohol use (35, 36). A year after fires in an Australian community, twice as many people (42%) were classified as "potential psychiatric cases" than in an unexposed comparison population (37). Most people do not develop psychological conditions following a natural disaster (38), but it is important to identify those at risk of doing so and to provide the support they require. Future research should also consider community factors such as community cohesion, competence and support (39) that may influence individual wellbeing, rather than focus solely on individual-level variables.

Women and men may experience, respond to, and recover from bushfires differently (40, 41). For example, women are more likely to report higher rates of PTSD (42, 43), and men to report an increase in alcohol abuse after experiencing bushfires (40, 44). In the current study, women reported higher rates of all physical health symptoms, poorer sleep, and mental health issues. Gender differences have been attributed to biological, social or situational factors (38, 40, 45).

Longer term mental health outcomes for communities exposed to bushfire are generally good, although a significant minority may experience persistent difficulties and vulnerability may increase with cumulative trauma exposures (44). In our study, previous exposure to fire was associated with greater odds of reporting poorer physical health outcomes and sleep disturbance, but not with mental health outcomes. More

disrupted sleep for people who had previously been directly exposed to a bushfire event is possible, as the smoke may have triggered memories of that event. Direct exposure to fire is inherently difficult to understand as exposure severity and personal experience vary among individuals. To investigate this, we explored this measure in several ways–by assessing a binary (yes/no) response, a cumulative measure of the number of effects identified, or a ranking measure, in which some experiences were weighted more strongly than others. Unsurprisingly, people who were directly affected by fire had increased odds of physical, sleep, and negative mental health outcomes. For all of these outcomes, the pattern of relationship was similar, with higher odds ratios in the group ranked severe, compared to the mild group. The different ways of measuring exposure were all statistically significant, suggesting the link between direct experience of bushfire with adverse health outcomes is robust. In contrast, the cumulative measure showed consistently weaker odds ratios compared to other measures. This poses questions about the level of detail needed in measuring people's objective and subjective experience with bushfire, whether there are severity of impact thresholds for concern, and how a single measure might account for different experiences of a similar event (for example voluntary vs. forced evacuation). The complexity of this issue warrants more detailed study.

Although participants in this study were asked to focus on the effects of smoke (and not fire) specifically, it is likely some people were unable to separate the effects of smoke from other factors, such as heat stress or the direct effects of fire. Also, this study coincided with the early stages of the COVID-19 pandemic in Australia, and participants may have been unable to disentangle their feelings of distress and anxiety about the bushfires from the uncertainty of the developing pandemic.

During the 2019–20 bushfire season, there was community concern about whether smoke exposure would have long-term effects on health (46). This continues to be an area that is not well understood as only limited studies have explored long-lasting or delayed effects of smoke on health. Some have identified increased incidence of influenza (47) and impaired lung function (48) for months to years after a fire event. Canberra had experienced a severe bushfire in January 2003 and a survey 3 years after this disaster found that for over half the survey respondents (56.4%, n = 272) the bushfire did not have a lasting effect on their overall health and 2.5% (n = 12) reported that their overall health was better than before (18). However, 40.9% (n = 197) reported a lasting negative effect of the bushfire on their overall health. As such, we hypothesized that community members who had been exposed to the 2003 bushfires in Canberra may have been at greater risk of negative health effects during the 2019–20 fire season, particularly regarding negative mental health outcomes. However, this was not evident from our results, perhaps indicating that people were resilient and had had sufficient time to resolve any adverse reactions to the 2003 fires. Further longitudinal research is needed to understand the long-lasting, as well as the acute, health effects of bushfire and smoke exposure.

Rapid research during or immediately following natural disasters is challenging (49, 50). Here, a survey was designed to

be deployed quickly to capture a broad snapshot of a population's health in response to a bushfire smoke event. Online data collection was suitable for a wide range of the population, but not when such as electricity or internet services are interrupted. The use of multiple sampling approaches captured experiences from a broad cross-section of the population, though the sample is not representative of the whole population as some groups such as the elderly, those with no fixed address, or those for whom English is not their primary language, may have been missed or underrepresented. Further, the focus here was on rapid and easy to measure self-report items with good face validity, rather than on more sophisticated measures of key constructs such as mental health. Despite these limitations, important trends concerning health and lifestyle burdens were identified, presenting an effective way to screen for specific areas or groups requiring more detailed examination. This method should, though, be refined to focus on the most pertinent and useful information to ensure ease of completion and associated rapid delivery of appropriate support and services to communities.

CONCLUSIONS

Bushfire smoke can have considerable and underestimated effects on physical and mental health, beyond those associated with direct contact with fire and the acute effects of smoke inhalation. Greater understanding of mental health and long-term health effects is needed, particularly for at-risk groups, including parents, those with existing health conditions, or those who had previous exposure to fire and smoke. Improved public health communication is needed to strengthen individuals' ability to prevent harm and protect the health of themselves and their families for future events.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by Human Research Ethics Committee of the Australian National University (protocol number: 2020/029). The patients/participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

RR, AS, AC, BC, AL, JL, JR, ST, SV, and IW contributed to the conception and design of the study. ST and RR obtained ethics approval, conducted data collection, and database management. RR was responsible for data analysis and drafting of manuscript. All authors contributed to manuscript revision, read, and approved the submitted version.

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The Health of Firefighters Deployed to the Fort McMurray Fire: Lessons Learnt

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Introduction: Firefighters were working in exceptionally difficult conditions during the Fort McMurray/Horse River fire in May 2016.

Methods: From mid-May, we recruited firefighters from 13 fire services as they returned from the fire. In October 2016 we extended recruitment to all Alberta-based firefighters deployed to the fire. In December 2017–May 2018 we sent a first online follow-up: this concentrated on mental health supports. The second follow-up, in October 2018–January 2019, included screening scales for respiratory ill-health and PTSD. All three contacts included visual analogue scales for chest symptoms and the Hospital Anxiety and Depression Scale. We estimated exposure to $PM_{2.5}$, and calculated an exposure mitigation index from reports of respiratory protective equipment (RPE).

Results: We recruited 1,234 firefighters and examined the relation of respiratory symptoms to estimated particulate exposure. The relation was strong immediately post fire but weakened over time. We found less chest tightness and cough in those whose RPE in the first week mitigated exposure by at least 10%. We examined the relation between particulate exposure and mental ill-health from screening questionnaires and found those with high exposure (reflecting the ferocity of the fire) had poorer mental health scores. Firefighters reporting their "worst moment during the fire" was life threatening were more anxious at second follow-up. Overall both anxiety and depression scores increased at successive contacts, more so in those with mental ill-health recorded in physician billing records before the fire.

Discussion: The results from this study overall suggest on-going fire-related health effects in a substantial minority of firefighters, similar to those reported in the longitudinal follow-up of firefighters after the collapse of the World Trade Centre. Self-reports of both respiratory symptoms and mental ill-health were strongly related, soon after the fire, to estimated particulate exposures. Anxiety increased over time since the fire in those who felt their life or safety had been threatened, underlining the need for ongoing support. Our conclusions about the benefits of rapid research relate particularly to the collection of biomarkers of exposure as quickly and widely as possible, and the establishment of a nominal list of participants before they are too widely dispersed.

Keywords: Fort McMurray fire, firefighters, particulate exposure, respiratory, mental ill-health

INTRODUCTION

The Fort McMurray/Horse River fire overwhelmed the conurbation and surrounding areas on May 3rd 2016 (1). It was immediately apparent that firefighters were being exposed to exceptionally difficult conditions and on 5th May we discussed a study of the effects of the fire on firefighters' respiratory health with the Occupational Health and Safety team at Alberta Employment (now Alberta Labour). By chance we had taken delivery that week of a clinical mobile laboratory (funded by the Canadian Foundation for Innovation) equipped to carry out respiratory function testing and to handle biological samples. With immediate collaboration from the Strathcona fire service we developed a protocol and exposure questionnaires and on the 16th May began our assessment of Strathcona firefighters who had been deployed to the fire.

This rapidly developed protocol formed the basis for all the work that followed and reflected the three areas that seemed of key importance: assessing effects on respiratory function (2–4) and mental health (5, 6) and making the best possible estimates of exposure. Early in the fire we were able to collect samples (urine and blood) to look for biological markers of exposure (7, 8) and to develop a questionnaire that allowed us to create exposure algorithms incorporating data from environmental monitoring and satellite imagery. There was no access for researchers to the fire area during the first weeks of the fire and we were dependent for environmental sampling on data collected by others. We assessed the firefighters as soon as we could after they had returned from a rotation.

The work we have done with the firefighters deployed to the Fort McMurray fire has aimed to identify exposures and work practises that could be modified to reduce harm in future conflagrations and to help in the recognition of fire-related ill-health. To do that successfully we needed to rely as much as we could on objective measures of exposure and effect. We have previously given detailed results on many aspects of the study (7–12) but here we want to consider particularly the firefighters' perceptions of their experiences and how these relate to their ongoing ill-health. We describe the evolution of respiratory symptoms with time since the fire and the nature of the respiratory conditions that do not resolve. We look also at the part played by respiratory protective equipment (RPE) in preventing respiratory ill-health in those exposed during the fire. Finally, we address the complex relation between firefighters' own perception of their worst moments during the fire and their mental health many months post-fire.

METHODS

Data Collection

In Phase 1 of the study, from May to October 2016, we visited 12 structural and one industrial fire service. At each we talked to the firefighters informally about their experiences during the fire and then asked them to consent to completing a recruitment questionnaire about their exposures during the fire and their health. We also asked if they would consent to linkage with the Alberta Administrative Health Data Base (AHDB). At two fire services we collected blood samples to analyze for inflammatory markers and at three we collected urine samples, to look for markers of exposure to polycyclic aromatic hydrocarbons (PAHs). At all 12 of the structural fire services we carried out spirometry to assess lung function after the fire. All the Phase 1 recruitment was face-to-face.

For Phase 2 we aimed to approach all firefighters based in Alberta who had been deployed to the Fort McMurray/Horse River fire. We had two sources to identify these. The provincial premier had requested that a list be drawn up of all those who had been deployed from structural and industrial fire services, so that they could be thanked individually. This showed the names and fire service and using this we were able to send letters (through the fire chief) to everyone on the list inviting them to take part and to complete the recruitment questionnaire online. For wildland firefighters an operation list had been drawn up with the names and management area of each wildland firefighter deployed and again we were able to contact many though their area manager. Neither list was fully inclusive: some fire services did not submit names to the premier's list and a high proportion of wildland firefighters worked only during the fire season and could only be contacted when and if they returned to employment. We increased recruitment among wildland firefighters by attending base camps when part-timers returned to employment in 2017 and 2018. We also made a concerted attempt to maximise enrolment among those based in the Fort MacMurray area by face to face meetings with structural and industrial fire fighters in the summer of 2017. Again, there was emphasis on getting factual data about experiences during the fire and consent, where forthcoming, to link to the AHDB.

The first follow-up was an on-line questionnaire in December 2017 to May 2018 (**Figure 1**). This asked, particularly, about the types of mental health supports that had been available through the employer, before, during and since the fire. Those who had very recently completed the recruitment questionnaire were not approached for this follow-up. The second follow-up was October 2018–January 2019: everyone who had completed the recruitment questionnaire was requested to complete this and, for those very reluctant, a short questionnaire was completed on-line or by telephone. The full questionnaire included screening questionnaires for anxiety and depression [using the HADS questionnaire (13, 14) and for PTSD with the PCL-5 (15)], and the European Community Respiratory Health Survey (ECRHS) (16) to screen for respiratory ill-health.

The final phase was to carry out clinical assessments using stratified random samples where the invitation to undergo assessment depended on scores on the screening questionnaires in the second follow-up. The respiratory assessment comprised lung function testing, a methacholine challenge test (to look for airways hyperreactivity) and a CT scan of the chest to assess bronchial wall thickening and to rule out other causes of lung dysfunction such as fibrosis. The psychiatric assessment took the form of a Structured Clinical Interview to see if the mental ill-health met the criteria for a particular diagnosis on the DSM-5 (17). This type of interview is known as a SCID-5. These assessments were important in that it allowed us to talk about

FIGURE 1 | Response of firefighters at each contact.
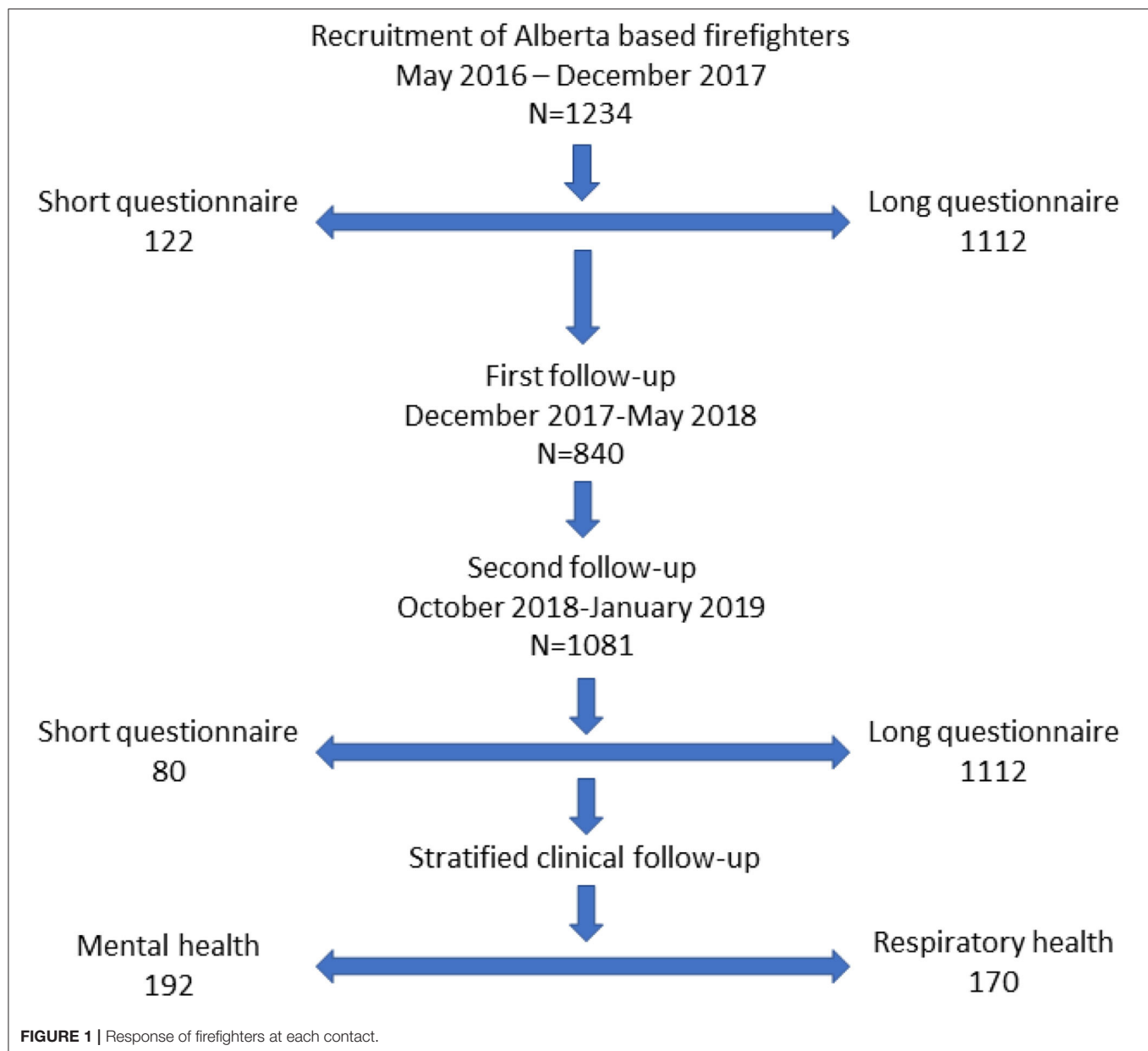
the prevalence of objectively measured ill-health associated with attendance at the fire.

We collected other data also. In May 2017–January 2018 we interviewed fire chiefs or, for wildland firefighters, area managers to ask them about the mental health provision and support offered to the deployed firefighters, before, during and after the fire. We also asked the firefighters if they had had spirometry as part of health monitoring by the fire service, and if so, whether they consented to us obtaining copies of the records before and since the fire. We requested consent to get information from the Workers Compensation Board (WCB) of any fire-related claims. Finally, we asked the Alberta AHDB to match each firefighter (who had given consent to be linked) with 5 people matched by age (±3 years), sex, geographic area and use of the health services

in the 12 months before the fire. In Alberta, to be paid for services, a physician has to record at least one diagnosis for each claim. For this set of firefighters and community controls we were able to look at the diagnosis for all physician claims in the 3 years before the fire and 2 years after, to see if the pattern diverged for the firefighters compare to controls. We were also able to use the information contained in billing records to document whether the firefighter had respiratory or mental ill-health, as recorded by a physician, in the 3 years before the fire.

Definitions of Outcome, Exposure, and Confounding Variables

In this paper we consider particularly respiratory and mental ill-health, as reported by the firefighter. Using visual analogue

scales, we asked the firefighter at recruitment to report how much they were bothered by five symptoms (cough, phlegm. breathlessness, wheezing, and chest tightness) before the fire, immediately after their last deployment and at the time of completing the recruitment questionnaire. We then repeated this set of scales at both the first and second follow-up, and used the responses (from 0 to 100) as continuous variables. At the second follow-up participants also completed the ECHRS. Using the approach of Sunyer et al. [18] we had extracted 4 factors [8, 12] we labelled as reflecting cough, phlegm, asthma and wheeze. We also asked if they had any ongoing lung or breathing problems related to the fire.

We screened for mental ill-health with the Hospital Anxiety and Depression Scale (HADS), completed at recruitment and again at first and second follow-up. This gave a score from 0 to 21 on each scale which we could use to look at changes over time. At the second follow-up we also asked the firefighters to complete a 20-item screening questionnaire (the PCL-5) for PTSD, which resulted in a score from 0 to 80. From our psychiatric interview assessment [9], we were able to determine cut-off points for each of the scales that indicated, in these firefighters, those at risk of clinically significant mental ill-health. For anxiety the cut point indicating "caseness" was 12 or greater, for depression 11 or greater and for PTSD, 16 or greater. We also examined mental health diagnoses in physician billing records in the 2 years from May 2nd 2016–March 2018, with any record of mental ill-health (ICD-9 codes 290-319, ICD-10 codes F00-F99.9) being taken as an additional indicator of post-fire mental ill-health.

The calculation of estimated exposure to particulates is explained in **Appendix 1**. It used information from the firefighter about dates of deployment, shift hours, tasks and geographic location and incorporated objective data from environmental monitoring stations and, for the wildland firefighters, satellite imagery. The **Appendix** also gives details on how an exposure mitigation index (EMI) was calculated, to reflect the extent to which reported use and type of respiratory protective equipment might be expected to reduce the inhalation of smoke particles. We also considered here the effect on health of the experiences reported by the firefighters. We took the answers to an open-ended question in which we asked the firefighter to "describe your worst moment while working on the Fort McMurray/Horse River fire" and developed a scheme to classify the answers (**Appendix 2**).

Important potential confounders, in addition to age, sex and, for respiratory disease, cigarette smoking, were the history of respiratory disease and mental ill-health before the fire. For respiratory health, we took a marker for chronic asthma and COPD developed by Alberta Health and included in the information obtained from data linkage. We supplemented this with a report from the firefighter of asthma before the fire. For mental ill-health before the fire we took any diagnosis of mental ill-health (ICD-9 codes 290-319, ICD-10 codes F00-F99.9) in physician billing records from April 1st 2013 to May 1st 2016.

Statistical Methods

We examined the relation of respiratory complaints at different time points to the composite estimate of exposure to $PM_{2.5}$

particles in a linear regression or, for the report of ongoing respiratory problems, logistic regression. We then carried out a multivariate analysis, adjusting for confounding and, for visual analogue scores of symptoms, reported values immediately prior to the fire. We divided the composite exposure index into two components, overall particulate exposure and the estimated mitigation from RPE and included both in the regression models with respiratory symptoms as the dependent variable. We use conditional logistic regression to analyse the community-based case-referent study, computing odds ratios for mental ill-health before and after the fire and for new onset mental ill-health for those without a mental ill-health diagnosis in the 3 years before the fire. We examined the bivariate relation between estimated particulate exposure (representing the ferocity of the fire) and mental health outcomes both as continuous screening scores (in a linear regression) and "caseness" by logistic regression. We then examined if the firefighters' perceptions of psychological stressors during the fire reflected their mental ill-health before the fire or related to mental ill-health post fire, having adjusted, in a multivariate logistic regression, for mental ill-health before the fire and estimated particulate exposure during the fire. We examined changes of scores on the anxiety and depression scales over time in a multilevel regression analysis and tested, in linear regression models, whether reports of specific "worst moments" added to the model. The analysis was carried out in Stata 14.2.

RESULTS

In all, 1,234 firefighters joined the study and completed at least the recruitment questionnaire. Among these were 749 structural, 329 wildland, and 156 industrial firefighters. Participation rates at each phase are shown in **Figure 1**. Characteristics of the three groups are shown in **Table 1**. The contract type was asked only in the first follow-up, for which the response rate was relatively low (as those recruited close to the first follow-up were not approached). Where the contract type was not known this was inferred from information from the fire chief for structural and industry-based fire services, with the firefighter assumed to be full-time if the fire chief indicated the majority of fire fighters were full-time and on call/volunteer if that type of contact was the majority for that service. For wildland firefighters all those recruited late (during start-of-season base camps) were assumed to be seasonal workers. There were important differences between the groups of firefighters, with wildland firefighters being younger and more likely to be female, industrial firefighters more likely to be smokers and aged over 40 years and structural firefighters most likely to do only one rotation at the fire. There was, however, considerable variation within the structural fire services, with those working for the regional municipality of Wood Buffalo/Fort McMurray (the Fort McMurray fire service) doing many rotations but firefighters from large city-based fire services generally doing only a single deployment on a rapid-rotation schedule whereby each firefighter spent only 2–3 days at the fire. Mean estimated exposures to $PM_{2.5}$ particles for individual fire services deploying

TABLE 1 | Characteristics of firefighters deployed to the fire.

	Structural		Industry		Wildland		Overall	
	N	%	*N*	%	*N*	%	*N*	%
Contract type (*assumed)								
Full time	548	73.0	142	92.2	78	23.7	768	62.2
Paid on call/volunteer/seasonal	170	22.6	6	3.9	220	66.9	396	32.1
Non-firefighter role	33	4.4	6	3.9	–	–	39	3.2
Other (e.g., Employed through contractor)	–	–	–	–	31	9.4	31	2.5
Based in area of Fort McMurray								
No	602	80.2	–	–	276	83.9	878	71.2
Yes	149	19.8	154	100.0	5.3	16.1	356	28.8
Repeat rotation								
One only	537	71.5	58	37.7	163	49.6	758	61.4
2 or more	214	28.5	96	62.3	166	50.4	476	38.6
Sex								
Male	693	92.3	147	95.5	267	81.2	1,107	89.7
Female	58	7.3	7	4.5	62	18.8	127	10.3
Ever smoker								
No	595	79.2	87	56.5	215	65.3	897	72.7
Yes	141	18.8	61	39.6	98	29.8	300	24.3
Unknown	15	2.0	6	3.9	16	4.9	37	3.0
Age (years)								
18–30	199	26.5	31	20.1	178	54.1	408	33.1
31–40	278	37.0	52	33.8	61	18.5	391	31.7
>40	274	36.5	71	46.1	90	27.4	435	35.3
Overall	751	100.0	154	100.0	329	100.0	1,234	100.0

*Where missing deduced from other information (see text).

5 or more firefighters are shown for the key (first) rotation in **Figure 2**. The estimates for wildland firefighters were derived from satellite imagery (see **Appendix 1**) rather than land-based monitoring: side by side estimates suggested that the satellite-based estimates were systematically lower than those based on terrestrial air monitoring and the wildland exposures shown in **Figure 2** may be underestimated. Among the structural and industrial firefighters, those based in and around Fort McMurray, who were in the midst of the fire right from the start, had the highest exposures.

In **Table 2**, we examine the relation between estimated exposure and respiratory symptoms, immediately after the fire and at the first and second follow-up. Using visual analogue scales, we asked the firefighter to rate, at the recruitment questionnaire, how troublesome symptoms had been before the fire (not shown) and how troublesome immediately after the fire. We asked them to record these also at the time of first follow-up in 2017–18 and the second follow-up in 2018–19. As can be seen in **Table 2**, the extent to which they were bothered by each symptom immediately after the fire was related to exposure, but this relationship was less evident by the time of the first follow-up, and by the second follow-up only cough and wheezing were related to exposure. At the second follow-up participants also completed the ECHRS. We had extracted 4 factors of which only one (wheeze) was related to exposure during the fire. We

also asked if they had any on-going lung or breathing problems related to the fire. Those who reported that they did (15.8%) had significantly higher estimated exposure.

The exposure measure used in **Table 2** was a composite (**Appendix 1**) of estimated particulate exposure (from monitoring stations or satellite images) for the dates and locations worked, adjusted by total hours worked on each day, the type of task they were doing and an exposure mitigation index (EMI) reflecting the type of RPE, if any, they reported using, the proportion of time they wore it and the frequency of changing masks or filters. If they wore no RPE the mitigation factor was 1. Sustained use of appropriate equipment reduced the EMI, with a calculated mitigation factor of 0.5 reducing the estimated exposure by 50%. Overall 30% of structural and industrial firefighters wore no RPE. None of the wildland firefighters did so. Among those that did, only 12.5% of structural firefighters and 18.5% of industrial firefighters achieved an EMI of 0.5. To examine the effects of wearing RPE we included everyone as a "wearer" who mitigated their exposure by at least 10%. This accounted for 47% of structural and 44% of industrial firefighters. Among structural firefighters the proportion was lower in those first deployed in the early days of the fire (to May 10th), when only 43% achieved 10% mitigation. In **Table 3**, we examined further the relation between exposure and respiratory symptoms, adjusting for potential confounders and pre-existing conditions,
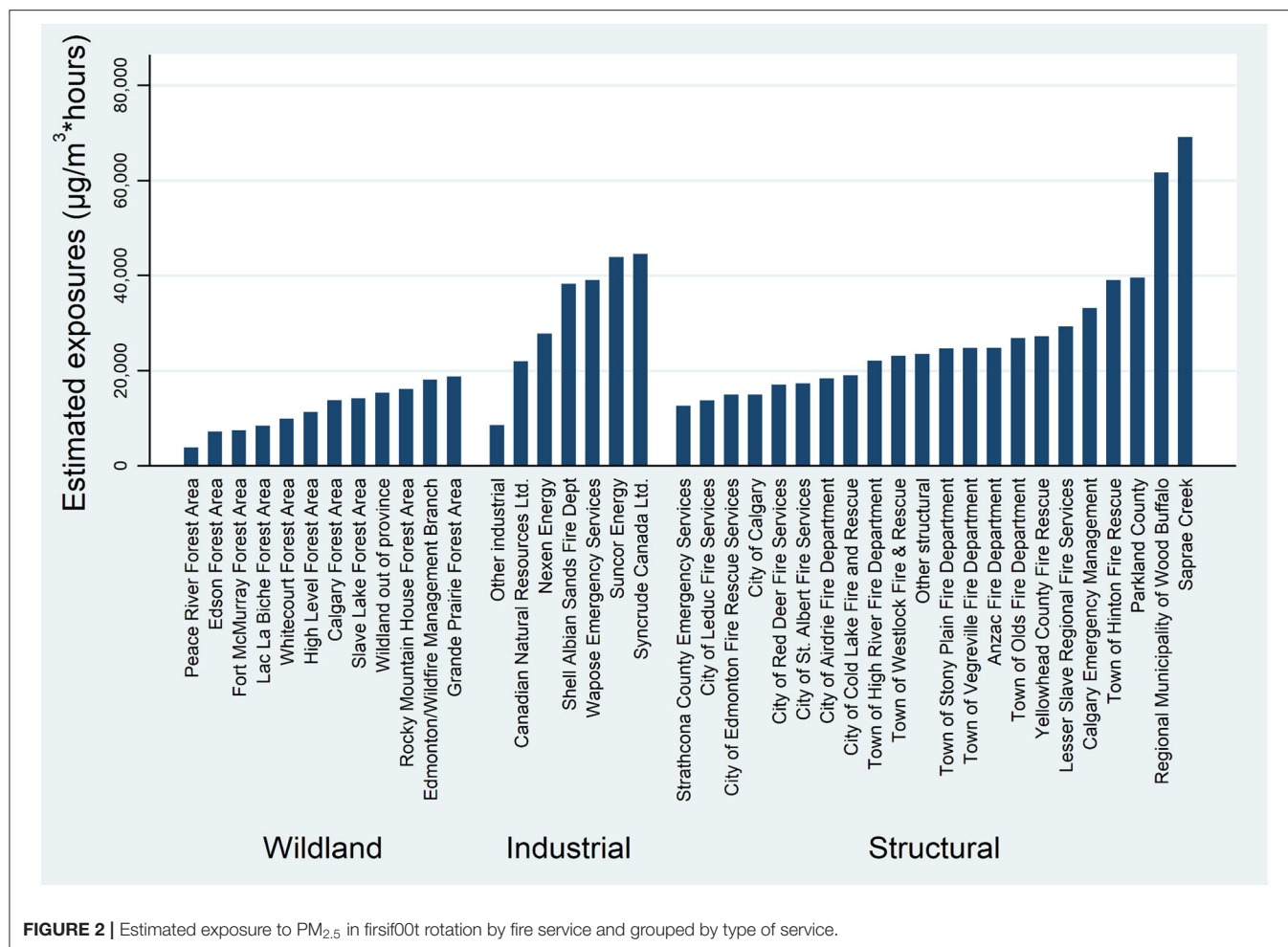
FIGURE 2 | Estimated exposure to PM$_{2.5}$ in firsif00t rotation by fire service and grouped by type of service.

and partitioning out estimated exposure and the use of RPE. The relation of exposure to symptoms recorded immediately post-fire remained strong, with some mitigation of symptoms of breathlessness, wheezing and, particularly chest tightness amongst "wearers" of RPE. At first follow-up the relation of exposure to symptoms was largely unchanged, with, as before, all but phlegm showing some relation. The coefficient associated with RPE use remained negative (indicating protection) but could be seen as protective only for cough and, weakly, for chest tightness. By the time of the second follow-up, none of the individual symptoms were related to exposure (after adjustment for other factors). The coefficients associated with RPE remained negative, with cough again less in RPE wearers. Among the factors extracted from the ECHRS wheeze remained related to exposure, but not to RPE use. On these scores, cough and asthma appeared to be lower in wearers. The strong relation of ongoing lung or breathing problems to exposure remained after adjustment, with no mitigation by use of RPE.

Two supplementary analyses were carried out. First, we examined the effect of wearing RPE just in those who had been deployed during the first week of the fire, where almost every task involved high exposures. Later in the fire those patrolling,

for example, did not necessarily need RPE. For breathlessness, wheezing and chest tightness immediately postfire the effects of RPE were seen only in those deployed during the first week (data not shown). Similarly, at the first and second follow-up the mitigating effect of RPE on cough was only in those deployed early. Second, we looked to see if we could establish a degree of mitigation that showed effects across all, or most, end points, and particularly that of ongoing lung problems. We did not find evidence of such a mitigation point and no fewer problems were seen in the small group whose exposure was estimated to be mitigated by 50% or greater.

A case-referent analysis of mental ill-health in firefighters compared with the matched community controls, in a conditional logistic regression, showed little effect of the fire (**Table 4**). Before the fire, somewhat fewer firefighters than community controls had a mental health diagnosis in physician billing records (OR = 0.84). This difference was smaller in the period after the fire (OR = 0.91) but there was no marked increase in the diagnosis of new onset mental ill-health in firefighters (OR = 1.09) in physician billing records. The number of diagnoses of PTSD recorded in billing records was very small (17 overall, 8 in firefighters, 9 in

TABLE 2 | Relation of estimated exposure to respiratory symptoms and complaints.

Visual analogue "troublesomeness of symptoms"	mean	SD	N	Unadjusted		P=
				β	95% CI	
After final deployment						
Cough	33.77	32.64	1,012	6.28	5.09 to 7.47	<0.001
Phlegm	25.76	29.81	1,011	4.37	3.23 to 5.48	<0.001
Breathlessness	18.13	25.33	1,010	4.11	3.17 to 5.05	<0.001
Wheezing	16.95	25.86	1,010	3.65	2.68 to 4.62	<0.001
Chest tightness	16.91	25.33	1,010	3.88	2.93 to 4.82	<0.001
At 2017–18 follow-up						
Cough	14.51	20.74	837	1.07	0.20 to 1.94	0.016
Phlegm	15.02	21.59	836	0.31	−0.60 to 1.23	0.499
Breathlessness	9.93	16.39	834	0.96	0.27–1.64	0.007
Wheezing	9.24	16.01	834	0.67	−0.01 to 1.34	0.052
Chest tightness	8.41	15.17	835	1.16	0.52–1.79	<0.001
At 2018/19 follow-up						
Cough	15.92	20.71	1,000	0.85	0.07 to 1.62	0.033
Phlegm	15.46	21.97	999	0.10	−0.72 to 0.93	0.804
Breathlessness	11.13	18.39	999	0.50	−0.19 to 1.20	0.153
Wheezing	10.15	17.70	999	0.70	0.03 to 1.36	0.039
Chest tightness	9.68	16.94	999	0.29	−0.35 to 0.93	0.370
Factors extracted from the ECHRS questionnaire (2018–19)						
Phlegm	0.00	1.00	995	0.00	−0.04 to 0.04	0.983
Cough	0.00	1.00	995	0.01	−0.03 to 0.05	0.494
Asthma	0.00	0.99	995	−0.00	−0.04 to 0.03	0.807
Wheeze	0.00	0.94	995	0.05	0.01 to 0.08	0.011
			%	**N**	**OR**	**95% CI**
Complaint of lungs or breathing problems related to the Fort McMurray Fire (2018–19)						
No			84.2	910	1.00	–	–
Yes			15.8	171	1.27	1.13 to 1.42	<0.001
All			100.0	1,081		

controls) but the odds of a PTSD diagnosis being recorded were higher in firefighters (OR = 4.47 95% CI 1.72–11.62 p = 0.002).

We considered next the relation of mental ill-health following the fire to estimated exposure to particulate matter during the fire (**Table 5**). We examined this in relation to "caseness," 2 years or more after the fire and to the anxiety and depression scores of the Hospital Anxiety and Depression Scale, completed on three occasions, at recruitment, and at first and second follow-up. Mental ill-health from physician records was not related to particulate exposure but the risk (odds ratio) for caseness, using definitions from screening scores, increased with increasing exposure during the fire, less strongly for depression than for anxiety or PTSD. The relation to exposure decreased with time since the fire, particularly for anxiety.

We next looked to see whether the firefighters' own reports of their "worst moment during the fire" recorded on the recruitment questionnaire was related to their mental health.

The open-ended responses were coded into 10 categories (**Appendix 2**), five reflecting psychological stressors and five physical ones. Many responses were a composite, such as sleep deprivation and smoke or devastation and noise such that a firefighter's response could receive multiple codes. Overall, 48% gave at least one worst moment coded as "psychological" and 42% one coded as "physical": 24% did not write anything or wrote "no worst moment." Responses referring to seeing/experiencing the devastation caused by the fire were most common, closely followed by references to the dense smoke. In **Table 6** we show these frequencies for all respondents and also broken down by the presence of mental-ill health in physician billing records in the 3 years prior to the fire. Those with such a pre-fire diagnosis were no more likely to report psychological stressors as their "worst moment" during the fire. The relation of each element coded as a worst moment to "caseness" is shown in **Table 7**. We carried out a logistic regression analysis for each stressor in turn, and for the total number of psychological and physical stressors recorded. Each regression was adjusted to allow for

TABLE 3 | Relation of estimated exposure and use of respiratory protective equipment (RPE) to respiratory symptoms and complaints, adjusted[*].

Visual analogue "troublesomeness of symptoms"	Exposure			RPE used		
	β	95%CI	P=	β	95% CI	P=
After final deployment						
Cough	6.34	5.16 to 7.33	<0.001	−2.81	−6.70 to 1.09	0.157
Phlegm	4.67	3.62 to 5.72	<0.001	−0.88	−4.33 to 2.57	0.617
Breathlessness	4.13	3.23 to 5.02	<0.001	−2.82	−5.78 to 0.14	0.062
Wheezing	3.66	2.73 to 4.59	<0.001	−2.70	−5.77 to 0.37	0.084
Chest tightness	4.01	3.11 to 4.92	<0.001	−3.13	−6.10 to 0.15	0.039
At 2017–18 follow-up						
Cough	1.22	0.33 to 2.10	0.007	−3.38	−0.63 to 0.46	0.023
Phlegm	0.61	−0.31 to 1.53	0.196	−1.34	−4.37 to 1.70	0.388
Breathlessness	0.82	0.15 to 1.49	0.017	−1.36	−3.57 to 0.84	0.225
Wheezing	0.62	−0.05 to 1.29	0.069	−0.29	−2.49 to 1.91	0.798
Chest tightness	1.18	0.55 to 1.82	<0.001	−1.82	−3.91 to 0.26	0.087
At 2018/19 follow-up						
Cough	0.69	−0.21 to 1.59	0.135	−3.63	−6.56 to 0.71	0.015
Phlegm	−0.05	−0.99 to 0.90	0.922	−2.67	−5.74 to 0.39	0.087
Breathlessness	0.45	−0.35 to 1.25	0.269	−1.46	−4.07 to 1.14	0.271
Wheezing	0.48	−0.26 to 1.21	0.203	−0.74	−3.13 to 1.66	0.547
Chest tightness	0.18	−0.55 to 0.90	0.634	−1.77	−4.14 to 0.57	0.139
Factors extracted from the ECHRS questionnaire						
Phlegm	−0.00	−0.04 to 0.04	0.986	0.02	−0.11 to 0.15	0.781
Cough	0.01	−0.03 to 0.05	0.630	−0.16	−0.29 to 0.02	0.021
Asthma	−0.00	−0.03 to 0.03	0.950	−0.11	−0.21 to 0.00	0.040
Wheeze	0.04	0.01 to 0.08	0.015	−0.05	−0.18 to 0.07	0.393
	OR	95%CI	P=	OR	95%CI	P=
Complaint of lungs or breathing problems related to the Fort McMurray Fire (2018–19)						
No	1.00	–		1.00	–	
Yes	1.30	1.15 to 1.46	<0.001	0.92	0.65 to 1.31	0.648
All						

Adjusted for smoking, sex, age at deployment, asthma prior to the fire, and for visual nscores, rating of troublesomeness on that dimension prior to the fire.

TABLE 4 | Case referent analysis of mental ill-health[*] as recorded in the Alberta administrative health database.

	Any mental ill-health from April 1st 2013 to May 1st 2016					Any mental ill-health from May 2nd 2016 to March 30th 2018				New onset mental ill-health from May 2nd 2016 to March 30th 2018			
	N	n	%	OR	95% CI	N	%	OR	95% CI	n	%	OR	95% CI
Firefighters	955	242	25.3	0.84	0.71–0.99	235	24.6	0.91	0.77–1.07	110	11.5	1.09	0.88–1.36
Community controls	4,775	1,362	28.5	1	–	1,260	26.4	1	-	508	10.6	1	–
All	5,730	424	7.4	–	–	312	5.4	–	–	126	2.2	–	–

ICD-9 code 290-319; ICD-10 code F00-F99.

mental ill-health before the fire, for the concentration of smoke particles (reflecting the intensity of the fire) and for sex and age. Mental ill-health from billing records post-fire was related only to reports of relational stress (involving worries about family, animals, homes, or communities to which they have a specific attachment–**Appendix 2**). With caseness defined from screening scores, anxiety, and PTSD were more likely in those reporting

multiple psychological stressors and all three were more likely in those who were in a situation where they perceived a threat to their life or safety.

We examined scores on the anxiety and depression scales over time (**Table 8**) and by the record of mental ill-health before the fire. At each point anxiety and depression scores were higher in those with pre-fire mental ill-health. Examination of the overall

TABLE 5 | Bivariate relation of particulate exposure during the fire to mental health post-fire.

	OR	95% CI	P=	N
(A) "Caseness" 2 years or more post-fire (logistic regression)				
Mental ill-health in billing records	1.07	−0.98 to 1.18	0.119	955
Anxiety ≥ 12	1.32	1.14 to 1.52	<0.001	1,000
Depression ≥ 11	1.23	1.00 to 1.50	0.046	1,000
PTSD ≥ 16	1.34	1.19 to 1.52	<0.001	998
	β	95% CI	P=	N
(B) Anxiety and depression as continuous scores by contact post-fire (linear regression)				
Recruitment				
Anxiety	0.41	0.27 to 0.56	<0.001	1,019
Depression	0.26	0.15 to 0.37	<0.001	1,019
First follow-up				
Anxiety	0.25	0.09 to 0.42	0.002	831
Depression	0.13	0.02 to 2.91	0.055	831
Second follow-up				
Anxiety	0.28	0.13 to 0.43	<0.001	1,000
Depression	0.24	0.11 to 0.37	<0.001	1,000

TABLE 6 | Reports of "worst moment" during the fire by mental health before the fire (from physician billing records).

Nature of "worst moment" reported	No		Yes		Unknown		Overall		P* =
	n	%	n	%	n	%	N	%	
Mental ill-health prior to the fire									
(A) Psychological									
Psychological/mental strain	92	15.0	25	12.3	32	16.5	149	14.8	0.468
Relational	56	9.2	11	5.4	15	7.7	82	8.1	0.229
Inter crew	60	9.8	22	10.8	16	8.2	98	9.7	0.688
Devastation	130	21.2	53	26.0	37	19.1	220	21.8	0.217
Threat	69	11.3	24	11.8	10	5.2	103	10.2	0.035
(B) Physical									
Smoke	105	17.2	44	21.6	37	19.1	186	18.4	0.359
Exhaustion	58	9.5	20	9.8	20	10.3	98	9.7	0.942
Sleep deprivation	59	9.6	21	10.3	21	10.8	101	10.0	0.881
Physical stress	60	9.8	22	10.8	30	15.5	112	11.1	0.090
Lack of resources	73	11.9	26	12.7	13	6.7	112	11.1	0.091
Number of psychological									
0	313	51.1	99	48.5	113	58.2	525	52.0	0.412
1	211	34.5	80	39.2	56	28.9	347	34.4	
2	69	11.3	20	9.8	21	10.8	110	10.9	
3–5	19	3.1	5	2.5	4	2.1	28	2.8	
Number of physical									
0	360	58.8	119	58.3	109	56.2	588	58.2	0.526
1	162	26.5	44	21.6	54	27.8	260	25.7	
2	79	12.9	35	17.2	26	13.4	140	13.9	
3–5	11	1.8	6	2.9	5	2.6	22	2.2	
N	612	100.0	204	100.0	194	100.0	1,010	100.0	-

*chi square.

TABLE 7 | Relation of mental ill health 2 years or more post fire to "worst moment."

Nature of "worst moment" reported	Mental ill-health from billing records post fire			Anxiety score > 12			Depression score ≥ 11			PTSD score ≥ 16		
	OR	95% CI	P=	OR	95% CI	P=	OR	95% CI	P=	OR	95% CI	P=
(A) Psychological												
Psych/mental stress	0.98	0.60–1.61	0.951	1.15	0.66–2.00	0.631	1.68	0.79–3.58	0.178	1.93	1.23–3.03	0.004
Relational	2.08	1.18–3.70	0.012	0.99	0.47–2.11	0.987	0.52	0.12–2.22	0.376	1.28	0.70–2.36	0.421
Inter crew	1.28	0.75–2.20	0.370	2.07	1.16–3.69	0.014	1.36	0.55–3.36	0.505	1.67	0.98–2.83	0.057
Devastation	0.93	0.62–1.40	0.717	1.22	0.76–1.97	0.408	1.38	0.70–2.72	0.352	1.95	1.32–2.88	0.001
Threat	0.93	0.54-1.60	0.796	2.06	1.17-3.63	0.012	2.57	1.19-5.53	0.016	1.98	1.20-3.29	0.008
(B) Physical												
Smoke	1.41	0.93–2.13	0.107	1.33	0.80–2.21	0.267	2.06	1.06–3.99	0.032	0.99	0.63–1.55	0.951
Exhaustion	0.49	0.25–0.95	0.034	0.68	0.31–1.47	0.326	0.65	0.20–2.18	0.489	0.48	0.23–1.00	0.049
Sleep deprivation	0.98	0.56–1.72	0.945	0.89	0.42–1.86	0.753	1.32	0.50–3.47	0.579	0.80	0.42–1.53	0.498
Physical stress	1.06	0.60–1.86	0.582	1.17	0.61–2.27	0.633	1.15	0.44–3.02	0.777	0.63	0.32–1.24	0.183
Lack of resources	1.37	0.84–2.26	0.210	1.95	1.12–3.41	0.019	1.71	0.76–3.86	0.196	1.14	0.67–1.95	0.631
Number of psychological	1.10	0.88–1.38	0.388	1.42	1.10–1.83	0.007	1.42	0.99–2.04	0.056	1.76	1.10–1.45	<0.001
Number of physical	1.04	0.84–1.28	0.750	1.10	0.86–1.42	0.448	1.24	0.87–1.76	0.231	0.82	0.65–1.04	0.105
N	881			840			840			838		

Logistic regression analysis.
Adjusted for mental ill health from billing records before the fire, estimated exposure to particles during the fire, sex and age.

mean scores suggested that both anxiety and depression scores increased with time since the fire, with scores at second follow-up higher than at recruitment. In a series of regression analyses with score at second follow-up as the dependent variable and with score at recruitment also in the model, we examined whether any of the reported "worst moments" appeared to accelerate or reduce this deterioration in mental health. Increase in anxiety was less in those who were older at recruitment and was unrelated to gender. Those with a pre-fire history of mental ill-health had a greater increase in anxiety than those without. From the worst moment data, only the perception of threat to life or safety was a predictor of greater increase in anxiety (**Table 9**). A parallel analysis for depression scores showed no relation to age or gender but again those with a previous history of mental ill-health had a greater increase in depression score. None of the psychological worst moments was related to the increase in depression but both the report of dense smoke and sleep deprivation were associated, with a final multivariate model (**Table 9**) including only sleep deprivation. We also conducted a parallel analysis stratifying by previous mental ill-health to see if those with such a history were particularly vulnerable to specific stressors. With this smaller group the power of the analysis to detect differences was lower but we saw increased anxiety at second follow-up in those who reported at recruitment that there had been difficulties in interpersonal relation with their crew during the fire (**Table 9**). Estimated exposure was not related to deterioration in mental ill-health between recruitment and 2nd follow-up and did not add to the models in **Table 9**.

Finally, we looked at exposures during the fire and previous ill-health in those who had a fire-related injury claim accepted by the Workers Compensation Board (WCB). Among 882 firefighters who agreed that we might access information from their WCB records, only 17 had an accepted compensation claim for respiratory ill-health and 37 for mental ill-health. Those compensated for either respiratory or mental ill-heath had higher particulate exposure than those who did not have such a claim. Those compensated for respiratory ill-health were no more likely to have a pre-fire history of chronic lung disease or to have been a smoker, but the 20 firefighters compensated for PTSD were more likely than those without an accepted claim to have had a mental-ill health diagnosis in the physician billing record in the 3 years before the fire. Less than half of those compensated for any psychological injury, and only 59% of those compensated for PTSD, had a physician billing diagnosis for mental ill-health in the 23 months after the start of the fire.

DISCUSSION

This paper has considered reports from the firefighters themselves on respiratory and mental ill-health in the years since the start of the Fort McMurray/Horse River fire. Respiratory symptoms were overall less marked with increasing time since the fire, with little relationship to estimated particulate exposure at the second follow-up, some 30 months after the start of the fire. The subgroup of 16% of firefighters reporting on-going lung or breathing problems related to the fire were drawn from those more heavily exposed and, as has been shown elsewhere (12), had an increased risk of clinically verified airways hyperreactivity and bronchial wall thickening. Mental ill-health, as reflected in the anxiety and depression scales of the HADS, showed a rather different pattern, with increased anxiety and depression with

TABLE 8 | Mean anxiety and depression scores by mental ill health before the fire, at recruitment and at each follow-up.

	Anxiety				F	P	Depression				F	P
	Mental ill health before the fire						Mental ill health before the fire					
Data point	No	Yes	Unknown	Overall			No	Yes	Unknown	Overall		
Recruitment												
Mean	4.51	5.41	4.50	4.69	4.45	0.012	2.28	2.90	2.59	2.47	3.70	0.025
SD	3.71	4.23	3.97	3.88			2.76	3.28	2.94	2.92		
N	616	207	196	1,019			616	207	196	1,019		
First follow-up												
Mean	4.69	6.21	4.99	5.05	9.85	<0.001	2.62	3.45	3.05	2.86	4.41	0.012
SD	3.68	4.21	3.86	3.86			3.09	3.57	3.26	3.23		
N	517	164	150	831			517	164	150	831		
Second follow-up												
Mean	5.59	6.92	5.96	5.92	7.97	<0.001	3.19	4.06	3.89	3.49	6.43	0.002
SD	3.95	4.43	4.08	4.10			3.23	3.87	3.57	3.45		
N	613	197	190	1,000			613	197	190	1,000		
P=												
Recruitment to												
1st follow-up	0.311	0.007	0.151	0.008			0.005	0.021	0.071	<0.001		
2nd follow-up	<0.001	<0.001	<0.001	<0.001			<0.001	<0.001	<0.001	<0.001		

TABLE 9 | Final models for anxiety and depression at second follow-up, with worst moment allowing for anxiety or depression score at recruitment.

	Anxiety						Depression		
	All			Just with prior mental ill health			All		
	β	95% CI	P=	β	95% CI	P=	β	95% CI	P=
Mental ill-health before the fire									
Yes	0.75	0.20 to 1.29	0.007				0.51	0.04 to 0.97	0.033
Unknown	0.14	−0.45 to 0.72	0.647				0.30	−0.20 to 0.51	0.240
Score at recruitment	0.69	0.63 to 0.74	<0.001	0.66	0.53 to 0.79	<0.001	0.78	0.71 to 0.84	<0.001
Age at recruitment	−0.03	−0.05 to 0.01	0.002				–	–	–
Worst moment									
Threat to life/well-being	0.77	0.70 to 1.46	0.031	–	–	–	–	–	–
Inter-crew difficulties	–	–	–	1.79	0.12 to 3.46	0.036	–	–	–
Sleep deprivation	–	–	–	–	–	–	0.80	0.16 to 1.43	0.014
Constant	3.66	2.80 to 4.51	<0.001	4.22	2.03 to 6.41	<0.001	1.48	1.20 to 1.75	<0.001
N	837			169			837		

longer time since the fire. At each contact, scores related to the intensity of exposure during the fire, but that relationship was stronger immediately post-fire. Those reporting at recruitment that they felt their life or safety had been under threat during the fire were more likely to have high scores, indicating risk of clinically significant mental ill-health, at second follow-up. As has been reported elsewhere (9) the prevalence of mental ill-health, estimated from structured clinical interviews, was high in this cohort (21% PTSD 16% anxiety disorders 14% depressive disorders). The increasing anxiety and depression scores with time since the fire might simply reflect a learning effect (with higher scoring as the scale became more familiar) but equally might reflect in part unresolved issues arising from the fire or the ongoing stresses of working as a first responder (19). The responses given during the structured clinical interview to assess PTSD (9) showed clearly that fighting fires was not the only, or necessarily the major, cause of PTSD. Only 42% of those with PTSD reported during the clinical interview any fire event as life threatening but cited rather the trauma of dealing with the dead and injured in road traffic and other incidents (20).

A strength of this study is its longitudinal follow-up, which allows us to look at the evolution and resolution of fire-associated symptoms. We were fortunate also to be able to link firefighters to their administrative health record and so have some indication of their pre-fire health and how this compared to others in their community. This was particularly valuable looking at respiratory

ill-health where we found an excess of asthma in firefighters pre-fire with increased numbers post-fire (12). A comparable analysis for mental ill-health, included here, was less successful in demonstrating a post-fire excess in firefighters largely, perhaps, because assessment or treatment by psychologists would not be reflected in this database (but was almost certainly part of the assessment in those with WCB compensation).

Weaknesses of the study include missing or imputed values for some wildland firefighters, many of whom were recruited some months after the fire, completed only a short recruitment questionnaire and were not asked to complete the first follow-up questionnaire. Not everyone agreed to be linked to the AHDB or to WCB records, and those who did may not be representative of the whole sample. Use of the physician billing records to reflect mental ill-health before or after the fire will have excluded mental ill-health assessed by other health professionals. The effectiveness of RPE was by an index that has not been objectively validated.

There have been many studies of the respiratory and mental ill health of firefighters, with systematic reviews concluding that the risk of ill-health was greater after large scale disasters (4, 6). Longitudinal studies, following up the health of firefighters in the months and years after the fire are uncommon. Those of mental health in Australian firefighters following disastrous bush fire in 1983 deserve mention (21) but the prototype for the current study was the longitudinal follow-up of first responders from the collapse of the World Trade Centre in 2001. As here, increases in asthma, airways hyperreactivity, PTSD, depression and stress reactions were well-documented (22). Although the exposures were different, with particulate exposure in the early hours being to dust clouds rather than smoke, and horrendous loss of life in the World Trade Centre disaster, the similarity in health outcomes is striking.

In setting up this study we wanted to help identify ways in which fighting future wild fires might be made safer. We have shown evidence here of the very limited respiratory protection achieved by RPE, particularly in the early days of the fire. Elsewhere we have shown the importance of skin hygiene to reduce absorption of polycyclic aromatic hydrocarbons both in urban and industrial firefighters in the Fort McMurray fire (7) and in wildland firefighters (23). The importance of administrative controls, in reducing exposures by deploying firefighters in rapidly rotating shifts, is demonstrated by the mean exposures during the first rotation shown in **Figure 2**. Firefighters from Strathcona and the City of Edmonton, for example, attended the fire from the earliest days alongside those from Fort McMurray/Wood Buffalo, but because of the short time each firefighter was deployed, the mean exposure was among the lowest for structural firefighters. Through our study of fire chiefs and their reports of mental health supports, we have shown also that anxiety and depression, and perhaps PTSD, were reduced by peer support provided after the fire (11). The result from the current analysis, showing that those who felt that their life or safety had been threatened during the fire had increasing anxiety with time since the fire, reinforces the need for ongoing support from peers and health professionals. Work on this cohort has also highlighted the link between difficult childhood circumstances and psychiatric ill-health suggesting the importance of trauma-informed mental health care in these first responders (10, 24).

Although the main aim of the study was to help identify approaches to the primary prevention of harm to firefighters, a secondary goal was to use the data to assist in determining whether damage to firefighters' health was indeed fire-related. In one paper (8) we examined the relation of inflammatory markers, taken 3–4 months after the start of the fire, to both exposure and respiratory ill-health and suggested that, in the absence of external estimates of exposure, long term biomarkers might be a useful proxy. From the clinical assessment of those with ongoing respiratory problems, we suggest that the combination of airways hyperreactivity and bronchial wall thickening might be used as a marker of fire-related damage (12).

We have been invited to consider, in this paper, how rapid research could improve health outcomes and resilience following a disaster such as the fire in Fort McMurray. We have learnt that the collection of data and samples, particularly biological exposure markers, as early as can possibly be achieved, may be critical in establishing the full effects of events and exposures that occur before control of the disaster site has been fully established (25). This may be very difficult, given the need to limit access to the site, but may be possible with collaboration from those within the perimeter. A second need is to establish a nominal list of participants before they are too widely dispersed. In this emergency we were particularly fortunate in having near instant support from potential collaborators, funders and the university ethics board. Serendipitously we had available the mobile clinical laboratory and access to detailed lists of firefighters. By getting on the ground early we were able to establish credibility with firefighters who could help us devise questions appropriate to their experiences. By establishing an Investigators Group, with representatives from firefighter organisations, we did our best to ensure that each of the follow-up contacts was appropriate and worthwhile. It was particularly valuable to the team to recruit firefighters face-to-face during the first phase of the study, and to hear about their experiences, often troublesome, during the early days of the fire. In this final report we have concentrated on the perceptions of the firefighters themselves: although changes to policies and programs must rest on the strongest and often most objective evidence, full insight into the fire and its effects needed the early and full collaboration of the firefighters, which we have tried to reflect here.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

ETHICS STATEMENT

The project was reviewed by the Health Ethics Board at the University of Alberta (Pro00089958 and Pro00098071). The

patients/participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

NC and JB designed the study and collected the data. NC and J-MG assembled the database and conducted the analysis. NC wrote the first draft of the manuscript. All authors reviewed, revised, and approved the manuscript.

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The Experience and Perceived Consequences of the 2016 Fort McMurray Fires and Evacuation

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Few studies have examined the scope of the subjective experience during and after a natural disaster. This qualitative study explored the perceptions of persons affected by the wildfires and evacuation of Fort McMurray in 2016. The objectives were to document (1) the experience of the evacuation, and (2) the biopsychosocial consequences of the wildfires as perceived by evacuees from Fort McMurray 3 months and 3 years after evacuation. This study included two data collections, one from 393 evacuees 3 months after evacuation using an online questionnaire, and the other from 31 participants (among those who participated in the 3-month evaluation) interviewed by telephone 3 years after evacuation. Eight themes describing the evacuation experience emerged from the qualitative analysis: the preparation for evacuation, the perceived traumatic nature of the evacuation, problems encountered while on the move, assistance received and provided, vulnerability conditions, presence of physical discomfort, relocation and no problem/no response. Seven categories of negative consequences emerged: material and financial loss, emotional/mental health disorders, cognitive impairments, behavioral changes, spiritual/existential reflections, social alterations, and physical conditions. Four categories of positive consequences emerged: posttraumatic growth, resilience/absence of consequences, altruism and community cohesion. This study showed a wide range of perceived consequences of fires and evacuations by Fort McMurray residents. The results highlight the importance of tailoring responses to the needs of evacuees and providing assistance to victims over a long period of time.

Keywords: natural disaster, wildfire (bushfire), evacuation, consequences, qualitative research

INTRODUCTION

Every year in Canada, several disasters occur (earthquakes, floods, landslides, tornadoes, etc.) (1). One major disaster that occurred in Canada was a wildfire that raged in Fort McMurray, Alberta, in May 2016. At first, the fire appeared to be under control. However, it spread rapidly with the arrival of high winds on May 3rd (2). The evacuation of the whole population became mandatory when the fire crossed the Athabasca river in the northern part of the city. About an hour after the evacuation was announced, the fire reached the city and blocked one of the two main routes out of the city (3). This fire forced more than 80,000 residents to evacuate the city and burned approximately 2,400 homes and buildings (4). There were no fire-related deaths, but two people lost their lives in a car accident during the evacuation. More than a quarter of the population required the assistance of mental health professionals (4). This type of disaster can have major economic, social, physical and psychological impacts (5), which may lead to long-term consequences for victims (6, 7).

Few theoretical models can explain the full range of consequences following a disaster and, to the best of our knowledge, none of them concern natural disasters. The Psychosocial Risk Assessment and Management Framework (P-RAM) proposes a structured model to identify a wide range of psychosocial consequences potentially associated with terrorist threats and attacks in order to guide emergency planners, decision makers, and responders in their interventions (8). Many elements proposed by the P-RAM model are applicable to an analysis of post-disaster consequences. In particular, the model posits that threats or events can bring about normal and abnormal psychosocial effects. The normal effects can be psychosocial adverse effect such as changes in the behavioral, emotional, cognitive, social, physical and spiritual spheres. Abnormal effects include the development of mental health disorders [for example, depression, anxiety disorders, or post-traumatic stress disorder (PTSD) or other disorders presented in the Diagnostic and Statistical Manual of Mental Disorders (DSM-IV) nosology], as well other psychosocial issues such as burnout or family violence. In addition, positive reactions or psychosocial benefits can be observed after a disaster, such as resilience, community cohesion, protective behaviors, and post-traumatic growth.

Even if evacuations are ordered to protect populations in imminent danger (9), the evacuation in itself can be a very stressful event, as can be the relocation process, thus potentially negatively impacting psychological health (10). Studies have shown increased levels of post-traumatic symptoms (11), depression and anxiety disorders (12–15) in evacuees and persons relocated in the context of disasters. Afifi et al. (16) reported that the evacuation process increased uncertainty about personal safety, home security and the duration of relocation. Another study of evacuees from the 2014 wildfires in the Northwest Territories of Canada reported that fear, stress, and uncertainty contributed to negative outcomes (17). However, most studies of evacuations following a disaster focus primarily on the choice of whether or not to evacuate, not on the process of evacuation *per se* and consequences that ensue.

Beyond symptoms such as fear or insecurity, more severe forms of mental health issues have been the object of much scientific attention following disasters (10), categorized as abnormal effects in the P-RAM model. Our team conducted interviews three months after the Fort McMurray wildfires and found that 29,1% of the participants had a probable PTSD diagnosis, 25,5% a probable depression and 43,6%, insomnia (18). Another study showed that six months after the disaster, there was an incidence of 19,8% of generalized anxiety disorder (GAD) among participants from Fort McMurray (19). Participants presenting this diagnosis were also at greater risk of substance abuse. Even 18 months after the wildfires, one study found that 13,6% of participants met criteria for PTSD, 24,8% met criteria for major depressive disorder (MDD) and 18% met criteria GAD (20).

In terms of physical effects, smoke inhalation during wildfires may cause temporary, progressive or permanent breathing problems (21) and lead to respiratory and vascular diseases (22). Some elements contained in the smoke from wildfires may even have carcinogenic properties (23). Nevertheless, the literature remains undeveloped with respect to the consequences on physical health following a wildfire and even more so outside of the United States (24). A team went to Fort McMurray 14 months after the fires to investigate the presence of toxic substances (e.g., arsenic, heavy metals) in the community. They found that the levels of these substances were not higher than in unaffected homes elsewhere in Canada (25). However, even when a danger is not objectively present, the affected population could still fear or perceive physical consequences following a disaster.

Other consequences of disasters are economic and can lead to significant financial stress for the community (24). The Fort McMurray wildfires were considered Canada's most expensive natural disaster at the time, with a $3.58 billion cost (26). Very few studies have focused on the perceived financial aspect of wildfires. Kulig et al. (27) administered 52 interviews to document several potential economic consequences on wildfire evacuees. In the qualitative component of this mixed-method study, participants reported financial problems due to the loss of their homes, insurance problems, job loss or financial burden due to relocation (27). Personal and financial losses due to disasters have been shown to be associated with increased psychopathology including depression, anxiety, somatic complaints, stress and PTSD (24, 28–30).

Natural disasters can also have negative social impacts, often because the needs for support outweigh the actual support available in the community. In addition, relocation and job losses deprive victims of opportunities for social support, as they no longer have access to the people who usually provide them with this support (31). The deterioration in social support networks can represent a risk factor for developing mental health problems following a natural disaster (32).

As the impacts of a natural disaster appear to persist for several years, there is a need to better document the long-term biopsychosocial consequences (33). The *Biopsychosocial response pattern and temporal phases of disaster* (**Figure 1**) first developed by Young et al. (34) and later modified by Math et al. (31, 35) describes the different phases of expected reactions in individuals experiencing a disaster. According to this model, a "heroic phase" occurs right after the event, can last for a few days, and is described by rescuing, sheltering, feeding and supporting behaviors. Then, a "honeymoon phase", lasting 2 to 4 weeks ensues, encompasses a period during which individuals are safe, taken care of, and receive help from different organizations that help to provide them a feeling of hope. Several positive effects identified in the P-RAM model such as community cohesion, altruism and adaptive coping probably occur during this phase. Then, a "disillusionment phase" can last from three months to three years. It is a phase of reconstruction and rehabilitation during which the assistance provided to the community and the media attention have diminished. The mental health of the community is more fragile during this phase. Finally, the

FIGURE 1 | Biopsychosocial response pattern and temporal phases of disaster from Young et al. (34) modified by Math et al. (31, 35).
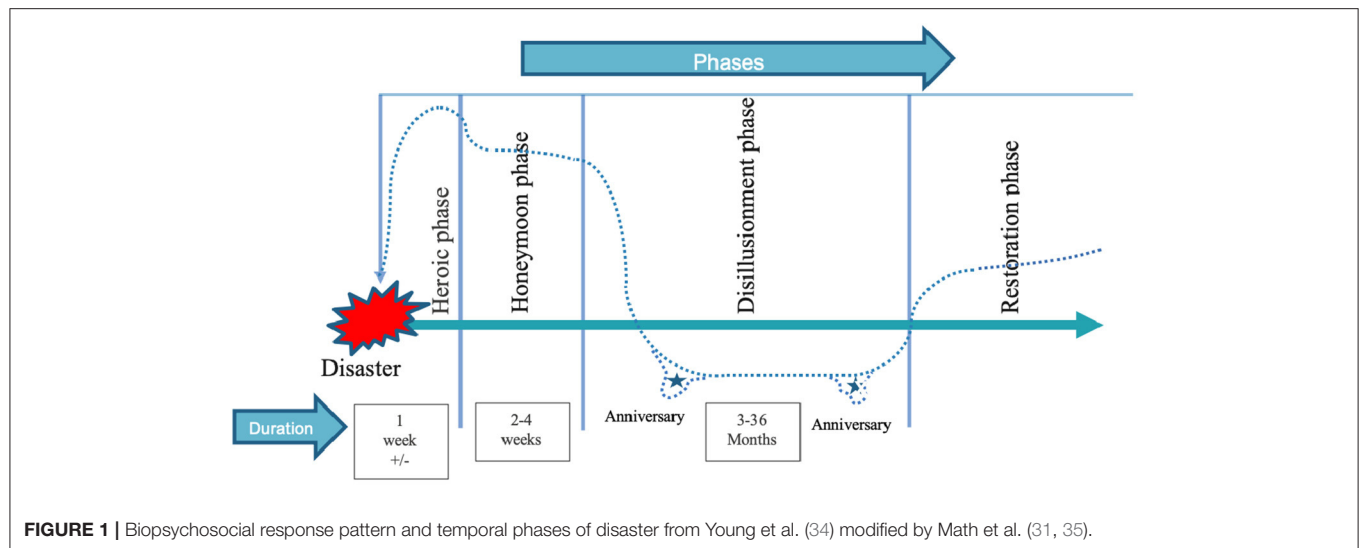
"restoration phase", which begins after three years, is described as the gradual return to normal functioning. This model suggests that the consequences of a disaster will evolve and persist over the years. The "disillusionment phase" appears to be a particularly critical period for the affected community and as such, merits more scientific attention.

Few studies have adopted a longitudinal lens to examine the evolution of the consequences of disasters. One of the few longitudinal studies of individuals exposed to wildfires investigated the psychological impacts of the disaster three to four years after the fires, then five years later after the Victorian Black Saturday bushfires in Australia (33). Rates of PTSD, MDD, serious mental illness and problem alcohol use decreased overall over time. However, these rates remained higher than in the general population. Such a quantitative portrait is essential, but having access to individuals' subjective experience and perceptions of the long-term impacts of disasters could help inform mental health professionals' practice even further, for example by documenting important perceptions, attitudes, reactions and main concerns of this particular population (36).

In sum, the existing empirical evidence concerning the consequences of natural disasters has largely explored psychological consequences, while little emphasis placed on other types of consequences presented in the P-RAM model (physical, social, positive effects), leaving significant knowledge gaps. There are also few studies on the long-term consequences of natural disasters, in particular very few qualitative studies, which could help gain a better understanding of the evolution of perceived consequences. Therefore, the overarching aim of the present study was to document subjective experience of wildfire evacuees and the perceived consequences of this type of disaster and how these perceptions evolved over time. More specifically, the first objective of the present study was to document the evacuation experience from the standpoint of the evacuees of the Fort McMurray wildfires. The second objective

was to document the biopsychosocial consequences of wildfires as perceived by evacuees from Fort McMurray, three months and three years later.

MATERIALS AND METHODS

Participants and Procedure: Experience of the Fires and Evacuation and Biopsychosocial Consequences 3 Months After the Fires

The data of the present study were collected as part of a larger project including quantitative measures of mental health published elsewhere (18). The Laval University institutional review board approved the research protocol, and participants provided informed consent. Two doctoral students in psychology went to Fort McMurray to recruit participants 3 months after the evacuation (July 25 to August 16, 2016). They distributed invitations to participate in the study to citizens in public places such as retail stores and supermarkets in Fort McMurray. They also publicized recruitment on local radio programs. The participants were invited to complete an online questionnaire. The survey was open between July 25 to September 5, 2016. To be eligible to participate in the study, all respondents had to: (a) be at least 18 years old; (b) have a functional knowledge of English, and (c) have experienced the evacuation from Fort McMurray. No exclusion criteria were applied. A total of 394 participants completed the survey.

At this first time point, in addition to completing validated quantitative questionnaires assessing psychological symptoms for the larger project, participants answered the following open-ended questions: (1) Describe briefly what happened. How did you personally experience the fires? and (2) What consequences have you suffered from the fires? Participants had unlimited typing space to answer.

Participants and Procedure: Experience of the Fires and Evacuation and Biopsychosocial Consequences 3 Years After the Fires

An e-mail was sent between June and September 2019 to the 141 participants (out of 394) who agreed to be contacted again after completing the first part of the study. They were invited to participate in a semi-structured interview conducted by telephone concerning their experience of the fires and evacuation three years after the event. No financial compensation was offered for participation. Thirty-one (31) individuals agreed to complete the interview and provided separate informed consent. These interviews were conducted by the first author of this study, a graduate student in psychology, and lasted approximately 15 minutes on average. The interviews were audiotaped and then transcribed verbatim by an undergraduate student.

During the interview, participants answered 11 open-ended questions: (1) What consequences of the fires and evacuation are still present in your life? (2) Do you experience psychological consequences? (3) Do you experience physical consequences? (4) Do you experience social consequences? (5) Do you experience financial consequences? (6) Do you experience positive consequences? (7) What did you find helpful during the evacuation? (8) What did you find difficult? (9) If you have had had the choice to evacuate or not, what would you have done? Why? (10) Have you received professional help to cope with the negative consequences of this event? If yes, describe this help. (11) What kind of help do you feel you would like to have today? These more directive questions were formulated in order to access to the full range of biopsychosocial consequences based on the P-RAM model.

Data Analysis

A qualitative thematic analysis was performed by the first author in order to categorize the participants' responses into the various aspects and consequences of the wildfires and the evacuation experience. The thematic approach based on the work of Paillé and Muchielli (37) was used as it allows the categorization of participant's answers into themes and sub-themes. The P-RAM model provided a framework for synthesizing the results of the present study, but the analysis was not restricted to the categories generated by this model. The coding method was inductive in order to highlight significant themes and sub-themes among the participants' responses (38). Responses from the questionnaires completed 3 months after the fires were first coded. A sample of the data corpus (about the 50 first questionnaires) were used to create the initial codes. When approximately 70 codes were created, these were then transformed into themes and sub-themes. A first draft of the codebook was created by the first author and reviewed throughout the process. The final codebook was then used to code the entire data corpus. This same codebook was used to code the interview data collected three years later. It was, however, modified again to adapt it to the participants' responses at this second stage, resulting in a second codebook.

An inter-judge agreement was reached to ensure the validity of the categorization. Using the codebooks for each assessment time, an undergraduate psychology student carried out an independent coding of 20% of the data corpus (from 78 questionnaires and from 6 interviews). All discrepancies were discussed, and decisions were made based on mutual agreement. The two codebooks were revised and merged into one through inter-judge discussions. The data corpus re- coded a final time by the first author to ensure that codebook adjustments over time were applied systematically to the entire set of results. The QDA miner 4 software (Provalis Research, Montreal) was used to perform the qualitative analysis.

RESULTS

The results are presented hereafter in four sections. First, the characteristics of the sample are presented. The second section presents results concerning the evacuation experience. Themes are presented in a loose chronological order, from the beginning of the evacuation day up to the phase of relocation. The third section describes the biopsychosocial consequences experienced by the participants three months and three years after the evacuation. Quotes are used to illustrate the themes. Preceding each quote, the gender ("F" for female and "M" for male) and ages of the respondents are indicated. Given the large number of participants in the study, the fourth section presents a frequency analysis quantifying the frequency of occurrence of themes and sub-themes.

Sample Characteristics

Sociodemographic characteristics of the sample are presented in **Table 1**. Among the 394 participants who responded to the questionnaires three months after the fires, it was found that one participant was under the age of 18. This participant was excluded from the analyses. The final sample three months after the fire of the study was composed of 291 women and 72 men. The majority of participants were aged between 18 and 34 years (38,7%) and were employed (79,9%). The majority were married or in a common-law relationship (75,5%).

The sub-sample assessed three years after the fire was composed of 23 women and 8 men. It was discovered after the interview that one participant had not experienced the evacuation. This participant's data are included in the 3-month questionnaire data, because there was no way to identify these data retrospectively, but not in the 3-year interview data. Most participants were aged between 35 and 49 years (48,4%). Twenty-nine identified as Canadian or European (93,6%), one as Hispanic (3,2%) and one as a member of a First Nation (3,2%). As a reference point, in 2016, in the general population of Fort McMurray, 77% identified as Canadian/European origins, about 1,6% as Hispanics and 5,3% as members of a First Nation (39). The majority of participants were employed (74,2%) and married or in a common-law relationship (64,5%). Among these participants, 22 still resided in Fort McMurray, whereas 9 had moved out of town.

Variables	3 months after the fires (n = 393)	3 years after the fires (n = 31)
Gender		
Male	79 (20,1%)	8 (25,8%)
Female	303 (77,1%)	23 (74,2%)
No answer	11 (2,8%)	
Age (years)		
18-34	151 (38,4%)	9 (29%)
35-49	130 (33,1%)	15 (48,4%)
50-64	95 (24,2%)	5 (16,1%)
65+	8 (2%)	2 (6,5%)
No answer	9 (2,3%)	
Ethnicity	X	
Canadian or European		29 (93,6%)
Hispanic		1 (3,2%)
Membership in a First Nation		1 (3,2%)
Employment status		
Employed	302 (76,8%)	23 (74,2%)
Unemployed	27 (6,9%)	8 (25,8%)
Student	7 (1,8%)	
Other	57 (14,5%)	
Relationship status		
Married/common-law	283 (72%)	20 (64,5%)
Separated/divorced/widowed	29 (7,4%)	2 (6,5%)
Single	69 (17,6%)	9 (29%)
No answer	12 (3%)	
Place of living after the fires	X	
In Fort McMurray		22 (71%)
Outside of Fort McMurray		9 (29%)

Evacuation Experience of the Fort McMurray Residents

Among the responses describing the participants' evacuation experience, eight themes were identified: preparation for evacuation, the perceived traumatic nature of the evacuation, problems encountered while on the move, assistance received and provided, physical discomfort, conditions, relocation and no problem/no response (**Table 2**).

Preparation for Evacuation

Three months after the evacuation, one theme concerned the efforts made by residents to prepare themselves for the evacuation. Some respondents decided to leave their home before the mandatory evacuation was announced. Some had prepared themselves in advance just in case they would need to evacuate, so they were ready to leave the day of the mandatory evacuation. For example, one participant (F, 36) explained: *"We had already packed valuables and our child's necessities the day prior, just in case"*. Other participants mentioned that they had no time to prepare themselves because the fire was already too close, and they could not access their house. Another respondent (F, 36) wrote: *"By the time we reached our neighborhood it was under a*

mandatory evacuation as well, so we were not able to go home to retrieve items"*. Others had had the time to access their home to get their personal belongings and pack their cars. They described having to pick up their children (at home, school, nursery) and pets before evacuating the city. For example, one participant (F, 34) wrote: *"I ran to the school to get my children and to the vet to get my cat and then drove out of town to save our lives"*.

Three years after the event, the respondents who had evacuated before the mandatory evacuation reported that it was a helpful factor. One participant (F, 36) said: *"I think my experience is very different from most, because I evacuated early and I went north, so I didn't have this fear that a lot of people did"*.

The Perceived Traumatic Nature of the Evacuation

This theme referred to the participants' perceptions of the evacuation experience. Three months after the evacuation, one recurrent perception was the unpredictable nature of the evacuation. Participants mentioned that they believed the fire was under control at the beginning of the day. Most people were busy with their usual schedules when the official order came. One participant (F, 23) described: *"The radio was saying that nothing was wrong. On my way to my mom's, I could see flames overtop the trees in the distance of the forest. I dropped my dogs off and was about to head to work when the radio said we had 30 minutes evacuation notice for Beaconhill"*.

Other than the unpredictable nature of the evacuation, three months post-evacuation many participants qualified their experience as traumatic, some as *"the most traumatic experience of [their] life"*. A related perception was that the evacuation was a chaotic experience. For instance, one participant (F, 46) wrote: *"Then, vehicles started racing through our street and blowing horns, yelling, telling everyone to get out. I ran outside it sounded like a war zone, propane tanks exploding. Dark. Scary"*. Participants also wrote that it was a highly stressful moment. For example, one (F, 19) described: *"The stress was crazy. I had to pack up everything for me and my fiancée, my cat, my parent's dog and wait for my fiancée's mom to come and get me while every person I knew was calling me at the same time"*.

These perceptions of the event as traumatic, chaotic or highly stressful were also mentioned three years later. One respondent (F, 69) expressed: *"There's no words that describes what happened, what we felt, what we went through. It was traumatic, scary, everlasting. Certainly, a learning experience. I don't know, I don't want to use the word hateful, but it got us feeling what we didn't know we were even able to have. It's been three years and I still cannot describe what the fire did to us"*.

Problems Encountered While on the Move

The participants evoked the conditions in which the evacuation unfolded. In the questionnaire, some respondents reported driving near or through the flames. One participant (F, 33) wrote: *"I drove through the smoke and flames, through all the abandoned vehicles and saw houses on fire"*. Likewise, some had to abandon their vehicle to escape the flames and smoke. In addition to the fire that was approaching on the road, participants pointed out the important traffic congestion they had to face to be able to

Evacuation experience							
Preparation for evacuation	***The perceived traumatic nature of the evacuation***	***Problems encountered while on the move***	***Assistance received and provided***	**Vulnerability conditions**	**Physical discomfort**	**Relocation**	**No problem/no response**
*Evacuated before the mandatory evacuation	*Traumatic	Driving threw/near the flames	*Helped others/help received	Being hospitalized	Eyes burning	Permanent	Did not encounter any problems or did not answer the question
Prepared in advance in case	*Chaotic	Traffic	from others	Not knowing how to drive	Breathing problems	Temporary	
No time to prepare	*Stressful	*Road closed	*No help	On foot	Asthma		
Got personal belongings at home	*Unpredictable	Out of gas/abandoned vehicles	First responders	Being in labor	Injury		
Picked-up children/animals		*Being separated from friends and family					
		*Communication issues					

The asterisk indicates themes and sub-themes that emerged in the participants' verbatims at the 3-month and 3-year collect.

leave town. The authorities were also forced to close one of the two main roads for a certain amount of time. One participant (F, 25) described: *"the entire town was on a mandatory evacuation and traffic was grid locked. We were told that we were no longer allowed to go south toward Edmonton and that we had to go north and stay in camps (...). It took us almost 5 hours to get there when normally it would take 45 minutes"*. Some evacuees ran out of gas. They wrote about being given gas by strangers, finding gas stations still open or having to find another means of transportation to leave town.

In this community, residents are aware of annual wildfires occurring in the vicinities, but these fires had never reached town in the past. When the evacuation order was given, the population was scattered across town. Respondents wrote about being separated from friends and family during the evacuation. For example, one respondent (F, 32) wrote: *"I had a friend picking up my daughter from school and evacuated with her, so we separated for 24 hours"*. Another participant (F, 49) wrote: *"My husband and I got separated as he made it south and I had to go north"*. In addition to being separated from loved ones, participants reported communication issues because of dead phone batteries, poor network, overloaded cell towers, etc.

In the interviews conducted three years after the disaster, most participants still noted that closed roads, having been separated from friends and family, as well as communications issues, were some of the most difficult aspects of their evacuation experience.

Assistance Received and Provided

Three months after the evacuation, respondents indicated that during the evacuation, they helped other people to evacuate (e.g., children at school, coworkers, general population) and checked in on neighbors. For instance, one participant (F, 62) explained: *"All along the street, neighbors were checking in with each other, offering help and advice and exchanging contact information, discussing how to contact neighbors who had not come home yet"*. Participants reported receiving assistance from other community members. One participant (M, 55) wrote: *"I had two families helping me packing up my vehicle and one of the couples split up, so they could drive my car to Athabasca (a small town between Fort McMurray and Edmonton)"*. However, some respondents

reported not receiving any assistance during the evacuation. For example, someone (F, 45) wrote: *"We fled with flames on both sides of us and no firefighters, police or anyone helping us. They let our neighborhood burn for days and didn't even attempt to fight it"*. There were also first responders among the participants, such as social workers, firefighters and evacuation center workers. One firefighter (M, 32) wrote: *"I was actively involved in the firefight. I had to watch my lieutenant's house and friends' homes burn while I was trying to stop the fire from spreading"*.

Three years later, respondents reported that they appreciated the assistance received during the evacuation. Indeed, participants mentioned organizations that helped them, such as the Red Cross, and people from the community helping each other during the evacuation. However, some participants also perceived the lack of assistance as a negative part of the evacuation. Participants mentioned experiencing delays in receiving assistance from the government and other organizations.

Vulnerability Conditions

This theme refers to participants who reported situations of extreme vulnerability and were left to fend for themselves. In the questionnaire, one hospitalized participant (M, 49) described: *"I left the hospital one hour after being evacuated. I walked 5km to Thickwood on ramp to be detained by RCMP, left at the airport with no food or water, slept on floor at bottom of escalator and in a wheelchair, an IV needle still in my arm"*. One person (M, 55) reported having to evacuate the city on foot. Another (F, 36) mentioned not being able to drive. One woman (F, 38) was pregnant and wrote: *"I was also 38 weeks pregnant at the time we left. We evacuated north to a work camp where I went into labor and had to be flown to Edmonton and later Calgary to have our son"*.

Physical Discomfort

During both data collection periods, some people reported experiencing physical discomfort during the evacuation because of the fire and the heavy smoke. Some participants reported having burning eyes, breathing problems and asthma attacks during the evacuation.

Negative consequences							*Positive consequences
*Material/financial loss	*Emotional/Mental health disorders	*Cognitive impairments	Behavioral changes	*Spiritual/ existential reflections	*Social alterations	*Physical conditions	*Resilience/no consequences
*Loss of house and sentimental belongings	*Anxiety	Memory problems	Increase use of tobacco and/or alcohol	*Changes in life perception	*Separation	*Changes in physical conditions	*Altruism
*Job problems	*Hostility	Poor concentration		*Uncertainty about the future	Conflicts		*Posttraumatic growth
*Financial issues	*Guilt	Impaired decision-making ability			*Withdrawal	*Health problems	[†]Community cohesion
	*Sadness	Nightmares			[†]Social changes		
	*Mood fluctuations	Flashbacks			[†]Feeling misunderstood		
	*Emotional distress after exposure to traumatic reminders	*Altered perception of safety/hypervigilance					
	*Self-reported mental health disorders (PTSD, anxiety, depression)						

*The asterisk indicates themes and sub-themes that emerged in the participants' verbatims at the 3-month and 3-year collect.

*The symbol [†] indicates themes and sub-themes only found during the interviews conducted at the 3-year follow-up.

Relocation

This theme describes the temporary or permanent relocation of the evacuees right after the evacuation. Three months post evacuation, participants described moving temporarily to shelters including crisis centers, family and friends' places, hotel/motel rooms or rented lodgings. The duration of the relocation varied from a few days to a few months, and some evacuees had to relocate several times. For instance, one participant (M, 55) wrote: *"We stayed in a work camp overnight and we were flown out on May 4 to Edmonton. We spent nine days in a hotel room and six more weeks in an apartment"*. Respondents also wrote about deciding to relocate permanently to another city.

No Problem/No Response

Finally, some participants reported having had no problem during the evacuation. Some respondents were in an area unaffected by the fires. In addition, 26 respondents to the online survey left the open-ended questions unanswered.

Biopsychosocial Consequences

When asked to describe the consequences of the wildfires at three months and three years, participants mentioned negative and positive consequences (**Table 3**). The negative consequences were grouped under seven themes: material and financial loss, emotional/mental health disorders, cognitive impairments, behavioral changes, spiritual/existential reflections, alterations in social functioning, and physical conditions. Positive consequences were grouped under four themes: posttraumatic growth, resilience/no consequence, altruism and community cohesion.

Negative Consequences
Material and Financial Loss

One theme included the direct and indirect impacts of the wildfire on participants' material possessions and finances. In the 3-month questionnaire, participants wrote about the loss of their homes and of all their personal belongings. For example, one respondent (F, 58) wrote: *"We lost everything but the clothes we were wearing"*. Financial issues sometimes included difficulties with their insurance company to rebuild their houses. Other financial problems were due to a period of time during which some participants could not work after the evacuation.

At the 3-year follow-up, respondents reported having lost their homes and personal belongings and still reported issues regarding insurance problems, rebuilding delays and job changes.

Emotional/Mental Health Disorders

This theme encompasses the range emotions and psychological disorders that participants mentioned when describing their experience. After three months, emotions could be categorized into anxiety, irritability/frustration, guilt and sadness. The anxiety category included fear and stress regarding their experience. Some were stressed or were afraid for their children, their finances, their return to the city, the separation from their family. Some feared other eventual disasters. One participant (F, 33) expressed: *"I am constantly thinking and stressing over things. It's so hard"*. Another category of emotions that participants described was irritability/frustration. Many participants reported feeling frustrated by the decisions made by authorities before and during the evacuation and by not being able to return to Fort McMurray for some time after the fires, whereas others did not identify a specific cause of their emotions. For example, one participant (F, 23) expressed: *"I am a lot more irritable, and easily angered"*. Other emotions reported can be categorized as guilt. Participants reported feeling guilty when comparing their losses to that of others. For instance, one participant (F, 47) explained: *"We were lucky we have our home still and our daughter has hers. But friends of mine don't and they don't know when they will rebuild. I feel very guilty about this. How did I get so lucky when others didn't?"* Some felt guilty about leaving their pets behind. A last category of emotions reported was sadness. Participants mentioned feeling sad about the changes in the city and hearing other people's stories. One participant (F, 37) expressed: *"I felt (…) sadness upon returning and seeing the devastation. Continue to feel sadness to hear stories of people affected"*. Participants reported emotional fluctuations, or that

their emotions felt irrational. One respondent (M, 38) described his emotions by an *"emotional roller coaster of feelings"*. In addition, participants mentioned experiencing emotional distress when exposed to traumatic reminders. For instance, participants felt anxious, upset, or afraid when they were exposed to sirens, smoke, fire pits, the smell of fire, pictures representing the event, heavy traffic, etc. There were also participants who specified suffering from a mental health disorder as a consequence of the wildfires. Participants wrote about suffering from PTSD, anxiety and depression.

Three years later, respondents reported the same categories of emotions, including experiencing emotional distress when exposed to traumatic reminders. Some participants also reported still suffering from PTSD, depression and anxiety regarding to the fires.

Cognitive Impairments

This category of consequences refers to cognitive alterations and cognitive intrusions reported by participants. Three months after the fires, some respondents had memory lapses about the event (such as being unable to remember some important moments of the evacuation). One respondent (F, 58) explained: *"The next morning my daughter said, "Imagine mom, we drove through that fire yesterday." but I couldn't remember doing so, even though I know I did. She showed me pics of it, but I am still unable to remember doing so. I do remember seeing embers while driving and was afraid that they would come down on the car and blow the car up. I remember hearing explosions, which later found out were propane tanks"*. Some respondents reported suffering from poor concentration, or impaired decision-making abilities, but they provided few additional details.

Three months after the wildfires, some mentioned having flashbacks during the day and nightmares during their sleep concerning the fires and evacuation. Participants also reported an altered perception of safety and a state of hypervigilance. For instance, one respondent expressed (F, 33): *"I'm feeling overcautious, sometimes I plan for potential emergencies"*.

Three years after the wildfires, among the different types of cognitive impairment, only hypervigilance was highlighted from the interviews. Some participants were still alert to signs of a possible danger. One participant (M, 32) explained: *"Every time I leave my place, I kind of take a look around and do a mental inventory of everything that's there. Just in case something happens while I'm gone"*.

Behavioral Changes

This theme includes behavioral changes reported by the evacuees three months after the evacuation. Increased use of tobacco or alcohol highlighted in the answers. Some participants began to smoke again and drank alcohol more frequently compared to before the event. Participants reported very few details about their consumption habits. No participant reported substance abuse or dependence problem three years after the fires.

Spiritual/Existential Reflections

Three months after the event, existential thoughts were identified from the answers concerning changes in identity and perception

of life. Participants mentioned having a different perception of themselves. For example, one participant (M, 33) wrote: *"My life will never be the same for us. It definitely alters who you are"*. Furthermore, participants felt uncertain about the future. They reported not knowing what they would become in a few months, where they would be, or what they would be doing. For instance, one respondent expressed (F, 19): *"The hardest part of everything was the uncertainty. When would we come back? Would we come back? Would we go back?"*

Three years after the disaster, participants reported having a new outlook on life. For instance, one respondent (M, 49) explained: *"The whole life changed. Who we are, how we identified, all our history and our past is all gone and we're starting over again"*. Participants also remembered the uncertainty. One participant (F, 29) expressed: *"I thought the uncertainty, the fear, leaving your house when you don't know if you're going back, was difficult. I wasn't able to take many belongings with me so there is a loss of security"*.

Social Alterations

This theme included the negative impacts on the participants' social life. Three months after the disaster, respondents were preoccupied by their separation from friends and family members after the fires and evacuation. They were concerned about temporary separation due to relocation of the community and about some residents' decision to move from Fort McMurray permanently. For instance, one participant (F, 20) mentioned: *"I got to see my parents every day, my brothers. Now my parents and brothers live 14 hours away in British Columbia"*. Moreover, respondents described feeling more lonely or isolated after the event, or having voluntarily decided to withdraw from certain relationships for personal reasons. For instance, one participant (F, 37) reported: *"withdrawing from certain friends because of their negative outlook/attitude"*. Respondents also experienced conflict in their relationships. Some felt that their relationships were more strained or falling apart. For example, one participant (F, 26) explained: *"My relationship is over. After eight years we couldn't handle the stress and started fighting so much that the relationship was no longer viable or healthy for either of us"*.

Three years later, participants still mentioned the negative impact of the relocation of family members and friends on their social life. They also expressed feeling more isolated than before the fire. Respondents mentioned changes in their relationships. Some reported having a different circle of friends because of relocation or change of employment. Others felt misunderstood by friends or the rest of the community. For instance, one person (M, 42) said: *"I realize that we don't have friends. The people misunderstood that at the time we wouldn't ask for money. I never asked for money. I just, sometimes, you need a person to talk, you know"*.

Physical Conditions

This theme included any physical consequences due to the fire and the evacuation reported by participants. In the 3-month questionnaire, some respondents mentioned changes in their physical condition, without providing further details. Some reported sleep problems, changes in appetite,

tiredness, exhaustion, and lack of energy. Participants mentioned health problems, such as lung infections, somatic complaints, headaches, high blood pressure, chest congestion, coughing, sneezing, nausea and hypothyroidism.

In the interviews conducted three years after the disaster, participants reported weight changes, sleep problems, and diabetes as physical consequences of the fires and evacuation.

Positive Consequences

This section encompasses all of the positive consequences that participants described throughout the study. It is divided into four themes: posttraumatic growth, resilience/no consequence, altruism, and community cohesion.

Posttraumatic Growth

This theme refers to personal development experienced by residents following the disaster. For instance, one participant the three-month questionnaire (M, 39) explained: *"I lost many opportunities but found new challenges"*. Another person (F, 34) expressed: *"I'm also more grateful for every moment with my family"*.

Throughout the interviews conducted three years later, participants still experienced positive consequences. For example, one respondent (M, 35) said: *"I mean, after going from being very close to suicidal to now… I would say I experience a lot of posttraumatic growth and I am definitely a stronger person than I ever was before"*.

Resilience/No Consequences

This theme describes participants who reported little or no consequences of the wildfires. In the 3-month questionnaire, these respondents expressed feeling resilient to the event. For instance, one person (F, 27) explained: *"It wasn't too bad though, I focused on the positives, so I wouldn't say I was that affected by it"*. Some participants also reported not suffering from any consequences of the fires and evacuation. Others simply did not answer the question, possibly meaning that they experienced no consequences or that they did not wish to answer the question. The adoption of new adaptive coping strategies was reported by some participants. For example, one participant stopped smoking after 37 years. Some respondents mentioned focusing on healthy living habits to help deal with various stressors. Others mentioned working on interpersonal communication issues.

Three years after the disaster, respondents still showed resilience or the use of adaptive coping strategies. For instance, one participant (M, 42) explained: *"I tried to get all the positive from all the situations that we have been through. I would say that I learned who I can trust. I learned also how I can manage better the resources that I have. I think I became a better person from being resilient"*.

Altruism

Altruism refers to participants who used their experience to help other people after the fires and evacuation. One person in the 3-month questionnaire (F, 34) wrote: *"I look for ways to help others. I think it's made me more aware of the suffering of others, and I look for ways to help ease it"*. Three years after the wildfires, some

respondents mentioned volunteering for the Red Cross to help people who go through similar situations.

Community Cohesion

This theme refers to the perception that relationships are more tightly woven in the community. This positive consequence was only identified in the interviews conducted three years after the fires. One participant (M, 46) explained: *"Positive consequences I think are social and community-based. (…) It's a shared experience as well, so what I find is that everybody that lived here in 2016 has that shared experience and therefore we have something in common which strengthen the relationships and the community. I think that is positive sense of community building"*.

Frequency Analysis of Themes

A few themes and subthemes were more prominent among the participants' responses. Concerning the evacuation experience, a large proportion of respondents reported struggles to find their children and pets before evacuating the city (95/393). Problems encountered while on the move were also frequently mentioned: participants reported driving through/near the flames (112/393), driving in traffic (99/393), and being separated from friends and family during the evacuation (75/393). Three years later, a large proportion of respondents recalled communication problems (10/31) and the distressing feeling of uncertainty (9/31).

Negative consequences were reported more often than positive ones. The most frequently mentioned ones concerned material and financial loss. Many participants reported losing their homes and possessions (82/393 three months later; 12/31 three years later) and having financial worries (82/393). Emotional/mental health disorders were also frequently identified. Three months after the fires, many reported suffering from anxiety (56/393) and three years later, still being hypervigilant to reminders of the trauma (11/31). Finally, certain elements reported by the participants concerning the social consequences of the event appeared more strongly three years after the fires. Responders reported the social impact of relocating their families and friends on their social circle (9/31), and finally, greater community cohesion (8/31).

DISCUSSION

The main objective of this study was to document the experience of individuals who went through the 2016 Fort McMurray wildfires evacuation, as well as the various consequences following the evacuation. The use of open-ended questions helped to gain an understanding of participants' personal experiences. Regarding the evacuation experience, the qualitative analysis highlighted eight themes: preparation for evacuation, the perceived traumatic nature of the evacuation, problems encountered while on move, assistance received and provided, vulnerability conditions, physical discomfort, relocation and no problem/no answer. When asked about the circumstances of the evacuation, respondents mostly described the difficult conditions under which they traveled from their residence to the temporary accommodation site. The analysis also highlighted seven themes summarizing the negative biopsychosocial consequences

of the fire and the evacuation: material and financial loss, emotional/mental health disorders, cognitive impairments, behavioral changes, spiritual/existential reflections, social alterations, and physical conditions. Positive consequences were also reported: posttraumatic growth, resilience/no consequences, altruism, and community cohesion. This study thus provides valuable knowledge to increase preparedness for individuals and communities to cope for future evacuations linked to wildfires.

The present study first provided a better understanding of the evacuation process *per se*. Participants underlined an important step of the evacuation: preparedness. Although some participants had prepared themselves in advance, most reported lacking time to prepare before the evacuation became mandatory, which increased stress and uncertainty as they struggled to reunite with their loved ones, retrieve their belongings and arrange transportation. Unfortunately, this appears to be common during evacuations from wildfires. Indeed, a study of two communities affected by a wildfire found that respectively 57 and 82% of their participants had not had time to prepare to evacuate (27). Another study highlighted the lack of public awareness of the real danger of the disaster (40). The results of the study demonstrate the importance of keeping the public well informed throughout the course of relatively predictable natural disasters, such as wildfires, hurricanes and floods, and of encouraging people to take action by preparing themselves for an eventual evacuation, even when the event seems under control.

When the disaster becomes a real and imminent danger and the evacuation of the population is ordered, there appear to be shared challenges and concerns. At both measurement times, respondents emphasized the heavy traffic and closed roads, as well as separation from relatives. These results are supported by the few studies on the evacuation process due to a natural disaster. Indeed, Wadsworth et al. (41) studied evacuees from Hurricane Katrina. The victims faced traffic for several hours, which was a stressful aspect of the evacuation. Other studies had also observed that sudden and unexpected separation from family members was a major concern during the evacuation from Hurricane Katrina (40), and that the lack of preparedness in addition to traffic increased the distress in Fort McMurray evacuees (42). Another important issue evoked by participants interviewed three years after the fires were communication problems among themselves and with the government during the evacuation. Communication seems to be important as soon as a wildfire strikes, in order to prepare the population for a possible evacuation. Communication from authorities also should continue during the evacuation, in order to keep the population informed of the latest developments, for example, about the location and intensity of fires and road conditions during the evacuation. These elements (traffic, being separated from relatives, communication issues), which were expressed by several participants, seem to represent the core obstacles encountered during the evacuation. These elements were prominent not only immediately after the disaster but also three years later, suggesting that they had a significant impact on evacuees over time. This information provides insight into the process of evacuating a wildfire itself and could guide efforts to improve preparedness of individuals and communities in regions prone to wildfires (e.g. having a family communication plan in case of evacuation, planning/identification of evacuation routes, practice drills).

During the evacuation, respondents expressed that they perceived the fires and the evacuation as a frightening, unpredictable, stressful and traumatic event. For many respondents, it was perceived as a traumatic event that led to many negative consequences. The Fort McMurray evacuation indeed unfolded quickly while the danger was imminent, and the dangerousness of the situation probably increased its chaotic and stressful character (16). It is striking that, three years later, even though very few people were injured in the evacuation, respondents still described the event with the same perceptions. Thus, even when an evacuation goes relatively well, the perception of danger during the traumatic event, more than the actual harm to one's physical integrity, seems to color people's experience. The data show that although evacuation is a life-saving measure, it is a potentially traumatic event in itself.

The present study also documented the experience of individuals who were more vulnerable and dependent upon others during the evacuation process. Clearly, there is a challenge in assisting people in special or vulnerable situations in the midst of a general evacuation. To our knowledge, few studies have considered these persons who may experience the evacuation very differently, compared to the rest of the population. Tally and colleagues (43) studied the impacts of the 2007 San Diego 2007 wildfires on persons receiving services in public mental health clinics in California. They found that compared to non-evacuated counterpart, evacuated persons reported stronger emotional impacts of the fires, confusion about whether to evacuate, and difficulty in obtaining medications. According to these authors, while the rest of the affected population is experiencing a great loss of control, individuals presenting mental health problems or illnesses may be more even more affected by this sense of loss of control (43). In order to better prepare for future events, there is clear need to document further the experiences of more vulnerable individuals during and after disasters, not only persons with mental health issues but also persons with health issues, mobility issues, cognitive impairment or other types of problems.

The second objective of this study was to document the biopsychosocial consequences of Fort the McMurray wildfires using part of the P-RAM model as a guide. Our results revealed elements relating to the behavioral, emotional, cognitive, social, physical, and spiritual consequences described in the model, as well as to the psychosocial benefits. The literature mentions that even if each context is unique, there are three main elements linking all types of disasters together: disasters threaten the lives of a large number of people at the same time (44), they affect the resources of a community, and they have secondary consequences, mainly physical and mental (24). These similarities could explain the common factors between the P-RAM model developed in the context of terrorist attacks and our findings collected in evacuees from a wildfire. There are, however, differences between the themes and sub-themes of the P-RAM model and those observed in this study. Firstly, the theme "material and financial loss", not included in the P-RAM

model, was identified from our findings. Indeed, as early as three months and even after three years, participants reported experiencing financial problems related to their insurance, house reconstruction, job loss and loss of material assets. It was one of the themes that stood out the most among the participants' responses. This is not surprising, given that the Fort McMurray was considered Canada's most expensive natural disaster at the time (26). In addition, the community of Fort McMurray was already struggling economically due to the collapse of the oil industry in 2014 (45). It is possible that a large proportion of community members were financially affected, more than once. These results are consistent with those of Kulig et al. (27) who reported that their participants who experienced a wildfire evacuation had experienced financial problems associated with the loss of their homes, insurance, job loss and relocation. These financial concerns could be critical to individuals' ability to recover from such an event (33). Personal and financial losses are also associated with several forms of psychopathology including PTSD (28).

Secondly, the "spiritual" category in the P-RAM model focused primarily on philosophical and religious beliefs. In the present study, no religious references were found in participants' responses. These results differ from those usually found in populations affected by natural disasters, where survivors frequently refer to their religion to give meaning to their lives despite the disaster (46). It is possible that the participants in this study were less religious than the populations formerly studied. We found it more relevant to include a category of "spiritual/existential reflections" to highlight the existential aspect of the participants' questioning of their life and future.

In line with the P-RAM model however, several types of consequences appeared to be directly or indirectly related to normal and abnormal psychological reactions, particularly symptoms of PTSD. For example, the emotional/mental health disorders category included a persistent negative emotional state (anxiety/fear, irritability, guilt, etc.) and distress from exposure to traumatic reminders. Anxiety/fear was very present in participants' responses both three months and three years after the fires. Similarly, some PTSD symptoms, such as difficulty concentrating and memory loss, were included in the cognitive impairments category and were particularly prominent three months after the event. Hypervigilance was apparent three months after the fire and was still present three years later. This constant state of alert could be associated with thoughts such as mistrust, suspicion and negative expectations about the future (47) and may persist over time (48). Moreover, spiritual and existential reflections included different perceptions of oneself and uncertainty about the future. This is quite similar to parts of the DSM definition of PTSD where negative beliefs or expectations about oneself, others, or the world that can be observed (49). Finally, we considered sleep difficulties as physical consequences of the wildfire, yet these are also a common symptom of PTSD (American Psychiatric Association, 2000). All these symptoms associated with different biopsychosocial categories that were identified

throughout the participants' discourse demonstrate the great impact of the event on their mental health. From a clinical perspective, the results show the importance of providing support and services to victims of a natural disaster over a long period of time, given that these elements associated with mental illness were reported three months and three years later.

Interestingly, participants' responses showed a positive evolution of social consequences over time. Indeed, three months after the fires, respondents reported more negative consequences (conflict, separation, isolation), whereas three years after the fires, respondents reported more positive changes in their relationships as well as community cohesion. These results are congruent with those of a study by Gibbs et al. (50), which found an increase in sense of community three to four years after wildfires in Australia. Another study of wildfires in the Canadian Northwest Territories also showed that a year later, the fires brought new opportunities for people in the community to help each other and bond together after these events (17). These results are also consistent with the *Biopsychosocial response pattern and temporal phases of disaster*, which describes the disillusionment phase, commencing about three months after the disaster, as a phase during which victims receive less social support. From three years onwards, the restoration phase corresponds to the return of harmony in the community (31). One hypothesis is that initially, the high intensity of short-term stressors (e.g., relocation, loss of property, PTSD symptoms) may affect the quality of some interpersonal relationships and that it is only with some distance, several months or years later, that bonds are rebuilt, or others are formed in the community. These findings provide further support for the potentially positive evolution of the social impact of disaster over time. Further research is needed to understand factors that promote community cohesion and to identify ways to harness the power of community to enhance the mental health of individuals.

Finally, positive consequences such as posttraumatic growth emerged very soon after the disaster and were still present three years later. A study by Tedeschi and Calhoun (51) identified five categories of possible positive types of posttraumatic growth: new possibilities, relating to others, personal strength, spiritual change, and appreciation of life. Many of our participants' responses related to these different categories. Other consequences that had a positive impact on participants were resilience, altruism and community cohesion. Participants reported being able to use their resources appropriately to deal with the aftermath of the disaster, either by making positive changes for themselves or by sharing their time and experience with other evacuees. Some authors posit that such positive actions could contribute to reduce post-traumatic symptoms over time (52). Further research should examine whether recognizing positive consequences of disasters could be incorporated in psychotherapeutic interventions. Indeed, the latter mainly focus on negative consequences, yet mental health professionals could help evacuees develop awareness of positive consequences which

might have emerged from a stressful event such as an evacuation, and harness the potential of positive actions and perceptions to enhance recovery.

LIMITATIONS

The results of this study need to be interpreted in light of certain methodological limitations. Firstly, cultural diversity of the sample may have been limited as no information was collected on the ethnicity of participants at the 3-month data collection and a large majority of participants in the 3-year data collection identified as Canadian or European. Secondly, the two data collection time points used different evaluation modalities (questionnaires and interviews). It was therefore not possible to thoroughly compare data from the two measurement time points because this was not a quantitative study. In addition, the questionnaire modality used at the 3-month assessment did not allow for additional questions in the case of incomplete answers. This may have resulted in some responses lacking in detail, such as for physical conditions, cognitive alterations and behavioral changes. However, the use of interviews during the second data collection made it possible to further question participants in order to obtain more in-depth information. The use of different evaluation methods also made it possible to obtain a diversity of responses. A future study could evaluate consequences in a more systematic manner with several measurement times and following more closely the biopsychosocial response pattern and temporal phases of disaster [Young et al. (34) modified by Math et al. (31, 35)] in order to empirically test the implications of this theoretical model.

Despite these limitations, this study also has several strengths. For a qualitative study, the sample size is quite large sample size, with almost 400 participants in the first data collection and over 30 participants. This ensured that excellent data saturation was achieved. The large sample size made it possible, among other things, to detect rare situations involving specific vulnerabilities (e.g., mobility issues, hospitalization, advanced pregnancy). Future qualitative studies should however specifically recruit people in various situations of vulnerability in order to better document their experience and their specific needs during evacuations in order to adapt emergency plans to these individuals.

CONCLUSION

In conclusion, this study has brought to light a large scope of biopsychosocial consequences experienced by the victims of the wildfires of Fort McMurray over a period of almost three years and documented their evacuation experience. With regard to evacuation, the present study clearly highlighted its traumatic aspect. Overall, the study found that it is important to pay attention to all biopsychosocial consequences, not only mental health consequences, as they all have an impact on evacuees. In addition, the qualitative approach emphasized the importance of attending to both negative and positive consequences of such a disaster, all of which are part of the participants' experience and can influence interventions with evacuees. Finally, this study underscores that there is a need to intervene and maintain services over the long term given the persistence of the consequences over time.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by Comités D'éthique de la Recherche avec des êtres humains de l'Université Laval (CÉRUL). The patients/participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

GB, M-CO, and CM designed the study. A research team collected the data three months after the fire. LT collected, analyzed, and interpreted the data three years after the fire and wrote the manuscript. All authors revised the manuscript and approved the final version before submission.

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Health Systems Responsiveness in Addressing Indigenous Residents' Health and Mental Health Needs Following the 2016 Horse River Wildfire in Northern Alberta, Canada: Perspectives From Health Service Providers

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Following the 2016 Horse River Wildfire in northern Alberta, the provincial health authority, the ministry of health, non-profit and charitable organizations, and regional community-based service agencies mobilized to address the growing health and mental health concerns among Indigenous residents and communities through the provision of services and supports. Among the communities and residents that experienced significant devastation and loss were First Nation and Métis residents in the region. Provincial and local funding was allocated to new recovery positions and to support pre-existing health and social programs. The objective of this research was to qualitatively describe the health systems response to the health impacts following the wildfire from the perspective of service providers who were directly responsible for delivering or organizing health and mental wellness services and supports to Indigenous residents. Semi-structured qualitative interviews were conducted with 15 Indigenous and 10 non-Indigenous service providers from the Regional Municipality of Wood Buffalo (RMWB). Interviews were transcribed verbatim and a constant comparative analysis method was used to identify themes. Following service provider interviews, a supplemental document review was completed to provide background and context for the qualitative findings from interviews. The document review allowed for a better understanding of the health systems response at a systems level following the wildfire. Triangulation of semi-structured interviews and organization report documents confirmed our findings. The conceptual framework by Mirzoev and Kane for understanding health systems responsiveness guided our data interpretation. Our findings were divided into three themes (1) service provision in response to Indigenous mental health concerns (2)

gaps in Indigenous health-related services post-wildfire and (3) adopting a health equity lens in post-disaster recovery. The knowledge gained from this research can help inform future emergency management and assist policy and decision makers with culturally safe and responsive recovery planning. Future recovery and response efforts should consider identifying and addressing underlying health, mental health, and emotional concerns in order to be more effective in assisting with healing for Indigenous communities following a public health emergency such as a wildfire disaster.

INTRODUCTION

A public health emergency such as, a natural disaster, places substantial burdens on the affected population's health and well-being, and on the health system's capacity to respond to changes in health and mental health needs. Emergency response plans and response activities are frequently designed to address and mitigate the immediate impact of the disaster on the health and safety of affected communities; however few plans fully anticipate and prepare for long-term health-related effects resulting from disasters (1). Natural disasters can also cause or exacerbate health-related concerns and inequities, overwhelming health service providers by dramatically increasing demand for their services after the disaster (2). The extent to which a disaster disrupts a health system's ability to care for population groups who are at a greater risk of poor health or mental health is an understudied but critical aspect of health system responsiveness after a disaster. Moreover, a health system overburdened by existing health disparities before a disaster may be the least well-equipped to respond to disaster compounded health and/or mental health concerns (1). For example, prior to Hurricane Katrina, one quarter of the New Orleans population lived below the poverty line. The devastating and long-lasting impacts of the hurricane resulted in an overwhelming load on an already overburdened health system (3). This paper focuses on services for Indigenous residents who were among those who experienced significant health and mental health impacts after the 2016 Horse River wildfire in northern Alberta, Canada. Qualitative research led by Montesanti et al. (4) documented heightened physical and emotional stress among First Nations and Métis Indigenous residents following this wildfire, as well as challenges that residents faced when accessing services and supports for health and mental health concerns. These findings are consistent with previous research showing that Indigenous communities are more vulnerable to the effects of wildfires (5, 6) compared to other sub-populations. Indigenous communities are often located in hazard-prone areas and inequitable access to services in addition to historical trauma can exacerbate vulnerability during a public health emergency (7–9). Further compounding this, a survey of adolescents aged 11–19 in the city of Fort McMurray showed worsening mental health 3.5 years following the Horse River wildfire, demonstrating the need for longer-term post-disaster support (10).

Responsive health systems during a public health emergency anticipate and adapt to changing needs, prepare for heightened health concerns, and promote access to effective, high-quality health services (11). Health system responsiveness was first conceptualized by the World Health Organization (WHO) in the 2000 World Health Report (12). That report defined the concept as follows: "…when institutions and institutional relationships are designed in such a way that they are cognisant and respond appropriately to the universally legitimate expectations of individuals…[including] safeguarding of rights of patients to adequate and timely care" (p. 3). This paper reports on results of a qualitative study to understand how the health system in the Regional Municipality of Wood Buffalo (RMWB) responded to the negative health and mental health effects experienced by Indigenous residents and communities during and following the 2016 Horse River wildfire.

The Meaning of Health System Responsiveness for Indigenous Peoples

The concept of "health system responsiveness" has been used to understand peoples experience with the health system and the expectations that both health service users and health system actors have regarding how individuals should be treated and cared for when accessing health services (11). A person's interaction with their health system shapes their initial expectations and experiences of care (11, 13). Today, many aspects of health system responsiveness are aligned with key health system performance goals such as, quality care, safety, accessibility, appropriateness, and being patient-centered.

There are several key frameworks for understanding health systems responsiveness that focus on different aspects of responsiveness. The most widely used framework was proposed by the WHO in the early 2000s (12) which addresses an individual's experience within the health system along seven elements: dignity, autonomy, confidentiality, prompt attention, quality of amenities, access to social support networks, and choice of service provider. Building on the WHO framework, Mirzoev and Kane (11) proposed a conceptual framework that locates people's experiences when interacting with their health system at the center of health system responsiveness. For Indigenous patients, pervasive negative healthcare experiences and provider–patient relationships can prevent Indigenous peoples from accessing health services or avoid seeking care because of their perceived expectations of how they may be

treated (14, 15). Beliefs, values, and assumptions held by health service providers shape their behaviors and interactions with patients and are influenced by discourses within society (16). In addition, the policy, legislative, historical, and social conditions that impact access for Indigenous peoples represent structural barriers to accessing health services (17, 18). Research shows that Indigenous peoples experience individual and systemic discrimination when seeking healthcare (19, 20), despite efforts within the health system to promote cultural responsiveness (20).

Valentine et al. (21) developed an alternative framework that outlines three key determinants of health system responsiveness. The first determinant–environment–defines the context of service provision, including health system expenditures, the structure of the health system, and available resources. The second determinant–agents defining need for care–refers to the role of users and providers in defining care needs and setting the context for care—for example, patient involvement in care decisions. The final determinant–the process of care and subsequent outcomes–is concerned with the process of seeking and receiving care at the micro (individual) level. The framework by Valentine et al. (21) provides a helpful approach for describing health system responsiveness for Indigenous peoples in Canada. Within the context of service provision, historical trauma, referring to the effects (direct and intergenerational) of colonization and residential schools on Indigenous peoples in Canada, contributes significantly to difficulties in accessing healthcare (22, 23) and has resulted in distrust of healthcare providers by the provincial and federal governments (24). The historical and ongoing forms of structural violence experienced by Indigenous peoples have unfolded against the broader context of neoliberal economic reforms, resulting in significant inequities in health. Health services are not typically designed to take into account the experiences of Indigenous peoples (25). For example, despite extensive evidence linking trauma and violence to multiple health problems (26, 27), these dynamics are rarely considered in the design and delivery of health services for Indigenous peoples. Thus, aligning health services with the needs of Indigenous peoples is lacking. Lastly, with respect to seeking and receiving care at the individual level, power dynamics and imbalances are particularly noteworthy and are at the root of inequities in healthcare. Previous negative experiences with healthcare services and/or healthcare providers among Indigenous peoples in Canada have repeatedly been found to create a barrier to accessing healthcare (28, 29). Thus, negative interactions with the health system shape Indigenous peoples' expectations of how they will be treated (30). Racism, discrimination, and harassment impede the development of trusting relationships with healthcare providers (24).

Study Area and Context

The RMWB is home to five First Nation communities, including Mikisew Cree First Nation, Athabasca Chipewyan First Nation, Fort McKay First Nation, Fort McMurray First Nation, and Chipewyan Prairie Dene First Nation. This region is also home to many urban First Nations people as well as five Métis local organizations located in urban and rural Métis communities across the region. In 2016, the Canadian census (31) reported

71,480 residents with 6,565 identifying as Aboriginal in the RMWB. The estimated number of residents that were evacuated following the wildfire was 88,000 people; this number differs from the census as the RMWB has a large transient population as the local oil sands provides jobs for Canadians across the country and many workers do not permanently reside there. Prior to the large-scale development of the oil sands from the 1960s, Indigenous peoples, both First Nations and Métis, were the principal occupants of the region. Fort McMurray in the early 1960s, was a small and primarily Indigenous town, both demographically and culturally, in which traditional Indigenous ways of life and livelihoods, including hunting, fishing, gathering, and trapping, were combined with seasonal labor on the docks and the rail (32–34).

The Horse River wildfire started on May 1st, 2016 and ended on August 2nd, 2016. As mentioned above, approximately 88,000 people were forced to evacuate from RMWB on May 3rd, until approximately June 1st, 2016, and over 2,400 buildings and homes were destroyed. Like other residents of the RMWB, many Indigenous people and communities were also evacuated during the wildfire due to the threat of the fire or smoke. Residents spent several weeks away from their homes, jobs, schools, and communities. However, when it was time to return, many of Fort McMurray's urban Indigenous residents did not have houses to return to. Notably, the neighborhoods that were hit hard by the wildfire such as Abasand and Waterways have been anecdotally reported by the Métis Local in urban Fort McMurray to include a higher proportion of Indigenous residents compared to other neighborhoods in the city. Outside the Fort McMurray urban center, nearby Indigenous communities were also affected by the wildfire with some having to evacuate while others housed thousands of evacuees who sought refuge during the initial evacuation. For Indigenous peoples and communities that did not evacuate during the wildfire, the almost complete "shut down" of Fort McMurray made accessing food, medical services, employment, and other resources difficult for the duration of the evacuation.

This study described how health systems in Alberta responded to the short and long-term health and mental health effects experienced by Indigenous residents and communities during and following the 2016 Horse River. It is important to note that we are not looking at a single health system responsible for addressing health and mental health needs, rather we use a "systems" lens that speaks directly to the responsibilities across several relevant health and social care service delivery organizations (e.g., non-profit and charitable organizations, local community health centers, primary health care clinics, mental health, and addiction centers). Thus, we define health systems in our research to include a wide-range of local, provincial and federal health service-delivery organizations that include emergency and acute health services but go beyond them (i.e., curative and rehabilitative care), as well as organizations across sectors with mandates for health, wellness, and recovery. Our study addresses the following research questions: (1) How did the health and social care systems in Alberta respond to the health and mental health needs of Indigenous residents and communities post-wildfire? (2) How did health services providers

TABLE 1 | Breakdown of service provider categories.

Service provider category	*n*
Front line provider (e.g., physician, mental health counsellor)	4
Community and social work	10
Directors and service team leads (e.g., clinical director)	5
Coordinators (e.g., cultural coordinator)	6

adapt to the immediate health threats posed on Indigenous communities and residents in the RMWB?

METHODS

Recruitment and Participants

Participants were recruited from the RMWB using a maximum variation sampling strategy (35). This sampling strategy was used to guide the selection and recruitment of service providers from different organizations with diverse perspectives and experiences. This included participant representation across rural and urban settings, First Nation (Cree and Dene individuals) and Métis population groups, and different service provider roles (e.g., nurse, social worker, health director). Participants were recruited through community engagement and relationship-building by connecting with local health directors and providers, and existing relationships and networks from community partners and recommendations from our Community Advisory Committee. Participants included a wide range of service providers that we have categorized as frontline workers, community and social workers, health directors and service team leads, and service delivery coordinators (**Table 1**). Service providers were invited to participate in an interview if they had directly provided or coordinated health or social services and supports during or following the 2016 wildfire for Indigenous residents or communities in the region.

Study Procedure

The interview question guide was developed with the Community Advisory Committee, which included representation from health service providers drawn from different organizations that serve the RMWB Indigenous populations (e.g., Canadian Red Cross, Alberta Health Services, Local Friendship Center) as well as community members and Elder representation from the different Indigenous groups in the region (Métis, Dene, Cree). The active participation of the Community Advisory Committee began at the start of the project until completion, a process which empowers local communities by valuing and legitimizing their knowledge and by balancing power relationships among community and researchers for the project (36). With the research questions in mind, interview questions were developed from conversations with the community advisory committee and aimed to investigate impacts and recovery as it relates to the health and wellness of Indigenous groups, the mental health impacts and mental health services provided to Indigenous peoples and communities

post-wildfire, culturally appropriate care and recommendations for service delivery (see **Supplementary Material 1**).

Semi-structured interviews were carried out with health and social care providers in the region to capture their perspectives on how the health needs and expectations of Indigenous peoples for accessing necessary services and supports during the traumatic experience of the wildfire, as well as their own expectations as providers in delivering support to the Indigenous population. Interviews were conducted with 15 Indigenous and 10 non-Indigenous service providers from the RMWB. As RMWB is a small region, no other demographic information was recorded other than their job title in order to maintain participant confidentiality. Interviews were ~1 h in duration and were completed by telephone or in person by the principal investigator (SM) or a trained community research assistant. Researchers explained the study and what to expect to participants and made sure they were aware they could stop the interview at any time. Participants signed an easily understood informed consent. Interviews were recorded on a recorder and transferred to a secure drive for analysis.

Following service provider interviews, a supplemental document review was completed to provide background and context for the qualitative findings. In addition, the document review allowed for a better understanding of the health systems response at a systems level following the wildfire. Documents were identified by recommendations from community leadership, complemented by a Google search. The google search included the search terms "Wildfire" and ("Northern Alberta" or "Fort McMurray" or "Regional Municipality of Wood Buffalo" or "Fort Chipewyan" or "Janvier" or "Conklin" or "Fort McMurray First Nation" or "Fort McKay" or "McMurray Metis"). Documents were included if they were published in English and if they discussed any impacts of the Horse River Fire on any Indigenous groups. Key questions were identified for the document review following the interviews and included: (1) Who funded health or mental health services during and following the wildfire? (2) Was there funding for Indigenous specific initiatives or programming? (3) What was the decision-making process for how funding was allocated? (4) What was the duration of the funding? (5) Were sustainability plans implemented? (6) Does the document or source include health-related findings resulting from the service provision? (7) Does the report include lessons learned on service provision for Indigenous peoples? Two researchers (KF, CP) thoroughly reviewed all relevant documents and extracted information pertaining to the questions. In total, 10 documents were analyzed (**Table 2**). **Table 2** is in the **Supplementary Materials**.

Data Analysis

Participant interviews were transcribed verbatim and imported into the qualitative data analysis software program QSR NVivo 12 for analysis. Two members of the research team (KF, TA) conducted coding and thematic analysis and consulted with the study PI (SM) and Co-I (CW) at the end of coding. One author on this manuscript (LA) is an Indigenous knowledge keeper as well as a service provider and used the two-eyed seeing approach to review and confirm our themes. Barlett and team (2012) define

Document title	Author(s)	Publication date (Year, Month)
2016 Alberta fires: 1 year donor update	Canadian Red Cross	2017
Athabasca Tribal Council's health and wellness report	Athabasca Tribal Council	N/A
Community partnerships Alberta wildfires 2016 (webpage)	Canadian Red Cross	N/A
Community partnerships table terms of reference	Canadian Red Cross	2016, September
Rebuilding resilient indigenous communities in the RMWB: final report	Clark, T.	2018, October
May 2016 Wood Buffalo wildfire: post-incident assessment report	KPMG International network	2017, May
Regional Municipality of Wood Buffalo: lessons learned and recommendations from the 2016 Horse River Wildfire	KPMG International network	2017, July
RMWB 2016 wildfire recovery plan	NOR-EX Engineering	N/A
CARE Wood Buffalo executive summary: 2017–2018 community outreach	Alberta Health Services, Regional Municipality of Wood Buffalo, YMCA Supports for Wellness	2019, April
Home again: recovery after the Wood Buffalo wildfire	Government of Alberta	2016, November

two eyed seeing as "to see from one eye with the strengths of Indigenous ways of knowing, and to see from the other eye with the strengths of Western ways of knowing, and to use both of these eyes together" [(37), p. 335]. The PI (SM) reviewed the coding for consistency and the PI and primary coder (KF) worked to identify, review, and name the themes. We used the framework method for the management and analysis of transcriptions. The framework method is a systematic method of categorizing and organizing data and is a flexible tool that is not aligned with a particular epistemological, philosophical or theoretical approach. This method encourages thick description and pays attention to the complex layers of meaning and understanding (38). Constant comparative content analysis was then utilized and involved an iterative process of moving backwards and forwards between transcripts, coding and analyzing passages. This method uses systemic coding and categorizing to determine patterns of words and phrases used (39, 40). By comparing, the researcher is able to better understand inductively, by categorizing and coding categories and connecting them (41). To further enhance rigor of the comparative content analysis the researchers (KF, SM) followed a 4-step framework by Whittemore et al. (42), by first paying attention to the voices of participants; second reflecting on how believable the results are; third critically appraising all decisions made during the research process; and lastly researchers (KF, SM) demonstrated ongoing reflection and self-criticality.

A document analysis approach was used as an independent source of evidence as a complement to the interviews. The answers to the key questions provided context resulting in a better understanding of the health system response (43). Triangulation of results obtained from semi-structured interviews and organizational report documents solidified our findings. Triangulation is the combination of methodologies in the same study looking at the same phenomenon which helps to increase validity, decrease researcher bias, and provide additional perspectives of the phenomenon being studied (44). For both the document analysis and comparative content analysis, researchers (KF, CP) were in contact with organizational leads to ensure data interpretation was accurate and appropriate.

Our final step for analysis was sharing our findings back to Indigenous communities for interpretation in a sharing circle format in both an urban and rural context. Through the sharing circle discussion, participants confirmed the findings and no major changes in analysis were identified. Community presentations and a report summarizing the research findings were also shared with the Community Advisory Committee. With the final results, a knowledge sharing and exchange forum with other disaster scholars who conducted research in the region following the wildfire was hosted in RMWB by the study PI (SM). The forum brought together community members, service providers, and representatives from the municipality to hear the findings from this study and others. This forum allowed for dialogue between researchers, community members, service providers and policy, and decision makers which informed local emergency preparedness and policy change at the community level.

Ethical Considerations

The study was reviewed for its adherence to ethical guidelines and approved by a Research Ethics Board at [University of Alberta REB Protocol # Pro00070845]. All service provider participants were informed and fully consented to participate in the study. Participants were assured that they could withdraw from the study up until data was analyzed without any consequences. All personal details were kept confidential and secure.

RESULTS

Service providers described their experience of providing support during and following the wildfire disaster. Three superordinate themes emerged from analyses of the interview data: (1) service provision in response to Indigenous mental health concerns, (2) gaps in Indigenous health services post-wildfire; and (3) adopting a health equity lens in emergency management. Findings from the document analysis supported these themes and added further context by highlighting contextual considerations for health system responsiveness including community engagement and ownership, culturally appropriate healthcare access, sustainable

and consistent funding for health programming, and recognition of increased vulnerability to public health emergencies.

Service Provision in Response to Indigenous Mental Health Concerns

In response to the negative impacts from the wildfire on mental health among Indigenous residents and communities, mental health and wellness services and supports were provided in the region's First Nation and Métis communities. Local service providers described an increase in the availability of mental health services which included counseling, psychosocial interventions, and outreach support. A community health worker described how pre-wildfire there was a lack of mental health services and supports for Indigenous communities, and only in times of a crisis are "*services pushed at you when it's chaos, and then when everything is settled, the services are all depleted*" *(Participant 9)*. While temporary services and supports were delivered to address the immediate risks and impacts to mental health, participants described an "*Indigenous mental health service gap*" that existed in the region before the wildfire. Service providers expressed concerns about how temporary mental health services and/or supports in community underscores the inequity of mental health service provision for Indigenous peoples. This was confirmed in the *Rebuilding Resilient Indigenous Communities* report which highlighted the challenges of intercultural communication and collaboration as well as the context of colonial legacies and their impact on how Indigenous peoples were affected by the wildfire. The report overall described how the evacuation and response lead to inconsistent and inequitable service delivery partly due to the inadequate representation of Indigenous leadership in the Regional Emergency Operations Center and was further hindered by lack of coordination between local Indigenous governments and municipal and provincial governments. This was further eluded to by service providers when commenting on the jurisdictional complexity of the region when it comes to providing services for Indigenous residents.

Additionally, participants stated that the provision of mental health and wellness services and/or supports to rural and remote Indigenous communities were generally sporadic and inconsistently delivered pre-wildfire and that this was significantly heightened post-wildfire. For instance, mental health therapists and cultural liaison workers were hired by the provincial health authority on limited-term contracts, to visit communities in rural and remote areas of the region one-to-two days per week. A health director from a remote community explains the challenges faced by community residents when accessing mental health and wellness services that are not consistently available in the community:

> *…we didn't have a consistent counsellor every day of the week or you know, they didn't have regular appointments. She did have a few and then they kind of tapered off after, um, after she was recommending them to come into town. She [counsellor] still comes and we would like her to come more often than not, but it has to do with their funding and having somebody, and resources, to be able*

to come out. I think the mental health system and team is spread pretty thin (Participant 24).

Many local service delivery organizations also adapted their services and collaborated with other agencies in order to respond to the immediate needs of Indigenous residents and communities. Organizations such as the provincial health authority quickly mobilized to develop resources such as mental health and wellness pamphlets, online tools for coping with stress, delivering emergency preparedness kits to communities, and supporting recovery and healing by hosting community gathering events. However, in KPMG's (Klynveld Peat Marwick Goerdeler) *Post-Incident Assessment Report* (p. 99) they state "*… while a re-entry booklet was prepared and provided to residents as they resettled in the Region, it contained limited information regarding access to other resources, supports and services that may have been necessary to help residents with their longer term resiliency*" (45). Concerns relating to Indigenous peoples' mental health in the region were expressed by all study participants. A frontline worker conveys the increased need for mental health services following the wildfire:

> *[…] We are being more available for them [clients]. We are more aware of mental health now, whereas it was something that was on our radar pre-fire, but now we find that a lot of people are struggling and need the support now […] (Participant 19).*

The need for mental health supports was also echoed in the document review. A massive jump in referrals (20,000 in 51 days compared to typical 1,200 per year) was received by local addictions and mental health staff between May 10 and June 30 (∼2 months post-wildfire) was identified in the *Post-Incident Assessment Report* (KPMG, 2017). In the same report, RMWB residents themselves identified a strong need for mental health supports and noted they had faced difficulties accessing supports. However, this increase in referrals was reported to include all population groups in the region.

Furthermore, participants described the ways in which their organization quickly adapted their services during wildfire recovery to maintain critical access to services and respond to worsening health and mental health concerns among Indigenous residents. One participant described how their organization was receptive to change and quick to adapt so that their clients have continued access to needed services and supports: "*That's what this team is built all on right there is adaptability. Meeting the person where they're at, or community where they're at, and knowing and respecting the boundaries*" (Participant 6). For service providers to meet the needs of Indigenous residents and communities and provide culturally relevant care, sustainable and long-term funding and equitable access to resources was highlighted as necessary as described in the *Rebuilding Resilient Indigenous Communities* report. As previously mentioned, participants noted gaps in mental health service delivery for Indigenous people during and following the wildfire as a barrier to service provision.

Health directors and community leaders played an important role to ensure delivery of "*culturally responsive mental health*

services and supports" (Participant 24). All Indigenous providers and some non-Indigenous providers in the study had described advocating for mental health services to include traditional aspects of healing with a trauma-focused lens long before the wildfire happened, and even more so following the disaster. A director of an Indigenous service organization shared how his staff turned to traditional and cultural healing practices to respond to trauma and stress within communities:

> *Specifically, for mental health we had to get creative with some of our service providers with the trauma counselling, relying on the holistic approach in taking more of a cultural, spiritual route for mental health and healing (Participant 8).*

The documents included in our review described 18 programs for the prevention and promotion of mental health (**Supplementary Table 3**) that were promoted in the region. To improve access to mental health services, the provincial health authority opened a free walk-in clinic in urban Fort McMurray from 2016–March 2018 and then from the Canadian Red Cross from April 2018 to March 2021 which also included a mental health therapist to travel to the rural Indigenous communities once a week.

Local providers also helped residents to adjust with their current circumstances by preparing them for future emergencies. Some participants explained that the stress Indigenous residents experienced was in part due to them being unprepared when the wildfire happened effecting their ability to cope. One community worker described how she supported Indigenous elders to prepare for future evacuations:

> *They have their medication lists now. They have those tucked away, in a little grab bag, like a book bag that we have prepared. In the book bag it has a couple of pairs of panties, it has a pair of underwear, some socks, um, a clean shirt and their medication. A couple of them have little candies in there, just in case they need to grab that really quick, then they'll have little things that they can kind of nibble on […] (Participant 1).*

This participant went on to describe that while it is impossible to be fully prepared when a traumatic event occurs, it offers people a sense of safety and control enabling people to cope better under stress.

Moreover, community connection can have positive effects on mental health and well-being (46). In the *CARE Wood Buffalo* report, mental health was ranked the most common barrier faced by residents, and family and socializing were rated highest for what improved residents' well-being post-wildfire. Many local service organizations worked together to mobilize and organize several community gatherings such as block parties. A community coordinator described how the event brought together all residents (Indigenous and non-Indigenous) and how the events were also an opportunity to distribute mental health resources (e.g., pamphlets or booklets on mental health and violence prevention services and supports available in the region and/or how to promote positivity and self-care):

> *We did lots of public community events and free events with no stigma attached. Just come out, have fun. We had lots of mental health resources available for anyone that came in, but we didn't force anyone to take anything. So, we just opened conversation with the attendees (Participant 2).*

The document review also provided detailed information about funding from charitable, municipal and provincial sources to local organizations in Fort McMurray to organize monthly block parties in urban Fort McMurray and rural Indigenous communities outside of the city.

Gaps in Indigenous Health-Related Services Post-wildfire

In describing the gaps in services for Indigenous residents and communities across the region, several participants emphasized the need to improve Indigenous people's access to high-quality and culturally relevant health and wellness services. Many of the services and programs that were delivered following the wildfire were limited in scope and resources. The provincial health system is also very regimented on funding travel for service providers. The main programing mentioned in the document review was the Canadian Red Cross caseworkers available at the Nistawoyou Friendship Centre as the only Indigenous-specific Welcome Centre for re-entry. Given the short-term funding allocated to specific services and programs this offered little opportunity to foster provider-client relationships. A frontline rural coordinator described her experience by stating,

> *It's temporary services … once you've finally engaged the people into a program, then it's gone the next day, you know. It's not enough personnel to cover how many people need to be seen here. Then at the same time, it's not even enough time to engage the people to get to know them, because they only pop in once a week. And how do you build a relationship with a community in one day in a week. I've been here for eight years and I'm still doing it… Their [mental health therapist] workday starts at 8:30am, they get here by 10:30am, they leave by 2:00pm and we have 400 people out here that want to see this one person (Participant 11).*

As a result of the temporary nature of many new service provision positions that were created to respond to the increasing demand for mental health and wellness services, provider turnover in the community was high, leading to inconsistent and sporadic service delivery. A social worker explains, *"turnover in Fort McMurray is a revolving door. Once you make a relationship with someone [a service provider], then six months later someone else, so you have to start all over again" (Participant 25).* A local community coordinator further emphasized the need for consistent services to support ongoing healing from trauma: *"from the healing and recovery perspective as well as for individuals, whether that's trauma from their past, growing up, environmental impacts, social impacts, the consistency on the level of supports that are coming in is very important" (Participant 8).* Frontline providers and staff explained that recovery from traumatic experiences such as the wildfire takes time and thus, sustainable and long-term planning for service provision is required. It was noted that immediately following

the wildfire there was an influx of temporary services to support early recovery; however, service providers felt that services and supports for long-term recovery were overlooked. A community health worker in one rural Indigenous community shared:

> It is kind of like victim services. They're there at the forefront and then they're not there when everything actually is calm, the shock is done, um, that's when the people really need to come (Participant 9).

Some participants also described how the temporary services were not equipped to address pre-existing health, mental health, and social concerns in the community, which were heightened after the wildfire. A local community worker shared,

> We are losing resources, but I could speak on behalf of the health centre because I was here at the time. There was no programming here. It was a lack of programming in the health centre in general, not much direction. So, our NNADAP [National Native Alcohol and Drug Abuse Program] programme was lacking. There was no pre- and post-natal. We had no public health. We had no home care services. We had no services. All we have here is a building planted on the reserves (Participant 11).

These findings suggest that new services and programs delivered to Indigenous residents and communities were not adequately resourced to respond to the determinants of Indigenous peoples' mental health and well-being. Also, participants spoke about the lack of cultural appropriateness among service providers who were deployed to the region. Because of the short-term funding for new services and programs, and especially when providers are out in the community once a week, there was mistrust among community members in providers outside the community. Additionally, lack of trust in governments and organizations from community members resulting from a history of being under-serviced and under-resourced and the added fall out from gaps in responses post-wildfire, was echoed in the document review:

> The lack of trust coloured perceptions of the RMWB's response to the wildfire, particularly in rural areas: 'I can say that it was a long standing issue with respect to being under-serviced by the municipality in the rural areas. And the fall out of the fire was added to a long list of shortcomings that the rural community has felt that they weren't receiving since amalgamation. So certainly that the whole fire response and the Fort McMurray focus kind of played into that (47).

With outside service providers spending 1 day a week in the rural communities, participants were critical of the quality of the services provided and noted several gaps. For instance, participants spoke about limited engagement and relationship-building with Indigenous clients and local health directors and staff in the communities, and how community members were unaware of new services and/or programs offered in their community. An Indigenous community health worker shared,

> There wasn't a lot of relationships built from the services providers coming from Fort McMurray, I worked long time with these

people [community members] and trust doesn't come easily to Indigenous people, it would have been helpful to see a familiar face (Participant 6).

Participants also shared their concerns about new services that were perceived as not being culturally appropriate or attuned to the social and cultural realities of Indigenous peoples. Another community health worker stated:

> So we want to have a lot of cultural components that's attached to the serviced offered, because we find that's important now, post wildfire believe it. And I'm sure it is always important, it's always important to me on a personal level. But I think post wildfire, everybody has just kind of come back to the roots, because there's nothing like a great big wildfire to bring you back to humility, right (Participant 19).

A youth/cultural coordinator from a rural community stressed the importance of community engagement as a critical first step in tailoring health services to the needs of Indigenous communities. She explains that a lack of engagement with the community had reflected on the number of community members who utilized the services: "...they don't do community engagement. Then they wonder why their numbers are low. Then they feel that there's not even a need to be out here..." (Participant 17). This quote reflects the need for Indigenous voices to be included in the design and evaluations of programing. This was supported in the *Rebuilding Resilient Indigenous Communities in the RMWB* report which focused on the effects of the wildfire on Indigenous peoples and highlighted the importance of inclusion of Indigenous voices for recovery following a public health emergency.

Adopting a Health Equity Lens in Post-disaster Recovery

Adopting and applying a health equity lens in post-disaster recovery planning was described by participants as essential to reducing disproportionate impacts on Indigenous residents and communities and creating a more sustainable and equitable approach to responding to health-related impacts following the disaster. Health equity refers to the commitment to work toward eliminating disparities in health and to strive for the highest possible health standard for all people (48). Reducing Indigenous health inequities includes promoting the delivery of culturally-safe and equitable care (49). The impact of colonial legacies and the need for reconciliation was emphasized in the *Rebuilding Resilient Indigenous Communities in the RMWB* report (47), and the need to improve culturally appropriate healthcare access was a major focus from the *Athabasca Tribal Council (ATC)* report (50). An important piece to improve cultural appropriateness is by ensuring community supports are Indigenous led and evaluated. Unlike the other reports included in the document analysis, the *Rebuilding* report (35) and the *ATC* report (36) were both led by Indigenous organizations. The *Rebuilding* report discussed a research project on the impacts of the wildfire on Indigenous peoples, and the *ATC* report shared the results of a

conference held to identify Indigenous communities' health and wellness needs and gaps in service post-wildfire.

Many participants described the gaps in Indigenous health services in relation to physical accessibility of services (e.g., staff turnover, inconsistent and sporadic service delivery, the number of service providers in the community) and the funding received to organize and deliver services and/or supports. Several other participants went on to discuss the critical role service providers can play to improve access to services by ensuring services are culturally safe, appropriate, and relevant to community needs. These participants emphasized that cultural awareness and an understanding of the effects of colonialism and intergenerational trauma are critical to providing culturally safe and culturally appropriate care for Indigenous peoples across the region. Several participants also recommended that cultural training be mandated for all non-Indigenous service providers outside the community. As stated by a director of an Indigenous-led organization:

> I think it starts with understanding the historical events with first going back to intergenerational trauma, the impacts of, not just residential but also the industry and the impacts that that took on the rural communities as well. Having that knowledge beforehand will allow a person to have a little bit more compassion, understanding and patience is the biggest thing. Because it takes a lot for anybody to go in to a service provider to ask for help (Participant 23).

Alternatively, a few participants advocated for dedicated funding from government to train and hire local Indigenous service providers. Concern regarding lack of Indigenous support workers and a preference for Indigenous-led support programs was expressed by Indigenous focus group participants in the *Rebuilding Resilient Indigenous Communities in the RMWB* report (47). On the other hand, non-Indigenous service providers also highlighted the limitations they experienced because of resource and funding inequities which consequently left them feeling incapable of fully meeting the expectations of Indigenous residents, families, and communities. While gaps in service provision were described by participants, feedback from service providers on how to improve service delivery in a post-disaster context were captured.

Some participants shared how power dynamics between service providers and clients/patients can pose barriers to accessing care from a service provider. A community coordinator explained that service providers need to remove their professional cloak to connect with their client/patient and work to establish trust with them. She goes on to state, *"you are wearing a professional hat, but you're really being a friend and that's what they need instead of saying, here, go figure it out, this is the number, call them [referring to a detox centre]" (Participant 1)*. A frontline worker reflected on how she meaningfully engaged with community leaders, residents and other local health workers to support *"knowledge and understanding of what's happening on types of services and supports provided" (Participant 18)*.

The importance of improving culturally appropriate emergency response and healthcare access was discussed in

three documents (47, 51, 52). Indigenous recovery post-wildfire was hindered by a lack of Indigenous support workers and Indigenous re-entry points–initially, most of the Welcome Centres were located in schools, without regard for how this could be a barrier for residential school survivors (47). A need for culturally safe support was identified, and the Nistawoyou Friendship Centre became the site of a re-entry point a few days after the initial re-entry centres were opened (52). Some participants stressed how important it is for outside service providers to understand the local context before visiting the community. They pointed out that a *"one size fits all approach"* to service delivery is not feasible as there is much diversity across Indigenous communities and between urban and rural Indigenous populations. This was described by a social worker:

> If we gave it [mental health resource pamphlets] to the community [rural reserve], the community [rural reserve] wouldn't know what to do with it. And so, that was something that I voiced, I helped develop a community-based plan that kind of took all of the elements of what they were saying, but made it kind of, you know, more plain English, more, um, user friendly I should say. They [helping organization] were making a plan for the community to use to recover, but they were doing it in such a high level, it wasn't community based. Community members would just look at it and become probably more anxious, you know, like, I don't know what this means, how am I supposed to recover if I don't know what it means? (Participant 7)

Thus, being attuned to the social and cultural realities of Indigenous clients/patients was believed to strengthen and promote positive provider-client/patient relationships.

Some participants highlighted the ways in which their organization adapted their procedures and policies to address equity and change how Indigenous clients are supported in their healing and recovery. One provider explained this well:

> For medical appointments, we do referral services, so if there's something that we can't help in. So, we have a client, let's say they'd called us or reached out to us either in urban or [rural reserve] community, and there, like, you know what, I really want to go detox or I really need to see mental health [support]. Then we don't just say, well, here's the number and call them, we'll say let's call them. So, we'll support them though that whole process and not just say, here, do it on your own, because sometimes when you're at that point you can't do it on your own. It was hard enough to ask for help (Participant 22).

Breaking down systemic barriers and advocating on behalf of clients was discussed in much detail by some participants. Despite systemic challenges, one mental health staff person described her commitment to advocate and goes on to say *"if I see things that were unjust or if, um, I see that there's possibilities, um, or things that are not being done that could be done, um, you know, I'm going to rally with them to get done" (Participant 7)*.

Community leaders and frontline staff also described how Indigenous models of health and healing can be used to guide the delivery and implementation of community-led health

services and programs in the community. As one public health nurse shared:

> *We include the medicine wheel and we just try to make it culturally appropriate with some of the stuff we gave, like little handouts, like for aboriginal youth or HIV. So, we try to make it culturally appropriate… We do have a working group with elders, women's groups, and more so turned out to be, in general a woman's support group where we worked with traditional medicines and cultural activities (Participant 9).*

Furthermore, individual and family-centered approaches to care were also advocated for to align services and programs with the needs of Indigenous residents, families and communities. A service team lead recounted how her team went out of their way to support clients:

> *I know we've done so much for so many people and it will be really, if people would ask, like, if they asked for something or something in particular, we'd go on the hunt and find [it]. Like, I know one family, she was really into, um, her beading and making moccasins and stuff like that. So, we went to Halfords and had her whole box of supplies waiting for when she moved in so she could have some basic tools to start doing what she loved again. And that's how we got back to bringing it right down to people. We talked to people, what do you need and what do your family need? Not so much looking on the greater scale sometimes, but focusing in and zoning in on that one family, how do we meet your needs (Participant 5)?*

DISCUSSION

This study described how mainstream health systems (health service-delivery organization across sectors) responded to the health and mental health needs of Indigenous residents following a wildfire disaster. The conceptual framework by Mirzoev and Kane (11) and Valentine et al. (21) for health systems responsiveness guided our data interpretation (11). The Mirzoev & Kane (11) framework "positions the experience of interaction between people and health system as the centerpiece and recognizes the determinants of responsiveness both from the health system (e.g., actors, processes) and the people (e.g., initial expectations) sides" (11). The service providers shared their experiences as actors following interactions within the health system as well as their perception of expectations and experiences of their Indigenous clients.

We applied the concept of health system responsiveness, originally developed by the WHO, and adaptations of the concept and frameworks. Our study findings present opportunities to explore health system responsiveness in relation to the realities of Indigenous peoples' within the context of a wildfire disaster. Our findings build on, and advance, core frameworks on health system responsiveness to propose new elements for a framework for health system responsiveness aligned with the realities and experiences of care for Indigenous peoples in the context of a public health emergency.

One of the elements of the Mirzoev and Kane (11) framework for assessing health system responsiveness is on the characteristics of health services (e.g., availability, accessibility, and quality). Findings from service provider interviews and the document review demonstrated that the delivery of health-related services in Indigenous communities following the wildfire were shaped by pre-existing health and mental health service gaps in the region, historical funding inequities toward Indigenous health, temporary funded service provider positions during wildfire recovery, and inconsistent delivery of programs and services throughout the wildfire; which ultimately meant that the needs and expectations of care for Indigenous residents and communities were not adequately met. Prior to the wildfire, Indigenous peoples in Canada faced precarious access to health services and had more unmet health needs compared to the non-Indigenous population (53, 54). Public health emergencies disrupt availability of services, cause damage to physical infrastructure, and engender psychological or mental distress which create increased need for mental health services and supports for individuals and families.

Service providers advocated for sustainable and long-term supports during a crisis and highlighted the missed opportunity to foster provider-client relationships with temporary services and inconsistent presence of service providers in the community. This is compounded by a distrust among Indigenous peoples with the health system because of past and current experiences with racism, discrimination and oppression in the Canadian healthcare system, leading to the perpetuation of health inequities (55). As trust is another identified element in the health system responsiveness framework by Mirzoev and Kane (11), future research is needed to examine the relationship between the sustainability of services and programs offered in communities and uptake or use of those services and programs by Indigenous people.

Cultural safety and cultural responsiveness are also an important determinant that shapes Indigenous users' experience across the health system. Contextual considerations such as historical traumas and current systemic racism greatly impact Indigenous people's interaction with health service-delivery organizations. Findings from the document analysis and service provider interviews offered suggestions for improving Indigenous residents' experiences with a health system following a public health emergency. This included providing cultural sensitivity training and education as a part of reconciliation to address colonial legacy and historical traumas. Minnican and O'Toole (56) categorized characteristics of culturally responsive communication for service providers to be reflexive, flexible, self-aware, respectful of diverse cultures, transparent, and non-judgemental (56). Noted in our interviews, service providers touched on similar characteristics of Minnican and O'Tooles (56) findings and also suggested education among providers to bring awareness about the local Indigenous context and cultural diversity (for instance, awareness of Dene, Cree, and Métis culture of the RMWB region).

Service providers highlighted the role of community engagement to build relationships, improve understanding of local contexts for service providers and foster community connectedness, which in turn supported emotional well-being. Moreover, connection to the land, culture, and spirituality must be considered when responding to mental health needs

of Indigenous populations (4). As an effort to normalize mental health disturbances experienced by the residents following the wildfire, Alberta Health Services (AHS) launched a campaign called "Recovery Takes Time" and emphasized that recovery looks different for everyone (57). This highlights the importance of tailoring resources and supports for diverse population groups and across intersections of gender, sex, culture, ethnicity, race, and Indigeneity. Furthermore, service providers in our study were critical of the limited mental health resources and supports available to Indigenous communities, and especially for rural communities. Funding and resources allocated to mental health service delivery for Indigenous populations during a public health emergency should account for how services and supports are organized and delivered. Our findings emphasized delivering services in a timely, culturally relevant and culturally safe manner, in order to best support Indigenous communities during and following a public health emergency.

All interviewed participants spoke about mental health support as a crucial aspect of recovery and the document review revealed positions that were created for mental health and psychosocial support (47, 58, 59). Several documents reviewed had reported on increase utilization of mental health services and supports, includes both Indigenous and non-Indigenous population groups in their reporting and mis-represents the experience of Indigenous people. In contrast, the interviews commented on lower utilization of support services and barriers to access for communities. In addition, while organizations documented programs and service availability in Indigenous communities, service providers discussed the inadequate amount of time allotted to programing and that temporary support did not meet the needs of communities.

Moreover, as some service providers commented on the jurisdictional complexity of the RMWB it is important that we understand the health systems' response to the health and mental health needs of Indigenous peoples following the wildfire within the context of the dual funding system (federal–provincial) for Indigenous health. The jurisdictional relationship between the Federal and provincial governments has generated tension regarding who is responsible for funding health, resulting in confusion, set-backs, resentment, and failure to address healthcare in Indigenous communities, not only related to funding for health initiatives but also with components that impact the determinants of health. Whereas, there is a fiduciary obligation of the federal government around Indigenous health in Canada, there has been a clear lack of federal leadership in emergency management for Indigenous communities. For instance, Indigenous Services Canada (ISC) delegates programs to the Alberta Emergency Management Agency (AEMA) but First Nations reserves remain outside of provincial jurisdiction and there is very little coordination support and guidance provided by ISC. As a result, there was inadequate coordination between the RMWB, the Province of Alberta, and First Nations during the 2016 wildfire, which enhances jurisdictional territoriality and impedes cooperation and coordination of services and supports to communities (47). Indigenous organizations and

local health service centers were reported as being underfunded and understaffed, impacting their ability to be prepared for public health emergencies (47).

There have been frequent crises that disproportionately affect Indigenous communities in Alberta over the past decade or more. These include the 2009 H1N1 epidemic, the 2013 floods in southern Alberta, the 2016 wildfires in northern Alberta, the opioid epidemic, and the recent COVID-19 pandemic. In all of these situations, delays in determining responsibility for the response were experienced, despite fiduciary obligations of the federal government to Indigenous peoples as well as jurisdiction over reserve lands, but with provincial governments tasked with health services supports delivery. The wildfire as well as the COVID-19 pandemic highlighted the problems that fragmented or "siloed" health and social care systems face in adapting to crises that require an urgent and collaborative response (60–62). With each of these emergencies or crises, health systems, and governments have been tested to demonstrate how care and supports can be organized and delivered rapidly, yet the relationships between decision-makers, providers, and community leaders have had to be reformed each time. The wildfire and COVID-19 pandemic in particular have demonstrated most prominently that community engagement, community leadership, and knowledge of Indigenous communities is an essential foundation for public health during moments of crisis.

The framework for Indigenous Disaster and Emergency planning developed by Montesanti and colleagues (63) from previous research on a major flood in First Nation communities in southern Alberta, provides a promising resource to guide future disaster response and recovery in Indigenous communities by addressing the social determinants of health and supporting community-led response to disaster recovery. This framework highlights several key characteristics discussed in this manuscript such as a holistic understanding of health and wellness, community-led emergency plans, and recognition that colonialism and racism still exist and are to be discouraged. Thus, our research findings presented in this paper enrich our understanding of the key characteristics outlined in the framework and can be used to inform local emergency responses at the community level. The overall structure of disaster and emergency management programs and policies has emerged from the dominant political system and has been overlaid on Indigenous communities. The results of this system exclude the voices of Indigenous peoples from public health emergency response, and ultimately result in continuing colonization through dominant disaster and emergency management programs and policies. Our document review underscored the exclusion of Indigenous communities in the planning of evacuation and response. By increasing awareness of the health and social inequalities in risk management, it will be possible to engage in risk reduction planning with communities and promote community-led and culturally safe responses to public health emergencies. Climate change is projected to continue to drive increased risks over the coming decades, risks that will be compounded

by non-climatic factors such as social, economic, cultural, political, and institutional inequities. It is important to understand how disaster response and emergency planning measures can play a role in reducing harm and promoting healing instead of perpetuating vulnerabilities and health and social inequities.

Health system responsiveness could be improved by encouraging community control over what services are provided (64). Self-determination not only leads to more appropriate services but also contributes to reconciliation as a tool to reduce the oppressive legacy of colonization and historical traumas (65). Further, similar to prior disaster response in Indigenous communities, jurisdictional and governance challenges were noted and lack of communication between leadership in communities was observed to influence the health systems' response (4). Prior research stresses the importance of coordination and collaboration between government and organizations that are supporting mental health and recovery (66). Inter-agency cooperation and collaboration were briefly discussed in the interviews and document analysis but was not identified as a common theme. Where collaboration of service delivery was discussed, Indigenous focused interagency collaboration was not mentioned.

It is important to note that community members perceptions and experiences were shared through the lens of the service providers. This is a possible limitation for this work as we relied on the input of service providers to understand health system responsiveness in the context of Mirzoev and Kane's conceptual framework. However, in our other work led by authors of this paper (KF, SM, TA, TM, LA) (4), community members did speak to the health systems response following the wildfire disaster. Our research findings provide insights into the development of an adapted health system responsiveness framework which acknowledges Indigenous peoples experience with the health system during a public health emergency. Based on our findings the following domains of responsiveness are critical to advocate for: (1) access to cultural safe and culturally responsive care; (2) trust between service providers and clients; (3) respect for Indigenous culture and knowledge; (4) inclusion of Indigenous values in the design and delivery health services; and (5) attention to equity. Further development of these domains of responsiveness needs to be explored and validated by Indigenous peoples and experts. Additionally, determinants of responsiveness for Indigenous peoples may be shaped by allocation of resources, health system organization, and historical and institutional factors.

CONCLUSION

This research examined how health systems responded to the immediate and long-term health and mental health needs among Indigenous residents and communities following the Horse River wildfire in northern Alberta, Canada. Interviews with health service providers and a review of available organization and government reports provided key information on the provision of health and mental health services following the wildfire, gaps in service delivery, socio-political factors that shaped

delivery and access to health-related services, and suggestions for strengthening responsive health systems for Indigenous health. The health system responsiveness concept was used to guide data interpretation and the application of proposed frameworks on health system responsiveness, to understand Indigenous peoples' interaction and experience with health services provided following the wildfire. Our findings demonstrated that the needs and expectations of care for Indigenous residents and communities following the wildfire were not adequately met. For instance, funding and resources for Indigenous health services was limited and in general not culturally safe or relevant. However, many service organizations did demonstrate how they worked with what they had and collaborated with other agencies to provide Indigenous peoples in the region with access to needed health and mental health services and adapted and implemented new delivery approaches to promote culturally-responsive care. A main service adaptation in response to the crisis, included an increased availability of mental health services such as counseling, psychosocial interventions, and outreach support. Adopting and applying a health equity lens in post-disaster recovery planning was highlighted as essential to reducing the disproportionate impacts on Indigenous residents and communities and creating a more sustainable and equitable approach to responding to health-related impacts following a public health emergency. Furthermore, attention to the roots of disaster and the colonial process of disaster and emergency management programs and policies can help Indigenous communities to heal and recover from a public health emergency.

DATA AVAILABILITY STATEMENT

The original contributions presented in the study are included in the article/**Supplementary Materials**, further inquiries can be directed to the corresponding author.

ETHICS STATEMENT

AUTHOR CONTRIBUTIONS

SM led the funding acquisition for the study and is the Nominated Principal Investigator for the funding grant. SM and KF led the writing of the manuscript. SM and TW designed the interview guide in partnership with the Community Advisory Committee. SM and a community research assistant conducted interviews. SM, TW, KF, and

TA developed the coding framework for analysis of the interviews. KF and TA completed initial data analysis, and KF and SM refined the key themes. KF and CP conducted the document review and extraction (led by CP). CP contributed to the manuscript writing and formatting. JS and LA confirmed results and contributed to manuscript writing. All authors reviewed the manuscript and provided edits and feedback.

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SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpubh.2021.723613/full#supplementary-material

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The Contributing Factors of Delayed-Onset Post-traumatic Stress Disorder Symptoms: A Nested Case-Control Study Conducted After the 2008 Wenchuan Earthquake

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Background: Delayed-onset post-traumatic stress disorder after catastrophes is a major public health issue. However, good designs for identifying post-traumatic stress disorder (PTSD) among earthquake survivors are rare. This is the first nested case-control study to explore the possible factors associated with delayed-onset PTSD symptoms.

Methods: A nested case-control study was conducted. The baseline (2011) and follow-up (2018) surveys were utilized to collect data. A total of 361 survivors of the Wenchuan earthquake were investigated and 340 survivors underwent follow-up. The survivors, from the hardest-hit areas, who met the criteria for PTSD were included in the case group, and PTSD-free survivors from the same area, matched for age, were included in the control group, with a ratio of one to four. Conditional logistic regression was used to evaluate the variables' odds ratio (OR).

Results: The overall prevalence of delayed-onset PTSD symptoms in survivors of the Wenchuan earthquake was 9.7% (33/340). The unemployed earthquake survivors had a higher risk of developing delayed-onset PTSD symptoms (OR = 4.731, 95% CI = 1.408–15.901), while higher perceived social support was a protective factor against delayed-onset PTSD symptoms (OR = 0.172, 95% CI = 0.052–0.568).

Conclusion: Delayed-onset PTSD symptoms, after a disaster, should not be ignored. Active social support and the provision of stable jobs can contribute to the earthquake survivors' mental health.

Keywords: earthquake, delayed-onset PTSD, contributing factors, mental health, public health policy

INTRODUCTION

Since earthquakes are not always predictable and are highly destructive, they can cause significant damage to physical and mental health (1). Moreover, since 1950, earthquakes have become the most devastating natural disaster (2). The Wenchuan earthquake, which occurred in Sichuan province on May 12, 2008, and resulted in 69,227 deaths, 374,643 injuries, and 17,923 people missing, was the most ruinous earthquake since its founding of the People's Republic of China (3, 4). Furthermore, the economic losses reached 84.51 billion Renminbi. In addition, it placed a great psychological

burden on the survivors (5). A study of 2080 Wenchuan earthquake survivors found that 40.1% of the participants suffered from post-traumatic stress disorder (PTSD) 1 year after the earthquake (6). Similarly, a related meta-analysis report showed a 29% incidence of PTSD in a sample of 76,101 survivors in the 9 months following the earthquake (7).

Post-traumatic stress disorder, a severe and complex mental disorder caused by exposure to a catastrophic event, is composed of three clusters of symptoms: re-experiencing, avoidance, and hyperarousal (8). PTSD onset can be close to the traumatic event or delayed (9), and some populations will never present with PTSD despite similar traumatic exposure (10, 11), so the symptoms of PTSD after the disasters could take multiple trajectories (12). One study revealed four trajectories of PTSD: resilience, recovery, chronic, and delayed (13, 14). Compared to it, a population-based longitudinal study identified six clusters of PTSD symptom trajectories after the disaster: low-stable, moderate-stable, moderate-increasing, high-stable, high-decreasing, and very high-stable (15).

About 70% of the world's ordinary people will experience potential traumatic events (PTE) in their lifetime (16), and many people will have post-traumatic stress symptoms (PTSS) (17). People with PTSS are at a higher risk of developing delayed-onset PTSD, especially after experiencing subsequent PETs or other stressors (18). Unfortunately, both PTSS survivors and PTSD survivors may have their brain function and structure changed after trauma, and trauma survivors are at high risk of developing mental disorders. For example, research has shown that the appearance of post-traumatic nightmare indicated delayed-onset PTSD, even if the delayed-onset PTSD has been solved, the nightmare associated with the PTSD would persist throughout life (19). Another study also confirmed that lifetime PTSD affected about 10% of women and 5% of men in the general population (20, 21). Moreover, a study focused on the nervous system and revealed the survivors' cognitive might decline, which might lead to loss of well-being in later life (22, 23). In addition, according to the stress sensitization hypothesis, that individuals who have experienced previous PTSD are more susceptible to developing PTSD following subsequent traumas (24, 25). In a word, our research on delayed-onset PTSD has a lot of scientific implications.

In delayed-onset PTSD, the PTSD symptoms are initially at a low level but increase gradually over time (13). Additionally, a study found that a significant number of survivors developed PTSD after six or more months after the initial traumatic event (26). Studies have demonstrated that people continued to suffer from PTSD 8 years after the earthquake (27–32). These studies focused on factors related to PTSD, such as alexithymia (27), post-traumatic growth (28), self-esteem (29), depression (30), suicidal behaviors (31), and community support (32). However, all of them were cross-sectional studies and none of them focused on delayed-onset PTSD. After reviewing a large number of studies, perceived social support was considered an important

variable among the various factors affecting PTSD (33–36). Moreover, according to the stress vulnerability model (37), emotional problems under stress are related to the individual's vulnerability to stress, the magnitude of stress, the impact of the environment, and the ability to cope with stress (38). PTSD is trauma and stress-related disorder (39), therefore, predictor variables in this study were selected based upon 3 levels: (1) individual factors, (2) social factors, and (3) disaster-related factors. We aimed to explore the relationship between these factors and delayed-onset PTSD symptoms by conducting a nested case-control study.

METHODS

Ethics Statement

This study was approved by the institutional review board of the West China Hospital of Sichuan University. The purpose and significance of the study were described in detail, and oral informed consent was obtained from each participant prior to the survey.

Study Design and Setting

This was an observational study using the nested case-control methods. The first survey was conducted in Wenchuan, Shifang, and Mianzhu—areas that were affected by the earthquake—from May to June 2011, and the follow-up survey was conducted from April to October 2018.

Cases and Controls

We used the PTSD Checklist-Civilian Version (PCL-C) scale, which was based on the fourth edition of the Diagnostic and Statistical Manual of Mental Disorders, to screen for PTSD symptoms related to earthquakes (40). Both English and Chinese versions of PCL-C were often used when a clinical interview was not feasible and had been demonstrated to have good validity, reliability, and accuracy in screening PTSD (41). In a previous study, the Chinese version of the PCL-C was validated and showed good internal reliability (Cronbach's alpha = 0.89) (40). This self-report scale contained 17 items and its total score ranged from 17 to 85 (42).

It was worth noting that we did not diagnose PTSD but screened for PTSD among this sample thus measuring PTSD symptomatology rather than PTSD. Survivors who were not screened for PTSD symptoms during the first survey and those with a score of 38 and above during the follow-up survey were classified as likely to have delayed-onset PTSD symptoms and were included in the case group. The control group comprised survivors, from the same area, with a PCL-C score <38, with a ratio of 1:4, and were matched for age (±2years).

Variables and Measurements

Demographic information (age, gender, nationality, education, and profession) and other factors (smoking behavior, drinking behavior, the prevalence of chronic diseases, whether injured during the earthquake, having relatives who were injured, disabled or killed, due to or during the earthquake) were collected using a predefined questionnaire. Participants with

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Abbreviations: PTSD, post-traumatic stress disorder; PCL-C, PTSD Checklist-Civilian; PSSS, perceived social support scale; OR, odds ratio; CI, confidence interval.

a formal diagnosis of at least one of the following were considered to have chronic diseases: malignant tumor, heart disease, chronic non-specific lung disease (asthma, bronchitis, and emphysema), atherosclerotic disease, cerebrovascular disease (stroke, excluding transient ischemic attack), diabetes, osteoarthritis, and rheumatoid arthritis. Family members who were injured, disabled, or killed in the earthquake were classified into two groups based on their relationship to the participants: the first group included parents, spouses, and children, and the second included grandparents, grandchildren, siblings, and other relatives.

Perceived social support was tested using the Perceived Social Support Scale (PSSS), which was considered to be reliable to measure social support (43), and the Chinese version of the PSSS was validated and showed good internal reliability (Cronbach's alpha = 0.89) in previous studies (44, 45). This self-report scale, which measured the support from three aspects—family, friends, and others—contained 12 items and its total score ranged from 12 to 84, with a higher score indicating a higher degree of perceived social support (46). A total score below 50 was defined as a low degree of perceived social support, and a score of 50 and above was defined as a high degree of perceived social support (47, 48).

Bias

A multistage random sampling procedure was performed to select the study sample to reduce selection bias. The field interviewers included both clinical psychologists and graduate students from preventive and clinical medicine, and all of them received uniform training prior to the commencement of the survey. Survivors with any pre-existing mental disorder were excluded at the baseline. Double entry of the questionnaire data was independently carried out by two trained staff for validation and quality assurance. Multivariate logistic regression analysis was used to adjust for potential confounding factors.

Statistical Analysis

Statistical analyses were performed using SPSS version 25 (IBM Corp. in Armonk, New York, U.S.). Categorical data were using frequencies and percentages. Means and standard deviations were analyzed for continuous variables and conditional logic regression was used to identify the risk factors for delayed-onset PTSD symptoms. The odds ratios (ORs) and 95 % CIs both were also calculated.

RESULTS

A total of 361 survivors without PTSD symptoms from the first survey were included in the cohort. During follow-up, it was found that the prevalence of delayed-onset PTSD symptoms was 9.7% (33/340). A considerable proportion of traumatized individuals subsequently developed PTSD. A meta-analysis showed that 27.0% of individuals developed initial PTSD symptoms but then recovered, 10.3% developed chronic and 6.4% had delayed-onset PTSD (14, 49). This supported the prevalence of delayed-onset PTSD symptoms in our study

to some extent. Meanwhile, 33 cases were identified, and 132 controls were matched with these cases (**Figure 1**). The mean age was 58.03 and 58.85 in the case and control groups, respectively. The majority of those in the case group were female, were a minority, were illiterate, had primary school education, were unemployed, were other professionals except farmers, workers, and unemployed people, did not smoke, did not drink, had chronic diseases, were either injured themselves or had a family member who was injured, disabled, or killed by the earthquake, and had lower perceived social support than those in the control group (**Table 1**).

In the univariate analysis, unemployment increased the risk of developing delayed-onset PTSD symptoms (crude OR = 2.987, P < 0.05); those with family members who were disabled during the earthquake were also at risk of developing delayed-onset PTSD symptoms (crude OR = 4.8, 95% CI = 1.465–15.728). However, a higher degree of perceived social support was a protective factor against developing PTSD symptoms (crude OR = 0.201, 95% CI = 0.082–0.493) (**Table 2**).

A multivariable conditional logistic regression analysis was then performed. However, after adjusting for the other variables, the family members who were disabled during the earthquake variable demonstrated no statistical significance. In the multivariate analysis, unemployment and a higher degree of perceived social support were also important factors in developing delayed-onset PTSD symptoms. Unemployment was a risk factor for delayed-onset PTSD symptoms (adjusted OR = 4.731, 95% CI = 1.408–15.901), while a higher degree of perceived social support was a protective factor (adjusted OR = 0.172, 95% CI = 0.052–0.568).

DISCUSSION

The aim of this nested case-control design was to identify the influence of latent factors—personal, social, and disaster-related variables—on delayed-onset PTSD symptoms. The findings revealed that unemployment increased the risk of delayed-onset PTSD symptoms, while a higher degree of perceived social support reduced the risk of PTSD symptoms.

It was necessary to point that we assessed PTSD among survivors at the follow-up survey 10 years after the Wenchuan earthquake so that this elapsed time might have also influenced the delayed-onset PTSD system. According to the stress vulnerability model, that the course of severe mental illness was determined by an interaction of biological vulnerability, stress, and coping (50). Therefore, other subsequent traumas (even of minor severity as grief) could act by adding their burden to promote the development of PTSD (51). To control for bias, we emphasized to the subjects that this was an investigation into the impact of the Wenchuan earthquake in 2008 during our follow-up, and when the investigators asked the subjects questions, they would repeatedly emphasize the words Wenchuan earthquake, in an attempt to guarantee that delayed-onset PTSD was promoted by the Wenchuan earthquake.

Though those who were unemployed and retired were both not actively employed, only those who were unemployed were

FIGURE 1 | Flowchart of sampling.
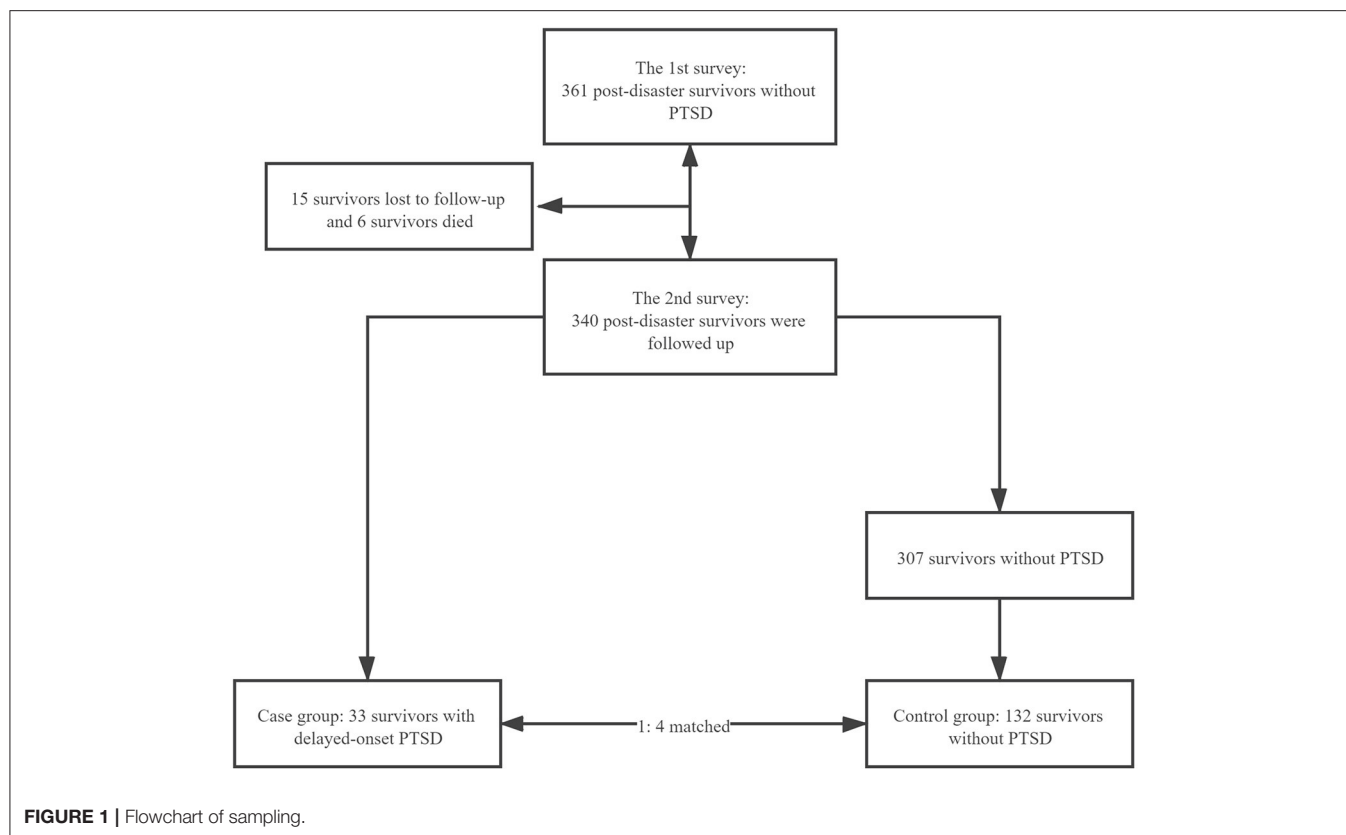
vulnerable to PTSD (52); since those who were unemployed did not have a stable income, however, most of the retirees had pensions to cover their living expenses. For unemployed post-earthquake, evidence showed that loss of own resources such as income (53, 54), was the most influential exposure variable for mental illness. This indicates that income is inherently a crucial factor in developing delayed-onset PTSD (40), therefore, the local government should create and provide more jobs to help the survivors guarantee adequate income.

Both social and interpersonal factors played a vital role in the trauma recovery process (55); we also found that a high degree of perceived social support could reduce the occurrence of delayed-onset PTSD symptoms. Furthermore, it should be emphasized that actual social support was not equal to perceived social support, and existing literature has demonstrated that perceived social support was more beneficial for survivors, to adapt and cope with stress after catastrophes (35). Therefore, we should provide practical and acceptable help for survivors through more effective communication with them, not just by providing routine social support.

A previous study found that there was a negative correlation between disability due to natural disasters and PTSD (56). As shown in the univariate analysis, disability also increased the risk of delayed-onset PTSD symptoms due to the presence of family members with disabilities. This could be because caring for relatives with disabilities amplifies the personal suffering

experienced during the earthquake, and some studies also showed that severe illnesses in family members might represent a complex burden for their caregivers, including a wide range of mental disorders, particularly PTSD (57, 58). For caregivers of disabled family members after the Wenchuan earthquake, they often had to struggle to adjust to new responsibilities and roles and were faced with double stressors-the stress of evoked memories about the Wenchuan earthquake and the burden of family care, so they had the risk for development of delayed-onset PTSD symptoms. Nevertheless, the multivariate analysis revealed an insignificant relationship between family members' disability and delayed-onset PTSD symptoms, which might be because family members' disability was not the most significant factor for developing delayed-onset PTSD symptoms, compared with unemployment and social support.

Three previous studies showed that subthreshold PTSD was associated with an increased risk of suicidality (59, 60, 64). Hence, taking into account survivors with both partial and sub-threshold PTSD symptoms was also important. Some studies focused on the survivors with subthreshold manifestations in a dimensional perspective. For example, if the survivors were defined as a report of at least one symptom in Criteria B (re-experiencing), C (avoidance), and D (hyperarousal), they would be considered as having "Partial PTSD" (61). Another study used The Harvard Trauma Questionnaire part IV (HTQ) to measure the presence of PTSD, patients were given a possible

Characteristic	At baseline, No. (%)	During follow-up, No. (%)	
		Case (*n* = 33)	Control (*n* = 132)
Age, years (mean, SD)	50.88 (9.93)	58.03 (10.04)	58.85 (9.94)
Gender			
Male	61 (37.0)	10 (30.3)	51 (38.6)
Female	104 (63.0)	23 (69.7)	81 (61.4)
Nation			
Minority	29 (17.6)	9 (27.3)	20 (15.2)
Han ethnic	136 (82.4)	24 (72.7)	112 (84.8)
Education			
Illiteracy	53 (32.1)	13 (39.4)	40 (30.3)
Primary school	71 (43.0)	15 (45.5)	56 (42.4)
Junior high school or above	41 (24.8)	5 (15.2)	36 (27.3)
Profession			
Farmer	51 (30.9)	7 (21.2)	48 (36.4)
Worker	49 (29.7)	5 (15.2)	37 (28.0)
Unemployed	57 (34.5)	19 (57.6)	41 (31.1)
Others	8 (4.8)	2 (6.1)	6 (4.5)
Smoking			
No	134 (81.2)	29 (87.9)	107 (81.8)
Yes	31 (18.8)	4 (12.1)	25 (18.9)
Drinking			
No	123 (74.5)	27 (81.2)	92 (69.7)
Yes	42 (25.5)	6 (18.2)	40 (30.3)
Chronic disease			
No	62 (37.6)	6 (18.2)	34 (25.8)
Yes	103 (62.4)	27 (81.2)	98 (74.2)
Injured in earthquake			
No	137 (83.0)	25 (75.8)	112 (84.8)
Yes	28 (17.0)	8 (24.2)	20 (15.2)
Family member injured during earthquake			
No	105 (63.6)	6 (54.5)	87 (65.9)
Yes	60 (36.4)	27 (45.5)	45 (34.1)
Family member disabled during earthquake			
No	154 (93.3)	27 (81.8)	127 (96.2)
Yes	11 (6.7)	6 (18.2)	5 (3.8)
Family member died during earthquake			
No	86 (52.1)	17 (51.5)	69 (52.3)
Yes	79 (47.9)	16 (48.5)	63 (47.7)
PSSS			
Low	32 (19.4)	7 (21.2)	18 (13.6)
High	133 (80.6)	26 (78.8)	114 (86.4)

PTSD diagnosis if they reported at least one re-experiencing symptom, three avoidance symptoms, and two hyper-arousal symptoms (62).

Moreover, the definition of the related post-traumatic stress symptoms is a hot topic of discussion in the recent past. For example, the DSM-V shifted from the previous three symptomatological criteria in DSM-IV to a four-criteria structure: Intrusion symptoms; Persistent avoidance; Negative alterations in cognitions and mood; Alterations in arousal and activity (51). Trauma and Loss Spectrum-Self Report (TALS-SR), which represented a valuable tool to assess the spectrum of clinical manifestations related to DSM mental disorders, also explored post-traumatic stress spectrum symptoms related to the three symptomatic criteria for PTSD diagnosis that were provided by the DSM-IV in its' Domains V, VI and VIII. The TALS-SR has been used to investigate both full and partial PTSD among survivors after L'Aquila 2009 Earthquake (63). These findings are important for the planning of future research since we can make a comprehensive evaluation of the PTSD symptoms.

This study has several strengths. First, to the best of our knowledge, this is the first nested case-control study, which is known for revealing the relationship between possible factors and delayed-onset PTSD symptoms after an earthquake. Second, this is a decade-long follow-up study, and the demonstrated relationships between unemployment/social support and delayed-onset PTSD symptoms are critical for local governments to promote survivors' health, which may be needed even 10 years after a catastrophe.

There are some limitations to this study. First, since the PTSD symptoms were not formally diagnosed by psychiatrists, self-report biases might exist. Second, the sample size was small, but the main reason for this was that most of the investigated survivors inhabited the mountainous regions, and the investigation was therefore difficult. Third, psychopathological comorbidities like mood disorders, anxiety disorders, or alcohol and substance abuse might have influenced the presence of PTSD symptoms at the second evaluation 10 years after the event (59). In addition, although we found some significant factors related to PTSD symptoms, our data were unable to shed light on causal associations.

Finally, further studies which are based upon clinician diagnosis would be needed in the future and using the Clinician-Administered PTSD Scale (CAPS) which is considered the "gold standard" for measuring PTSD is necessary (60). Moreover, the exact causative relation needs further exploration.

CONCLUSION

In summary, the current evidence demonstrates that delayed-onset PTSD symptoms continue to affect earthquake survivors; fortunately, a higher degree of perceived social support would reduce the risk of delayed-onset PTSD symptoms. However, it should be noted that unemployment increases the likelihood of delayed-onset PTSD symptoms. Therefore, social support should be provided not only through psychological counseling but also through targeted unemployment assistance to help survivors improve their quality of life.

TABLE 2 | Results of conditional logistic regression analyses.

	Univariate estimate			Multivariate estimate		
	OR	95% CI	P	OR	95% CI	P
Gender						
Male	Ref.			Ref.		
Female	1.464	0.636–3.371	0.371	0.672	0.179–2.524	0.556
Nation						
Minority	Ref.			Ref.		
Han ethnic	0.421	0.154–1.150	0.091	0.637	0.173–2.351	0.499
Education						
Illiteracy	Ref.			Ref.		
Primary school	0.716	0.281–1.823	0.484	0.968	0.261–3.592	0.962
Junior high school or above	0.36	0.103–1.259	0.11	0.245	0.038–1.584	0.14
Profession						
Farmer	Ref.			Ref.		
Worker	0.829	0.229–3.009	0.776	0.693	0.125–3.853	0.675
Unemployed	2.987	1.147–7.774	0.025	4.731	1.408–15.901	0.012
Others	2.237	0.401–12.490	0.359	3.847	0.431–34.364	0.228
Smoking						
No	Ref.			Ref.		
Yes	0.597	0.195–1.833	0.368	0.816	0.129–5.175	0.829
Drinking						
No	Ref.			Ref.		
Yes	0.524	0.204–1.345	0.179	0.734	0.137–3.939	0.719
Chronic disease						
No	Ref.			Ref.		
Yes	1.58	0.593–4.213	0.36	1.908	0.524–6.943	0.327
Injured in earthquake						
No	Ref.			Ref.		
Yes	1.762	0.712–4.361	0.221	3.138	0.911–10.81	0.07
Family member injured during earthquake						
No	Ref.			Ref.		
Yes	1.639	0.747–3.596	0.217	2.068	0.642–6.666	0.224
Family member disabled during earthquake						
No	Ref.			Ref.		
Yes	4.8	1.465–15.728	0.011	2.364	0.409–13.668	0.336
Family member died during earthquake						
No	Ref.			Ref.		
Yes	1.029	0.492–2.152	0.94	1.332	0.469–3.781	0.59
PSSS						
Low	Ref.			Ref.		
High	0.201	0.082–0.493	<0.001	0.172	0.052–0.568	0.004

DATA AVAILABILITY STATEMENT

The datasets presented in this article are not readily available because the data supporting the findings of the article are not publicly available, but it can be provided by the corresponding author on reasonable request. Requests to access the datasets should be directed to Jin Wen, huaxiwenjin@163.com.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by the Institutional Review Board of West China Hospital of Sichuan University. The patients/participants provided their written informed consent to participate in this study. The ID of the ethical consent form is 2019343.

AUTHOR CONTRIBUTIONS

YY, WZ, BL, and JW conceived the idea for the study and designed the study methodology. YY and WZ accessed and validated the dataset, did the formal data analysis, and prepared the first draft of the manuscript. YY and BL curated the data. JW supervised the study and acquired the funding for the study. All authors agreed to be cited as co-authors, accepting the order of authorship, and approved the final version of the manuscript and the manuscript submission to Frontiers in Public Health, also did the investigation, participated in the critical revision of the manuscript, and were responsible for the figures.

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A Qualitative Assessment of Studies Evaluating the Classification Accuracy of Personnel Using START in Disaster Triage: A Scoping Review

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Background: Mass casualty incidents (MCIs) can occur as a consequence of a wide variety of events and often require overwhelming prehospital and emergency support and coordinated emergency response. A variety of disaster triage systems have been developed to assist health care providers in making difficult choices with regards to prioritization of victim treatment. The simple triage and rapid treatment (START) triage system is one of the most widely used triage algorithms; however, the research literature addressing real-world or simulation studies documenting the classification accuracy of personnel using START is lacking.

Aims and Objectives: To explore the existing literature related to the current state of knowledge about studies assessing the classification accuracy of the START triage system.

Design: Scoping review based on Arksey and O'Malley's methodological framework and narrative synthesis based on methods described by Popay and colleagues were performed.

Results: The literature search identified 1,820 citations, of which 32 studies met the inclusion criteria. Thirty were peer-reviewed articles and 28 published in the last 10 years (i.e., 2010 and onward). Primary research studies originated in 13 countries and included 3,706 participants conducting triaging assessments involving 2,950 victims. Included studies consisted of five randomized controlled trials, 17 non-randomized controlled studies, eight descriptive studies, and two mixed-method studies. Simulation techniques, mode of delivery, contextual features, and participants' required skills varied among studies. Overall, there was no consistent reporting of outcomes across studies and results were heterogeneous. Data were extracted from the included studies and categorized into two themes: (1) typology of simulations and (2) START system in MCIs simulations. Each theme contains sub-themes regarding the development of simulation employing START as a system for improving individuals' preparedness. These include types of simulation training, settings, and technologies. Other sub-themes include outcome measures and reference standards.

Conclusion: This review demonstrates a variety of factors impacting the development and implementation of simulation to assess characteristics of the START system. To further improve simulation-based assessment of triage systems, we recommend the use of reporting guidelines specifically designed for health care simulation research. In particular, reporting of reference standards and test characteristics need to improve in future studies.

INTRODUCTION

Mass casualty incidents (**MCIs**) can occur as a consequence of a wide variety of events, such as those resulting from emergencies, disasters, or pandemics, and often require enhanced prehospital and emergency supports and coordinated emergency response. When MCIs cause the demand for medical care to exceed capacity, prioritization of patients shifts from treatment of the most severe casualties to an attempt to provide the best care for the highest number of victims. In these situations, medical professionals allocate priority to those who are most likely to benefit from the available resources and have the best chance of survival and recovery (1).

Created in the 1980s, the Simple Triage and Rapid Treatment (**START**) triage system was developed to be used in the event of a MCI (2), allowing responders to triage a patient in fewer than 60 seconds (s). (3). It has since become widely adopted (4, 5), especially in the United States, Canada, Australia and the Israeli-occupied territories (6). Its main goal is to appraise and identify conditions that can lead to death if not treated within 1 h by prioritizing clinical markers of respiration, perfusion, and mental status to identify impaired breathing, severe hemorrhage, and head injury. Responders employing START evaluate victims assigning them to one of four triage categories: deceased/expectant (black), immediate (red), delayed (yellow), and walking wounded/minor (green). Inaccuracies in correctly evaluating victims to a START triage category can result in either under-triage (not recognizing that victims could likely benefit from urgent medical intervention) or over-triage (in which valuable resources are used prematurely or unnecessarily). An effective triage tool should have a high sensitivity to minimize the occurrence of under-triage, but should not undermine specificity to prevent the occurrence of over-triage. Sensitivity and specificity can be determined using the rate of appropriately assigned clinical priority levels for victims of a MCI against a reference standard.

The highly stochastic nature of MCIs, as well as the complexity of subsystem interactions, makes simulation one of the best strategies for preparing individuals and health systems to develop the most efficient procedures. START is often utilized in simulation studies employing a variety of MCI scenarios assessing, for example, the impact of educational interventions, the effect of different simulation technologies, or its performance in comparison to other triage systems (7–9). A common element in these studies is the evaluation of the ability of participants to apply START in view of various outcome measures of classification accuracy. This is done to assess whether victims are being triaged to the appropriate triage category. Thus, observing simulation strategies employed in different studies and whether participants/trainees are triaging appropriately using one of the most adopted triage systems is an important step to advance studies using simulation in the field of disaster medicine.

Despite the widespread utilization of START across the literature, there was just one published synthesis of the classification accuracy of START. In this recently published systematic review it was found that the accuracy of START is insufficient to serve as a reliable disaster triage tool (10); however, it was noted that the included studies varied considerably in terms of the use of true vs. simulated MCIs, the implementation and conduct of the simulations, as well as the assessors applying the START triage system. While beyond the scope of the systematic review (10), a description of the characteristics of the simulations in which START accuracy is assessed is essential for several reasons (11–15). First, it can reveal nuances of the interaction of both (simulation techniques and triage systems) and recommend adaptations (if necessary). Second, reproducibility of findings can also be considered. Thus, the research question directing this scoping review is: What is known about simulation studies of MCIs assessing the classification accuracy of the START triage system? The purpose of this scoping review is two-fold: first, to explore the existing literature related to the current state of knowledge about simulation strategies of studies assessing the classification accuracy of the START triage system; second, to consider implications for further research.

METHODS

This scoping review was conducted following the methodological framework described by Arksey and O'Malley (16) including: identifying the design and search question; searching for relevant studies; selection of studies; charting the data; and finally, collating, summarizing and reporting the results. The methods of this study were enhanced by the recommendations of Levac, Colquhoun and and O'Brien (17), which include connecting the research question to the purpose, ensuring that practicality does not limit the findings of the study, and identifying practical implications of the review. We did not engage in the optional stage 6—consultation with the community—in this current study, although such consultation may form a part of future knowledge translation. This scoping review followed the Preferred Reporting Items for Systematic Reviews and

Meta-Analyses for Scoping Reviews (PRISMA-ScR) (18) (see **Supplementary Material 1**).

Search Terms and Strategies

Following an initial search to identify publications on the topic, a health sciences librarian (SC) developed a search of nine electronic databases including OVID Medline, OVID EMBASE, OVID Global Health, EBSCO CINAHL, Compendex (Engineering Village), SCOPUS, Proquest Dissertations and Theses Global, Cochrane Library, and PROSPERO. The search strings for each database was adjusted appropriately for different databases and included controlled vocabulary and keywords for three concepts: (1) START, (2) triage and (3) mass casualty. The search was conducted in March 2020 and databases searches were limited from 1983 to present. No other language or publication limitations were applied. Detailed search strategies are available in **Supplementary Material 2**. Search results were exported to RefWorks citation management system (ProQuest, LLC, Ann Arbor, USA) and the Covidence systematic review program (Veritas Health Innovation Ltd, Melbourne, Australia).

To identify additional studies, a search of the gray literature was conducted in May 2020 which included Google Scholar, Controlled-trials.com, a forward search of the included studies using Web of Science SCOPUS, and a search of the references of included studies and relevant reviews. In addition, recent conference abstracts (2017–2020) from *Canadian Journal of Emergency Medicine*, *Academic Emergency Medicine*, and *Annals of Emergency Medicine* were searched. Non-English language papers were translated first *via* native speaker, or using Google Translate if a native speaker was not available.

Study Screening and Selection

Following the removal of duplicates, the title and abstract of all articles identified in the search were reviewed by two independent reviewers (UDW and SWK) to identify potentially eligible studies based on the inclusion criteria. Once identified, the full-text of all studies classified as potentially eligible were reviewed by two reviewers (UDW and SWK) in duplicate. Decisions of inclusion or exclusion were made independently based on pre-defined inclusion criteria.

To be eligible for inclusion in the current scoping review, studies had to utilize the START triage system either in a true or simulated MCI scenario for the triage of adult victims. Studies that strictly used a modified version of START were not eligible. In addition, studies had to report outcomes related to the classification accuracy of START (i.e., accuracy, over-triage, under-triage, sensitivity, specificity) to be included. Studies were required to consist of a single cohort or multiple groups as long as at least one of the study cohorts were triaged using the START triage system. Non-experimental studies including case-reports, case-series, reviews, and editorials/opinion pieces were excluded.

Reasons for exclusion were documented. Multiple reports of the same study were collated so that each study, rather than each report, was the unit of review. Disagreements regarding study inclusion were resolved via a third-party adjudication (JMF). The

results of the search, screening, and selection are reported in full in a PRISMA flow diagram (19).

Charting, Collating, and Reporting the Results

For studies included in the review, pre-specified outcomes were extracted onto standardized forms in Microsoft excel. Data were extracted independently by at least two of three reviewers (JMF, SWK, UDW). Disagreements were settled via discussion between the reviewers and any conflicts that could not be settled were mediated via third party adjudication (BHR, JMF). The primary outcome of interest was the summary of the methods employed to develop the MCI real or simulation study in which START was applied. As such, information regarding the nature of the simulated MCI, how the simulation was implemented, who conducted the assessments, education/training of assessors, and the triage process was collected. Additional extracted outcomes included study characteristics, reporting of classification accuracy outcomes, and details regarding the reference standard. Definition of type of MCI was based on standard definitions (20).

Study Analysis

The heterogeneity in study methods and reported findings required a narrative approach to synthesis. Findings were grouped into themes after careful reading of the final selected publications by two reviewers (SWK, UDW). These groupings were determined in relation to the research question, and in consideration of logical presentation of the findings to a diverse audience of stakeholder readers (researchers, policy developers, educators, etc.). Face validity of the themes was established by a physician specialized in emergency and disaster medicine (JMF) and a physician specialized in emergency medicine and research synthesis (BHR). This process resulted in themes that were derived from the intended scope of the study, and included the reviewers' interpretation of the data. Thematic analysis was developed using the Lancaster University Guidance on the Conduct of Narrative Synthesis in Systematic Reviews (21). Variable labels included in the studies were extracted as "themes" in the same way as conceptual themes are extracted from qualitative research (21). Development of themes was influenced by the theoretical and disciplinary lenses of emergency medicine.

RESULTS

After removing duplicates, the literature search yielded 1,820 citations. Following the screening of titles and abstracts, 349 publications were identified as potentially relevant. Ultimately, full-text screening resulted in the inclusion of 32 studies involving 37 cases/simulations in the review. The PRISMA flow chart of study selection is presented in **Figure 1**.

Descriptive Summary of the Studies

From the 32 included studies, 30 were peer-reviewed articles, one was a conference abstract (22), and one was a master's thesis (23). The included studies were published between the years 2005 and 2019, with 28 published in the last 10 years (i.e., 2010 and onward). Studies originated from 13 countries; the United States

FIGURE 1 | Literature search flow diagram.
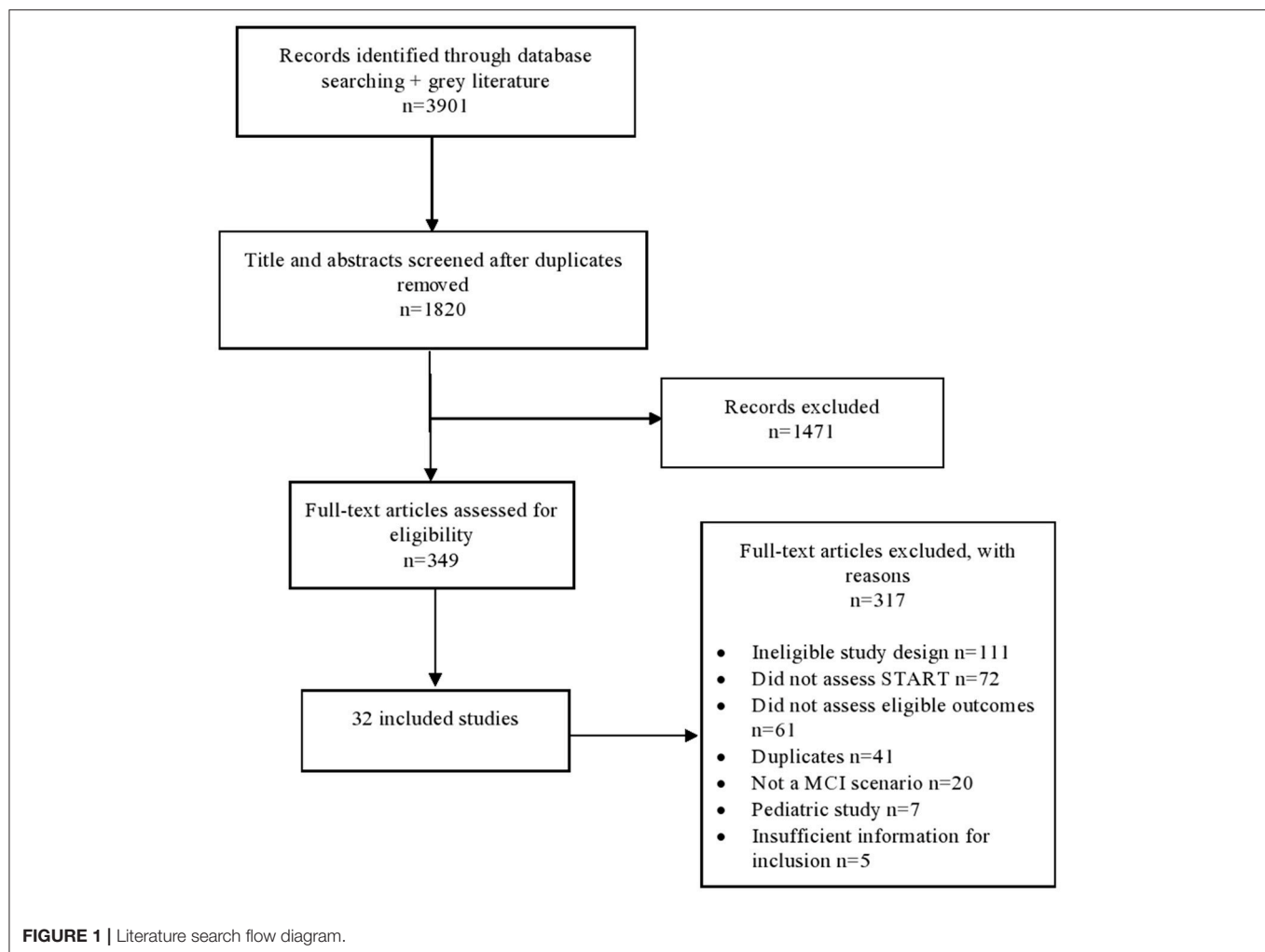
of America ($n = 12$), Italy ($n = 5$) and Canada ($n = 4$) accounted for the majority of them. Most studies were published in English, with the exception of two (24, 25).

Research designs of included studies consisted of five randomized controlled trials (26–30), 17 comparative non-randomized studies (8, 9, 22, 25, 31–43), eight quantitative descriptive studies (7, 24, 44–49), and two mixed-method studies (23, 50). Twenty-two studies did not report their source of funding (6–9, 22, 23, 26, 31, 32, 35–42, 44, 45, 47, 48, 50) and 12 studies did not mention or acknowledged any potential conflicts of interest among the study authors (9, 22, 23, 26, 29, 32, 38, 39, 41, 43, 44, 47). Six studies did not report any study limitations (8, 24, 26, 39, 44, 49).

Together, these studies involved 3,706 participants conducting triaging assessments involving 2,950 victims. Participants conducting the triage assessment were nurses, physicians, pharmacists, emergency medical technicians, paramedics, first responders, firefighters, non-medical personnel, as well as students from different medical areas, such as paramedic, nursing, medical and various levels

of training. The majority of the studies ($n = 25$) did not specify whether the participants conducting the triage assessment had prior experience with real or simulated disaster events. **Tables 1**, **2** presents a descriptive summary of included studies that align with the objective of the scoping review.

Narrative Summary of the Studies

Thematic analysis of the charted findings led to the identification of two themes: (1) typology of simulations and (2) START system in MCIs simulations. Each theme contains sub-themes regarding the development of simulation employing START as a system for improving individuals' preparedness.

Theme 1: Typology of Simulations

This theme explores the common types and characteristics of simulations employed in the studies. Sub-themes include simulation technologies, simulation settings, disaster types, assessors and their training/experiences in MCI (see **Table 3**).

TABLE 1 | Descriptive summary of the studies included in this review.

References and country	Aim of the study	Study design, participants (assessors and victims, at baseline)	Key findings
Arshad et al. (35), USA ✤	Determine if modification of the START system by the addition of an Orange category would reduce over- and under-triage rates in a simulated mass-casualty incident exercise.	• Quantitative non-randomized comparative study • Assessors: firefighters and paramedics ($n = 1,457$) • Assessors prior experience with MCI: not reported • Victims: computer-based cases ($n = 30$)	• The FDNY-START system may allow providers to prioritize casualties using an intermediate category (Orange) more properly aligned to meet patient needs, and as such, may reduce the rates of over-triage compared with START. • Overall correct accuracy rate was 91.2% of cases using FDNY-START whereas non-FDNY-Eagles providers correctly triaged 87.1% of cases using unmodified START
Badiali et al. (26), Italy ✤	Address whether "last-minute" START training of nonmedical personnel during a disaster or mass-casualty incident would result in more effective triage of patients.	• Quantitative randomized controlled trial • Assessors: nonprofessional first responders ($n = 400$) • Assessors prior experience with MCI: not reported • Victims: paper-based cases ($n = 30$)	• Even a "last-minute" training on the START triage protocol allows nonmedical personnel to better identify and triage the victims of a disaster or MCI. • The START group correctly triaged 94.2% of their patients, as opposed to 59.83% of the non-START group ($P < 0.01$). • Under- and over-triage were, respectively, 2.73% and 3.08% for the START group versus 13.67% and 26.5% for the non-START group. • The non-START group had 458 "preventable deaths" on 6000 cases because of incorrect triage, whereas the START group had 91.
Bolduc et al. (31), Canada ✤	Compare both accuracy and speed (triage time) of computer-based (electronic) to traditional paper-based (manual) START triage during a mass-casualty incident in a hospital setting.	• Quantitative non-randomized comparative study • Assessors: paramedics ($n = 2$) + medical doctors ($n = 2$) + registered nurses ($n = 2$) • Assessors prior experience with MCI: not reported • Victims: actors (students from an undergraduate health science program, $n = 30$)	• No significant difference in accuracy of triage when comparing electronic and manual methods, regardless of triage provider type or acuity of patient presentations
Buono et al. (22), USA ✦	Evaluate the accuracy of triage using an embedded algorithm in a wireless electronic system compared to traditional methods of triage.	• Quantitative non-randomized comparative study • Assessors: professional emergency responders ($n =$ not reported) • Assessors prior experience with MCI: not reported • Victims: Unclear ($n = 100$)	• The control manual group had a 73.7% (CI: 56.9–86.6%) accuracy when compared to the gold standard. • The WIISARD-PDA group had a 72.2% (CI: 46.5–90.3) accuracy and the WIISARD-iTag group had a 67.8% (CI: 47.6- 84.1%) accuracy when compared to the gold standard ($P = 0.09$). • There was no significant difference in accuracy between the 3 methods of triage acuity determination in our MCI drill.
Challen and Walter (34), England ✤	Assess the predictive power of three different triage systems using data from an actual mass-casualty incident (the London bombings of 7th July 2005).	• Quantitative non-randomized comparative study • Assessors: Unclear ($n =$ not reported) • Assessors prior experience with MCI: not reported • Victims: victims of a real mass-casualty incident ($n = 208$)	• The triage systems performed identically in identifying the critically injured, with sensitivity 50% and specificity 100% if using only the highest priority, or sensitivity 75% and specificity 99% if using the top 2 priority groups.
Crews (23), USA [t]	Evaluate the efficacy of START triage during actual mass-casualty incidents and full-scale MCI exercises.	• Mixed-methods study • Assessors: first responders ($n =$ not reported) • Assessors prior experience with MCI: not reported • Victims: victims of a real mass-casualty incident ($n = 36$) + actors ($n = 113$)	• Data analysis from actual incidents and exercises confirm that "just-in-time" training does increase the accuracy of the START triage model used from 42 to 73%.

(Continued)

TABLE 1 | Continued

References and country	Aim of the study	Study design, participants (assessors and victims, at baseline)	Key findings
Curran-Sills and Franc (37), Canada ✤	Compare emergency department triage nurses' time to triage and accuracy of a simulated mass-casualty incident population using a computerized version of CTAS or START systems.	• Quantitative non-randomized comparative study • Assessors: ED triage nurses ($n = 20$) • Assessors prior experience with MCI: yes ($n = 5$) • Victims: paper-based cases ($n = 9$)	• The cumulative triage accuracy for the cCTAS and START tools were 70/90 (77.8%) and 65/90 (72.2%), respectively. • The percent difference between cumulative triage was 6% (95% CI −19-8%).
Djalali et al. (48), Italy ✤	Test the association between the level of preparedness and the level of response performance during a full-scale hospital exercise	• Quantitative descriptive study • Assessors: hospital staff ($n =$ not reported) • Assessors prior experience with MCI: not reported • Victims: Unclear ($n = 61$)	• The preparedness of the chosen hospital was 59%, while the response performance was evaluated as 70%. • The hospital staff conducted START triage while they received 61 casualties, which was 90% correct for the yellow group and 100% correct for the green group.
Ellebrecht et al. (25), Germany ✤	Analyze the assigned triage level of casualties and compare paramedic's performance.	• Quantitative non-randomized comparative study • Assessors: paramedics ($n = 25$) • Assessors prior experience with MCI: not reported • Victims: actors + mannequins ($n = 559$)	• Overall correct accuracy rate was 81.5%. • Percentages of inappropriately assigned triage levels ranged from 0% to 60%. A conspicuous finding was the discrepancy between fire brigade paramedics (12.3%) and other emergency services paramedics (38.5%) but the low number of cases in the study should be taken into consideration.
Ersoy and Akpinar (47), Turkey ✤	Examine the accuracy of triage decision-making among emergency physicians using a multiple casualty scenario.	• Quantitative descriptive study • Assessors: emergency physicians ($n = 128$) • Assessors prior experience with MCI: yes ($n = 65$)	• Overall accuracy rate ranged from 83.6 to 90.0% for four immediate casualties, 26.4 to 78.2% for seven urgent casualties, 70.9 to 91.8% for four delayed casualties, and 82.7 to 97.3% for two dead cases. • Emergency physicians tended to under-triage patients • Personal and professional characteristics were found to be statistically significant in five cases ($p < 0.05$).
Ferrandini-Price et al. (33), Spain ✤	Determine the e?ciency in the execution of the START triage, comparing virtual reality to clinical simulation in a mass-casualty incident.	• Quantitative non-randomized comparative study • Assessors: emergency and special care nursing master's students ($n = 67$) • Assessors prior experience with MCI: not reported • Victims: actors (3rd year students from the superior school of dramatic arts) + virtual reality cases ($n = 20$)	• No significant differences between the clinical simulation with actors group (88.3% [SD = 9.65]) and the virtual reality simulation (87.2% [SD = 7.2]) • Overall triage rate was 87.65% (SD = 8.3)
Ingrassia et al. (42), Italy ✤	Test a new disaster simulation suite evaluating its application during the same type of full-scale exercise on two different occasions.	• Quantitative non-randomized comparative study • Assessors: emergency department physicians ($n = 36$) • Assessors prior experience with MCI: yes ($n = 18$) • Victims: actors ($n = 135$)	• No differences were found as regards triage or prehospital treatment accuracy. • No usability problems arose during either simulation. • Trained physicians were faster than non-trained physicians in dispatching the victims from scene to hospital [median (interquartile range) times, 67.5 (50.0–111.0) vs. 145.0 (110.0–150.0) minutes, $P < 0.001$] • Trained physicians also treated and discharged more patients in the emergency department (32/38 vs. 14/31, $P < 0.001$) and performed better on command-and-control items (31/44 vs 17/44 for trained and non-trained players respectively, $P < 0.05$).

(Continued)

TABLE 1 | Continued

References and country	Aim of the study	Study design, participants (assessors and victims, at baseline)	Key findings
Ingrassia et al. (40), Italy ✤	Develop a core curriculum of disaster medicine centered on blended learning and simulation tools	• Quantitative non-randomized comparative study • Assessors: medical students ($n = 524$) • Assessors prior experience with MCI: yes ($n = 37$) • Victims: computer-based cases ($n = 30$)	• The blended approach and the use of simulation tools were appreciated by all participants and successfully increased participants' knowledge of disaster medicine and basic competencies in performing mass-casualty triage.
Ingrassia et al. (27), Italy ✤	Explore the ability of virtual reality simulation, compared with live simulation, to test mass casualty triage skills, in terms of triage accuracy, intervention correctness, and speed to complete triage, of naive medical students using the START triage algorithm in a simulated mass-casualty incident scenario and to detect the increase in this expertise after a brief learning session on mass casualty triage.	• Quantitative randomized controlled trial • Assessors: medical students ($n = 56$) • Assessors prior experience with MCI: no ($n = 0$) • Victims: actors (3rd year medical students, $n = 10$)	• No significant differences in START triage accuracy when comparing virtual reality and live simulation. • Training could improve the ability to correctly categorize patients.
Izumida et al. (39), Japan ✤	Propose a triage training system in which the expression of information changes according to the skill level of each trainee.	• Quantitative non-randomized comparative study • Assessors: university students and graduated school students ($n = 12$) • Assessors prior experience with MCI: no ($n = 0$) • Victims: virtual reality cases ($n = 10$)	• The results revealed the system was e?ective to implement triage quickly and accurately.
Jain et al. (28), Canada ✤	Compare unmanned aerial vehicle technology (UAV) to standard practice in triaging casualties at a mass-casualty incident	• Quantitative randomized controlled trial • Assessors: second-year primary care paramedic students ($n = 20$) + advance care paramedic students ($n = 20$) • Assessors prior experience with MCI: not reported • Victims: actors ($n = 10$)	• No significant differences in START triage accuracy when comparing UAV technology and standard practice. • One-hundred-percent accuracy was noted between both groups. • A non-clinical statistical difference in the time to completion with UAV groups was noted.
Kahn et al. (46), USA ✤	Analyzed whether START is accurate in assigning acuity levels to victims of a real train crash.	• Quantitative descriptive study • Assessors: paramedics ($n =$ not reported) • Assessors prior experience with MCI: not reported • Victims: victims of a real mass-casualty incident ($n = 265$)	• No triage level met both the 90% sensitivity and 90% specificity requirement set forth in the hypothesis. • START ensured acceptable levels of red under-triage: 100% sensitive (95% CI 16% to 100%). • START ensured acceptable levels of green under-triage: 89.3% specific (95% CI 72% to 98%). • START incorporated a substantial amount of over-triage. • The Obuchowski statistic was 0.81, meaning that victims from a higher-acuity outcome group had an 81% chance of assignment to a higher-acuity triage category. • This analysis demonstrates poor agreement between triage levels assigned by START at a train crash and a priori outcomes criteria for each level.
Khan (29), Qatar ✤	Evaluate the mass-casualty incident triage skills of the medical staff like doctors and nurses at Hamad General Hospital Emergency Department.	• Quantitative randomized controlled trial • Assessors: physicians ($n = 50$) + nurses ($n = 50$) • Assessors prior experience with MCI: not reported • Victims: paper-based cases + computer bases cases ($n = 40$)	• The study results report 90% triage accuracy in the intervention group and 70% in control group with a difference of 20–30%. • The over and under triaging were 5% for both in the intervention side but 20%, 10% respectively in the control side. • The reliability also improved in the intervention group due to repeated training.

(Continued)

TABLE 1 | Continued

References and country	Aim of the study	Study design, participants (assessors and victims, at baseline)	Key findings
Lee and Franc (30), Canada ✤	Assess the ability to implement a two-step Emergency Department triage model with pre-triage using START, then subsequent triage using CTAS, during a mass-casualty incident using a computer-based disaster simulation.	• Quantitative randomized controlled trial • Assessors: emergency medicine resident physicians ($n = 21$) + triage nurses ($n = 2$) • Assessors prior experience with MCI: yes ($n = 23$) • Victims: computer-based cases of patients presenting to the ED due to a MCI ($n = 174$)	• No significant difference in accuracy of triage and patient flow when comparing a two-step emergency department triage model (CTAS + START) to START alone.
Lima et al. (45), Brazil ✤	Describe the teaching strategy based on the Multiple Victims Incident simulation, discussing and evaluating the performance of the students involved in the initial care of trauma victims.	• Quantitative descriptive study • Assessors: medical and nursing students and prehospital care team ($n =$ not reported) • Assessors prior experience with MCI: not reported • Victims: actors (medical and nursing students, $n = 56$)	• Overall accuracy rate was 94.1% • Following the primary evaluation with the ABCDE mnemonic, all steps were performed correctly in 70%.
Loth et al. (36), USA ✤	Examine an adapted training protocol using START triage principles, which incorporated visually complex triage situations	• Quantitative non-randomized comparative study • Assessors: college students ($n = 18$) • Assessors prior experience with MCI: no ($n = 0$) • Victims: computer-based cases ($n = 8$)	• A short, directed triage training tool in improving the recognition of triage features was shown to be effective. • Those who underwent training only on patient transport and not on the adapted START triage protocol demonstrated no statistically significant between-session gaze measurement. • Subjects who underwent START triage training significantly improved in their first fixation entry time, indicating a faster recognition of salient triage features.
McCoy et al. (7), USA ✤	Evaluate the feasibility and effectiveness of using tele-simulation to deliver an emergency medical services course on mass-casualty incident training to healthcare providers overseas.	• Quantitative descriptive study • Assessors: healthcare providers including physicians, nurses and EMT/paramedics, pharmacists and educators/technicians ($n = 32$) • Assessors prior experience with MCI: not reported • Victims: virtual reality cases ($n =$ not reported)	• There was significant difference in accuracy of triage when comparing providers
McElroy et al. (49), USA ✤	Describe the planning and implementation process, share results, and facilitate other regions as they conduct similar preparatory drills.	• Quantitative descriptive study • Assessors: EMS ($n =$ not reported) • Assessors prior experience with MCI: not reported • Victims: paper-based cases + simulation cases ($n = 445$)	• Of the 445 transported patients, 270 (60%) were entered correctly into the state patient tracking system; 68 (25.2%) upgrades and 34 (12.6%) downgrades from scene triage categories were noted.
Mills et al. (50), Australia ✤	Compare the simulation efficacy of a bespoke virtual-reality (VR) mass-casualty incident simulation with an equivalent live simulation scenario designed for undergraduate paramedicine students.	• Mixed-methods study • Assessors: undergraduate paramedicine students ($n = 29$) • Assessors prior experience with MCI: yes ($n = 29$) • Victims: actors + virtual reality ($n = 10$)	• No significant differences were observed in accuracy in each platform. The VR simulation provided near identical simulation efficacy for paramedicine students compared to the live simulation.
Navin et al. (38), USA ✤	Evaluate the operational viability of Sacco Triage Method and to compare its performance to START.	• Quantitative non-randomized comparative study • Assessors: EMT-1 + EMT-Ps ($n =$ not reported) • Assessors prior experience with MCI: not reported • Victims: actors ($n = 20$) + mannequins ($n = 79$)	• Sacco Triage Method scoring was more accurate at 91.7% than START assessments at 71.0%. • Surveyed providers preferred START to Sacco Triage Method falsely believing it to be more accurate, faster, and better able to identify the most serious patients.

(Continued)

TABLE 1 | Continued

References and country	Aim of the study	Study design, participants (assessors and victims, at baseline)	Key findings
Risavi et al. (8), USA ✤	Assess the effectiveness of written and moulage scenarios using video instruction for mass-casualty triage by evaluating skill retention at six months post intervention.	• Quantitative non-randomized comparative study • Assessors: emergency medical technician + emergency medical technician paramedics ($n = 45$) • Assessors prior experience with MCI: not reported • Victims: actors ($n = 12$) + paper-based cases ($n = 12$)	• No significant differences between written and moulage testing results at either initial testing or at six months. • Prior skill level did not in?uence test performance on the type of testing conducted or long-term retention of triage skills. • There was a significant decrease in performance between initial and six-month testing, indicating skill decay and loss of retention of triage skills after an extended nonuse period.
Riza'I et al. (41), Indonesia ✤	Evaluate the accuracy of triage decisions made by first-year medical students after receiving two intervention methods.	• Quantitative non-randomized comparative study • Assessors: first-year medical students ($n = 54$) • Assessors prior experience with MCI: not reported • Victims: paper-based cases ($n = 10$)	• The mean of method 2 (8.03 ± 0.72) was significantly improved for correct triage compared with the mean of method 1 (6.33 ± 1.63) for 54 students ($P < 0.001$). • The under-triage rate was significantly reduced ($P < 0.001$) from method 1 (2.24 ± 1.54) to method 2 (0.94 ± 0.73). • The over-triage rate was also reduced from method 1 (1.42 ± 0.92) to method 2 (1.01 ± 0.56) ($P < 0.001$).
Sapp et al. (32), USA ✤	Evaluate the accuracy of triage decisions made by newly enrolled first-year medical students after receiving a brief educational intervention.	• Quantitative non-randomized comparative study • Assessors: first-year medical students ($n = 315$) • Assessors prior experience with MCI: no ($n = 0$) • Victims: paper-based cases ($n = 15$)	• Overall accuracy rate was 64.3%. First-year medical students who received brief START training achieved triage accuracy scores similar to those of emergency medical providers in previous studies. • The overall rate of over-triage was 17.8%, compared to an under-triage rate of 12.6% suggesting that a need exists for improving the accuracy of triage decisions in this group. • There were no significant differences in triage accuracy between subjects with and without printed materials (63.9% vs. 64.6%, $P = 0.729$) or those completing the age-variant test types (64.4% vs. 64.1%, $P = 0.889$).
Schenker et al. (44), USA ✤	Evaluate the accuracy and speed for the triage of multiple patients during a disaster drill by Emergency Medical Service personnel.	• Quantitative descriptive study • Assessors: EMS personnel ($n = 40$) • Assessors prior experience with MCI: not reported • Victims: actors (police cadets, $n = 99$) + mannequins ($n = 31$)	• Overall triage accuracy rate was 78%, exceeding data suggesting that the triage accuracy rates using different triage strategy algorithms are approximately 45% to 55%. • Contrary to expectations, the triage to transport times for the green-, yellow-, and red-tag patients were similar.
Silvestri et al. (9), USA ✤	Compare the START and SALT classifications of patients to a published reference standard category, and evaluated the accuracy of the START method applied by emergency medical services personnel in a field simulation.	• Quantitative non-randomized comparative study • Assessors: EMS personnel ($n =$ not reported) • Assessors prior experience with MCI: not reported • Victims: actors + mannequin ($n = 82$)	• SALT triage system was overall more accurate triage method than START at classifying patients, specifically in the delayed and immediate categories. • In the field exercise, paramedic use of the START methodology yielded a higher rate of under-triage compared to the SALT classification.

(Continued)

TABLE 1 | Continued

References and country	Aim of the study	Study design, participants (assessors and victims, at baseline)	Key findings
Simoes et al. (24), Brazil ✤	Analyze the quality of pre-hospital care provided by agencies in Vitória-Espirito Santo, Brazil.	• Quantitative descriptive study • Assessors: the military fire brigade (n = not reported) • Assessors prior experience with MCI: not reported • Victims: paper-based cases (n = 40)	• Overall correct accuracy rate was 92.5% using START. • Overall correct accuracy rate was 92.5% of the cases using the mnemonic method (ABCDE), in terms of Airway; 97.5%, in Breathing; 92.5%, in Circulation; 90%, in Neurological Assessment; and 50%, in the Exhibition and Control of the Environment. • The ABCDE joint analysis showed that the service was correct in 42.5% of the cases.
Wu et al. (43), Taiwan ✤	Evaluate the effectiveness of a brief training course on (START.	• Quantitative non-randomized comparative study • Assessors: physicians (n = 18) + nurses (n = 145) + EMTs (n = 23) + hospital administrators (n = 41) + volunteers (n = 64) • Assessors prior experience with MCI: yes (n = 131) • Victims: paper-based cases (n = 12)	• The trainees' scores increased significantly after the training ($P < 0.001$). • Improvement (post-test score minus pre-test score) was not significantly different among the occupational groups. • Medical (physicians, nurses, and EMTs) and non-medical groups displayed similar improvement, but post-training scores were significantly lower in the non-medical participants ($P < 0.001$). • Trainees with prior triage training had higher pre-training scores ($P < 0.05$), but no significant improvement was evident in the non-medical personnel with prior triage training. • The level of performance of triage by non-medical personnel was less than optimal (post training score = 9.32), but the ability to divide casualties into minor (green) and major (yellow and red) groups was reliable.

[D] Abstract.
[†] Master's thesis.
[F] Article.

Simulation Technologies

The technology employed in the delivery of simulations varied considerably across the literature (see **Table 3**). In a few studies, victims from MCI were re-assessed retrospectively using real mass casualty incident data (23, 34, 46) or data from a previous simulation exercise (24). In some studies, paper-based simulations were employed in which a scenario was described involving victims of a MCI and participants were asked to review and apply START (8, 26, 29, 32, 37, 41, 43, 47). Other studies employed computer-based simulations, which generally involved a multimedia-facilitated activity (28–30, 35, 36, 40, 49). Computer-based simulations varied from use of latent images to more complex software in which a series of victims of a disaster or MCI arrive to an ED or other hospital setting requiring participates to triage presenting victims *via* START. The majority of the studies required participants to partake in a live simulation exercise, of which participants are at the scene of a simulated MCI and are required to apply START to actors or manikins representing the victims (8, 9, 23, 25, 27, 28, 31, 33, 38, 42, 44, 45, 49, 50).

Within the last 6 years, studies started utilizing virtual reality, where participants usually wear a head-mounted display allowing them to have a 360° visual of images and videos (27, 33, 39, 50). Virtual reality was also used by live broadcasting a MCI scenario to participants; however, instead of wearing a head-mounted display, participants guided a person via video call (7). The guide at the scene would verbalize information needed for participants, so that they could evaluate each victim and assign them the appropriate triage category (7).

It should be noted that some of these studies applied a mixed technology approach when implementing their simulations (8, 23, 27–29, 33, 49, 50). For example, one study employed the use of unmanned aerial vehicles to allow paramedical students to survey a simulated multi-vehicular accident with live actors with moulage playing the victims (28). Other studies compared different technologies for implementing simulations such as virtual reality-based simulation vs. live simulation with actors (27, 33, 50). Two studies did not report the technology employed to perform simulation exercises (22, 48), while another study reported using moulage without specifying whether manikins or live actors were used (8).

TABLE 2 | Transparency of the studies.

References	Funding source	Conflicts of interest	Limitations	Limitations reported by authors
Arshad et al. (35)	✗	Stated	✓	• Lack of pertinent information (age, gender, years of service, training, and experience) about the comparison group. • Challenges of implementing system-wide changes to EMS protocols and training personnel. • Difficulty of prospective analyses in EMS systems.
Badiali et al. (26)	✗	Not stated	✗	Not reported.
Bolduc et al. (31)	✗	Stated	✓	• Single-center study. • Ordering of different triage modalities may have impacted triage time. • Simulation conducted differently between groups.
Buono et al. (22)	✗	Not stated	✓	• Small sample size. • Unintentionally ambiguous scenarios made triage level determination difficult.
Challen and Walter (34)	✓	Stated	✓	• There was a paucity of available documentation. • Data collection challenges since staff at the incident scenes were using their own tags as well as official supplies. • There was missing data within the medical records.
Crews (23)	✗	Not stated	✓	• Lack of previous studies. • Confinement of geographical region studied.
Curran-Sills and Franc (37)	✗	Stated	✓	• One group (nurses) were non-randomized. • Simulation was done with paper-based assessment tool, which is an oversimplification of actual triage. • It only includes adult victims.
Djalali et al. (48)	✗	Stated	✓	• Sample size from only one hospital. • Response performance indicators were limited to command and control actions.
Ellebrecht et al. (25)	✓	Stated *	✓	• Limited generalizability
Ersoy and Akpinar (47)	✗	Not stated	✓	• The scale of the decisions may not reflect the real conditions that physicians encounter in their daily practice.
Ferrandini-Price et al. (33)	✓	Stated	✓	• Both groups were not comprised by the same individuals, so that there could be a variability due to the possible individual variations • The use of *ad hoc* test preclude authors to provide data on the efficiency of the tool.
Ingrassia et al. (42)	✗	Stated	✓	• For practical reasons treatment accuracy was evaluated only in the pre-hospital phase. • Although similar, the two scenarios were not identical since there were slight differences with regard to the resources available to each group. • The evaluation of performance indicators could be observer biased. • Since it was necessary to set a time limit, it is clear that the overall evaluation of the hospital response to the simulations is potentially biased by shorter simulation time.
Ingrassia et al. (40)	✗	Stated	✓	• Apart from the theoretical knowledge acquired and the increase of mass-casualty triage skills, the students were not evaluated for an improvement in other medical disaster management competencies.
Ingrassia et al. (27)	✓	Stated *	✓	• Small sample size. • Selection bias.
Izumida et al. (39)	✗	Not stated	✗	Not reported.
Jain et al. (28)	✓	Stated	✓	• Technological challenges. • Small sample size.
Kahn et al. (46)	✓	Stated	✓	• The study methodology could not discern whether errors in assignment of triage categories resulted from failure of the triage algorithm as a tool or failure of emergency personnel to apply it correctly. • Possibly over-triage bias as researchers did observe that some of the assigned triage levels differed from what strict application of the START algorithm would have mandated. • The black, or "deceased," category was not examined.
Khan (29)	✓	Not stated	✓	• Small sample size. • Single-center study. • Using only one tool or system of triage (START).
Lee and Franc (30)	✓	Stated *	✓	• Logistical and technological challenges. • Issues during data collection.

(Continued)

References	Funding source	Conflicts of interest	Limitations	Limitations reported by authors
Lima et al. (45)	✗	Stated	✓	• Potential Hawthorne effect. • Unknown experience of participants with START prior to study. • Lack of preparation of victims to act accordingly to injuries. • Displacement of the victims from the triage area to the canvases for care during simulation. • Place of collection and the limitation of the material used in the simulation to care for the victims were not well-defined for the participants as well.
Loth et al. (36)	✗	Stated	✓	• Small sample size. • Pictures only showed one victim at a time, which isn't realistic for an MCI. • This study failed to show significance for its secondary objective of improvement in triage accuracy.
McCoy et al. (7)	✗	Stated	✓	• Voluntary enrolment in the course, thus sample may not be representative of all professions. • Not designed as an observational-analytical study so not powered to detect differences between groups. • Heterogeneous group of "other" participants.
McElroy et al. (49)	✓	Stated	✗	Not reported.
Mills et al. (50)	✗	Stated *	✓	• Small sample size of participants • Small number of patients (victims)
Navin et al. (38)	✗	Not stated	✓	• Assessment and scoring of victims were done from reading patient profile cards and not by making actual physiologic assessment. • Exercises assumed unlimited transport and treatment resources. • The use of mannequins slightly impacted the study. • The impact of the familiarity of the scene is unknown. • STM triage and resource management software was not tested.
Risavi et al. (8)	✗	Stated	✗	Not reported.
Riza'l et al. (41)	✗	Not stated	✓	• Small sample size.
Sapp et al. (32)	✗	Not stated	✓	• Lack of information of participants previous MCI training. • Limited generalizability to the general population as the study was done with medical students
Schenker et al. (44)	✗	Not stated	✗	• Not reported
Silvestri et al. (9)	✗	Not stated	✓	• Some of the volunteer victims might not have appropriately displayed their injuries on the cards they were wearing, which could account for some of the under-triage
Simoes et al. (24)	✓	Stated	✗	Not reported
Wu et al. (43)	✗	Not stated	✓	• Seniority of the participants were not taken into consideration. • The same written test was given before and after the training session, which may rise the concern of improvement comes from short-term practice but not learning.

✓Reported.
✗Not reported.
*Potential conflict of interest.

Simulation Settings

Simulation exercises conducted *via* paper, computer, and virtual-reality tended to occur in hospital or university settings (27, 29, 30, 32, 36, 37, 40, 49, 50). Live simulation exercises occurred in a variety of settings including university campuses (9, 27, 45, 49, 50), airports (25, 28, 49), emergency department (31), soccer stadium (49), fire department (38), and police academy (50). Twelve studies did not specify the location of the simulation exercises (8, 22, 26, 33, 35, 39, 41–44, 47, 48).

Disaster Types

MCI simulations across the included studies were most frequently based on transportation disasters on land (i.e., motor vehicle crashes, $n = 10$) (23, 24, 27, 28, 35, 40, 45–47, 50),

followed by bomb threats/terrorist attacks ($n = 5$) (7, 9, 23, 34, 49). The remaining studies used a variety of MCI events including chemical explosion (9, 23, 44, 48), bomb threats/terrorist attack with chemical explosion (9), toxic release (31, 32), transportation disaster on air (23, 25), transportation disaster on land with chemical spill (31), and structural collapse (38, 42). Eleven studies did not report on the types of MCI they were simulating (8, 22, 26, 29, 30, 33, 36, 37, 39, 41, 43).

The sources of the simulation scenarios varied with some studies using real events with actual clinical characteristics of the victims (23, 24, 28, 34, 46). Study researchers (9, 42, 45, 47, 50) and healthcare professionals (32, 33, 44) created the MCI events and victims, while in other studies the MCI event was retrieved from third-party databases (26, 27, 30, 37, 49), which include

TABLE 3 | Typology of simulations.

References	Type of disaster	Simulation technology	Setting of MCI enactment and/or physical location assessors	MCI/disaster data source
Arshad et al. (35)	• Land disaster (motor vehicle accidents)	• Computer-based (victims description)	• Unclear	Unclear
Badiali et al. (26)	• Unclear	• Paper-based (victims description)	• Unclear	Derived from a web-based platform, which clear defines how the cases were created
Bolduc et al. (31)	• Land disaster (train derailment) • Toxic release (chemical spill)	• Live simulation (actors)	• Emergency Department	Unclear
Buono et al. (22)	• Unclear	• Unclear	• Unclear	Unclear
Challen and Walter (34)	• Bomb threats/terrorist attack (shooting)	• Retrospective analysis of real mass casualty incident	• Not applicable: retrospective analysis	Medical records
Crews (23)	• Bomb threats/terrorist attack (shooting) • Land disaster (motor vehicle accidents) • Explosions (chemical explosion) • Air disaster (airplane accident)	• Retrospective analysis of real mass casualty incident • Live simulation (actors)	• Not applicable: retrospective analysis	Real MCI
Curran-Sills and Franc (37)	• Unclear	• Paper-based (victims description)	• Emergency Department	Derived from a web-based platform (www.disastermed.ca) but unclear how MCIs scenarios were created and validated
Djalali et al. (48)	• Explosions (chemical explosion)	• Unclear	• Hospital	Unclear
Ellebrecht et al. (25)	• Air disaster (airplane collision)	• Live simulation (actors)	• Airport	Unclear
Ersoy et al. (47)	• Land disaster (motor vehicle accidents)	• Paper-based (questionnaire with a MCI scenario)	• Unclear	Borrowed from another study, which was created by the study researchers
Ferrandini-Price et al. (33)	• Unclear	• Virtual reality (head mounted display) • Live simulation (actors)	• Unclear	Created by healthcare professionals
Ingrassia et al. (42)	• Structural collapse (ceiling collapse)	• Live simulation (actors)	• Unclear	Created by researchers
Ingrassia et al. (40)	• Land disaster (motor vehicle accidents)	Computer-based (electronic simulation designed using Adobe Flash)	• University campus	Unclear
Ingrassia et al. (27)	• Land disaster (motor vehicle accidents)	• Virtual reality (joystick) • Live simulation (actors)	• University campus	Derived from a web-based platform (VictimBase) but unclear how MCIs scenarios were created and validated
Izumida et al. (39)	• Unclear	• Virtual reality (head mounted display)	• Unclear	Unclear
Jain et al. (28)	• Land disaster (motor vehicle accidents)	• Live simulation (actors) • Computer-based (unmanned aerial vehicle)	• Airport runway	Real MCI
Kahn et al. (46)	• Land disaster (motor vehicle accidents)	• Retrospective analysis of real mass casualty incident	• Not applicable: retrospective analysis	Medical records
Khan (29)	• Unclear	• Paper-based (details not reported) • Computer-based (details not reported)	• Emergency Department	Unclear
Lee and Franc (30)	• Unclear	• Computer-based (SurgeSim)	• Emergency Department	Derived from a web-based platform (SurgeSim version 2.2.0) but unclear how MCIs scenarios were created and validated
Lima et al. (45)	• Land disaster (motor vehicle accidents)	• Live simulation (actors)	• University campus	Created by researchers
Loth et al. (36)	• Unclear	• Computer-based (latent images)	• University campus	Unclear

(Continued)

References	Type of disaster	Simulation technology	Setting of MCI enactment and/or physical location assessors	MCI/disaster data source
McCoy et al. (7)	• Bomb threats/terrorist attack (shooting)	• Virtual reality (broadcasting)	• High-rise office building	Unclear
McElroy et al. (48)	• Bomb threats/terrorist attack (terrorist attack)	• Computer-based (details not reported) • Live simulation (actors)	• University campus, soccer stadium and airport	Created by a private firm, but unclear how scenarios were created and validated
Mills et al. (50)	• Land disaster (motor vehicle accidents)	• Virtual reality (actors) • Live simulation (head mounted display)	• Virtual reality: Police academy's ground • Live simulation: University campus	Created by researchers
Navin et al. (38)	• Structural collapse (building collapse)	• Live simulation (actors and mannequins)	• Fire Department academy	Unclear
Risavi et al. (8)	• Unclear	• Paper-based • Moulage	• Unclear	Unclear
Riza'l et al. (41)	• Unclear	• Paper-based (details not reported)	• Unclear	Unclear
Sapp et al. (32)	• Toxic release (sarin gas)	• Paper-based (questionnaire with a clinical scenario)	• University campus	Created by healthcare professionals
Schenker et al. (44)	• Explosions (chemical explosion)	• Live simulation • Mannequins	• Unclear	Created by healthcare professionals
Silvestri et al. (9)	• Explosions (chemical explosion) • Bomb threats/terrorist attack (shooting)	• Live simulation (actors and mannequins)	• University campus	Created by researchers
Simoes et al. (24)	• Land disaster (motor vehicle accidents)	• Retrospective analysis of a simulation exercise	• Unclear	Medical records
Wu et al. (43)	• Unclear	• Paper-based (details not reported)	• Unclear	Unclear

various MCI scenarios from which researchers can choose. The source of the MCI event, as well as the characteristics of the victims, was not reported in 14 of the included studies, and so it was not clear how the MCI scenarios were created and validated (7, 8, 22, 25, 29, 31, 35, 36, 38–41, 43, 48).

Assessors

Studies employed a variety of medical professionals to assess the classification accuracy of START across the literature (see **Table 1**). First responders/paramedics were most commonly recruited to participate in studies requiring to apply START (8, 9, 22, 23, 25, 31, 38, 44, 46, 49), with two studies specifically recruiting firefighters (24, 35). Students of various professions, including a variety of college-level (36, 39), medical (27, 32, 40, 41), nursing (45), and paramedic students (28, 50) were the second most common participants recruited to apply START. Other professionals including nurses and physicians were also recruited; however, studies tended to assess the ability of a mix of health professionals to accurately apply START (7, 29–31, 37, 42, 43, 47). Few studies compared the differences in the accuracy of START among different healthcare professionals (7, 25).

Experience and Training in Disaster Medicine and START

Seven studies specifically reported participants had previous experience with the START system (9, 30, 35, 37, 38, 44, 46) and

11 studies specified whether or not participants had any prior experience with MCI (27, 30, 32, 36, 37, 39, 40, 42, 43, 47, 50). Seven of the 21 studies that did not report participants' prior MCI experience also did not involve any MCI education intervention or reported whether participants were trained in MCI triage for the specific study (22–24, 34, 35, 48, 49).

Of the 22 studies that offered training in MCI prior to the simulation, 14 studies included training on START (7, 8, 25–28, 32, 36, 38, 39, 41, 43, 45, 47). Training included lecture (27, 28, 32), courses (7, 41), provision of reading materials (39) symposium (45), video presentation (8). Six studies did not specify how training was provided (25, 26, 36, 38, 43, 47). Among the 16 studies that reported to offering lectures/courses, the majority of studies reported to implementing a single course/session lasting between 5 and 1,200 mins (median: 60 min; IQR = 110 min).

Theme 2: START System in MCIs Simulations

This theme explores how the classification accuracy of START triage system was assessed across the different studies (see **Table 4**).

Diagnostic Properties

A summary of the various diagnostic outcomes assessed across the studies are provided in **Table 4**. As per the inclusion criteria,

TABLE 4 | Assessment of accuracy outcomes.

References	Reported outcomes	Reported points	Reference standard
Arshad et al. (35)	• Accuracy (total and all sub-groups) • Over-triage (total and all sub-groups) • Under-triage (total and all sub-groups)	• START • Modified START	Not reported
Badiali et al. (26)	• Accuracy (total and all sub-groups) • Over-triage (total and black sub-group) • Under-triage (total and black sub-group)	• Non-START training • START last minute training	Not reported
Bolduc et al. (31)	• Accuracy (total and all sub-groups)	• START manual • START electronic	Expert opinion
Buono et al. (22)	• Accuracy (total)	• START (WIISARD*-PDA**) • START (WIISARD*-iTag***) • START (Control****)	Expert opinion
Challen and Walter (34)	• Sensitivity (subgroup red, subgroup red + yellow) • Specificity (subgroup red, subgroup red + yellow)	• START • Manchester Sieve • CareFlight triage	Outcomes regard sensitivity and specificity. Baxt and Upeniek criticality
Crews (23)	• Accuracy (total) • Over-triage (total) • Under-triage (total)	• START and the total population, year 2016 • START and the total population, year 2017 • START and the total population, year 2018	Expert opinion
Curran-Sills and Franc (37)	• Accuracy (total) • Over-triage (total) • Under-triage (total)	• START • CTAS	Expert opinion
Djalali et al. (48)	• Accuracy (subgroup green, and subgroup yellow)	• START	Not reported
Ellebrecht et al. (25)	• Accuracy (total, and all subgroups with exception of black) • Over-triage (total, subgroup yellow, and subgroup green) • Under-triage (total, subgroup red, and subgroup yellow)	• START	Not reported
Ersoy et al. (47)	• Accuracy (total and all sub-groups) • Over-triage (total and all sub-groups) • Under-triage (total and all sub-groups)	• START	Not reported
Ferrandini-Price et al. (33)	• Accuracy (total)	• START with clinical simulation with actors • START with virtual reality • START with both clinical simulation with actors group and virtual reality	Expert opinion
Ingrassia et al. (42)	• Accuracy (total and all sub-groups) • Over triage (green sub-group, yellow sub-group, and black sub-group) • Under triage (green sub-group, yellow sub-group, and red sub-group)	• START with virtual reality on day 1 • START with virtual reality on day 3 • START with live simulation on day 1 • START with live simulation on day 3	Expert opinion
Ingrassia et al. (40)	• Accuracy (total)	• START before learning module (pre-test) • START after learning module (post-test)	Not reported
Ingrassia et al. (27)	• Accuracy (total and all sub-groups)*	• START with disaster medicine training in the in pre-hospital setting	Not reported

(Continued)

TABLE 4 | Continued

References	Reported outcomes	Reported points	Reference standard
	• Over-triage (total and all sub-groups with the exception of red ED trained subgroup, red pre-hospital non-trained subgroup)*	• START without previous training in medical disaster management in pre-hospital settings	
	• Under-triage (total and all sub-groups with the exception of green trained and non-trained subgroup, and trained yellow subgroup)*	• START with disaster medicine training in the emergency department	
	*Accuracy, over- and under-triage of black group and subgroups were not reported, with exception of accuracy of prehospital trained.	• START without previous training in medical disaster management in the emergency department	
Izumida et al. (39)	• Accuracy (total)	• START with a novel training system	Not reported
		• START with a training system in which difficulty does not change dynamically	
Jain et al. (28)	• Accuracy (total)	• START with an unmanned aerial vehicle drone	Not reported
		• START with live simulation	
Kahn et al. (46)	• Sensitivity (green, yellow, and red subgroups)	• START	Other triage guideline
	• Specificity (green, yellow, and red subgroups)		
	• Positive predictive value (green, yellow, and red subgroups)		
	• Negative predictive value (green, yellow, and red subgroups)		
	• Positive likelihood (green, yellow, and red subgroups)		
	• Negative likelihood (green, yellow, and red subgroups)		
	• Accuracy (total)		
	• Over-triage (total)		
	• Under-triage (total)		
Khan (29)	• Accuracy (total)	• START intervention group	Not reported
	• Over-triage (total)	• START control group	
	• Under-triage (total)		
Lee and Franc (30)	• Accuracy (total and all sub-groups, with exception of black)	• START (one-step triage)	Expert opinion
	• Over-triage (total and all subgroups, with the exception of two-steps red sub-group, and one- and two-step black sub-groups)	• START and CTAS (two-step triage)	
	• Under-triage (total and all subgroups, with the exception of two-steps red sub-group, and one- and two-step black sub-groups)		
	• Under-triage (red classified as black)		
	• Under-triage (red classified as yellow)		
Lima et al. (45)	• Accuracy (total)	• START	Not reported
Loth et al. (36)	• Accuracy (total)	• START with training in triage before training	Not reported
		• START with training in triage after training	
		• START with training in transportation before training	

(Continued)

TABLE 4 | Continued

References	Reported outcomes	Reported points	Reference standard
McCoy et al. (7)	• Accuracy (total)	• START with training in transportation after training • START use by educator/technician/other • START use by EMT/paramedics • START use by nurses • START use by pharmacists • START use by physicians	Not reported
McElroy et al. (49)	• Accuracy (total) • Over-triage (total) • Under-triage (total)	• START	Not reported
Mills et al. (50)	• Accuracy (total)	• START using virtual reality • START using live simulation	Not reported
Navin et al. (38)	• Accuracy (total) • Over-triage (total) • Under-triage (total)	• START • Sacco Triage Method	Not reported
Risavi et al. (8)	• Accuracy (sub-groups green, yellow, and red) • Accuracy for moulage (mean number of patients triaged correctly) at 6 months (total) • Accuracy for written scenario (mean number of patients triaged correctly) at baseline (total) • Accuracy for written scenario (mean number of patients triaged correctly) at 6 months (total) • Accuracy for moulage (mean number of patients triaged correctly) at baseline (total) • Over-triage (sub-groups green, yellow, and red) • Under-triage (sub-groups green, yellow, and red)	• START with written triage first • START with moulage triage first • START with written triage second • START with moulage triage second • START with moulage at baseline • START with moulage at 6 months • START with written scenario at baseline • START with written scenario at 6 months	Not reported
Riza'I et al. (41)	• Accuracy (total) • Over-triage (total) • Under-triage (total)	• START with lecture method • START with simulation method	Not reported
Sapp et al. (32)	• Accuracy (total) • Over-triage (total) • Under-triage (total)	• START performed by students from year of 2008 • START performed by students from year of 2009 • START performed by students from year of 2008 and 2009	Expert opinion
Schenker et al. (44)	• Accuracy (total and all sub-groups, with exception of total black and first responding ambulance subgroup black) • Over-triage (total and sub-groups) • Under-triage (total and sub-groups)	• START performed on victims exiting triage area • START performed by first responding ambulance • Sum of START performed on victims exiting triage area and by first responding ambulance (?)	Not reported
Silvestri et al. (9)	• Over-triage (total) • Under-triage (total)	• START • SALT	Expert opinion

(Continued)

TABLE 4 | Continued

References	Reported outcomes	Reported points	Reference standard
Simoes et al. (24)	• Accuracy (total) • Over-triage (total) • Under-triage (total)	• START	Not reported
Wu et al. (43)	• Accuracy (total)	• START performed by medical staff before training • START performed by medical staff after training • START performed by medical staff with no prior training before training • START performed by medical staff with no prior training after training • START performed by medical staff with prior training before training • START performed by medical staff with prior training after training • START performed by individuals with no prior training before training • START performed by individuals with no prior training after training • START performed by non-medical with no prior training before training • START performed by non-medical with no prior training after training • START performed by non-medical with prior training before training • START performed by non-medical with prior training after training • START performed by participants with prior training before training • START performed by participants with prior training after training	Not reported

*Wireless Internet Information System for Medical Response in Disasters.
**Personal digital assistant.
***Electronic triage tag.
****Traditional paper technology.

all of the studies reported at least one outcome related to the classification accuracy of START. All but two studies (34, 46) assessed the accuracy of START by comparing participants' performance (correctly matching of triage levels to a reference standard).

With the exception of two studies (9, 48), all studies measuring classification accuracy of participants performance reported the overall accuracy for all victims. In addition, some studies also reported the accuracy of participants' performance based on the triage subgroups of START (i.e., black, red, yellow, and green) (8, 25, 26, 30, 31, 35, 42, 44, 47, 48). Still within accuracy of participants performance, some studies teased out the proportion of patients over and under-triaged within the START triage subgroups (8, 9, 23–27, 29, 30, 32, 35, 37, 38, 41, 42, 44, 46, 47, 49). Only two studies reported on outcomes related to START diagnostic properties, such as specificity, sensitivity, positive and negative predictive values, or likelihood ratios (34, 46).

Lastly, the vast majority of included studies ($n = 22$) did not specify which prerequisite they used to measure classification

accuracy (i.e., a reference standard). When specified, the reference standard was most commonly described as expert opinions (9, 22, 23, 30–33, 37, 42) followed by the Baxt and Upeniek criticality (34), and the modified Baxt criteria (46). From the nine studies using experts' opinions as the reference standard, five studies did not specify the background of the experts or how this consensus was determined (22, 23, 30, 31, 33).

DISCUSSION

Given the widespread use of START for the triage of victims in real-world MCI's, training simulations, as well as assessing educational interventions, this scoping review aimed at exploring and summarizing the existing literature related to the current state of knowledge regarding studies assessing the classification accuracy of START. Gaining a better understanding of the literature helped us to identify gaps in reporting that may hold implications for future studies. Through an extensive and systematic search of the literature, 32 studies assessing the

classification accuracy of START were identified. These studies were conducted around the world, with the majority of the studies published in the last 10 years, indicating that knowledge about simulation strategies using START for triage is a global concern and growing field of research.

Over the years, the methods used for simulations has changed as technological advancements occurred. For example, computer simulations replaced the early text-based paper exercises, and live simulations with actors have more recently been replaced by virtual reality technology. Studies included in our review employed different types of simulation technologies and, despite technological advancements, some of the most recently published studies employed technologies ranging from basic text-based exercises to the more advanced ones. This may be attributable to the high cost of using more advanced technologies during simulations, and the paucity of funding opportunities for disaster research within the research ecosystem. Although simulation can be effective at preparing individuals and systems to effectively deal with MCIs, it comes at a price. Different types of simulation technologies have different costs aggregated to them including training, equipment and systems, technicians, laboratory setup, maintenance and so on. In fact, the elevated costs of many simulation technologies has been a key criticism of medical training using simulation (51, 52). Therefore, it is reasonable that researchers developing MCI studies using simulation consider their population needs, available resources and return on investment to determine which type of technology they will study and adopt.

Other common themes arose when reviewing the articles, one of which was the reporting and implementation of the simulation. For the most part, studies provided satisfactory details regarding how the simulation exercises were conducted; however, the establishment of more systematic reporting is warranted. As discussed below, many studies lacked information that should be included in articles involving MCI simulation for them to be transparent, reproducible, and usable (53–55).

This review found that some important details regarding the methodologies of the studies and classification accuracy assessment were inconsistently reported across the literature. Approximately a third of the studies assessing the classification accuracy of START failed to report the type of MCI from which the victims were being triaged. Almost half of the studies did not specify the source of disaster scenarios—whether or not the MCI was based on a real event or created by the research staff, healthcare professionals, or disaster medicine experts. In many studies using live simulation, it was unclear if the mock victims had previous training on how to simulate clinical conditions or how these mock victims were prepared (e.g., use of make-up). At this time, it unclear whether the complexity of the disaster or MCI affects the classification accuracy of disaster triage, but this might be worth exploring in future studies.

Another common theme explored in this study was the reporting regarding the assessors of START and their experiences. It was not surprising that the majority of studies assessed the classification accuracy of paramedic/EMS providers to apply START; however, it was perhaps a little surprising that students (including paramedical, nursing, and medical) were the second most common assessors of START across the literature. It is not clear why this is the case. It could be that studies assessing novel technologies for simulations or triage methods may see students as a population of participants more available, willing and able to embrace novel technologies. In addition, students are more likely to lack any prior experience in disaster triage or START, allowing researchers to assess the impact of training or educational interventions on START classification accuracy.

A fundamental methodological bias associated with this literature is a lack of transparency which impacts the trustworthiness of the science. More than a third of the studies did not state if there was any potential conflict of interest. Over two-thirds did not state if there was any funding source. In addition, several studies did not acknowledge any limitations to the study, and the ones acknowledging them overlooked or reduced to simplistic and minimally relevant themes (e.g., single institution study or small sample size) (56). With respect to the assessment of the classification accuracy of START, while the majority of the studies reported overall accuracy, a third of them did not report under- and over- triage. It is vital for studies assessing triage accuracy to provide a full assessment of the classification accuracy of START. Beneficial triage decisions direct victims to the most appropriate hospitals, resulting in lower mortality and better resource allocation (57).

Yet, one of the most concerning issues we found in this review exploring the current state of knowledge of studies assessing the classification accuracy of the START system was that two-thirds of the studies completely lacked details regarding the reference standard to which START was being compared. When a reference standard was reported, the most common was expert opinion, although details regarding the credentials of the experts were not provided. The traditional classification accuracy paradigm is based on studies that compare the results of the system under evaluation (index system) with the results of a reference standard, and it is regarded as the soundest method to determine the classification accuracy of the system or measure participants' performance. To appraise the classification accuracy of the index test, its results are compared with the results of the reference standard; subsequently indicators of accuracy can be determined. The reference standard is therefore an important determinant of the classification accuracy. From a theoretical perspective the use of an appropriate reference standard is critical and the lack of information regarding it impacts the confidence readers have in research findings.

Strengths and Limitations

We aimed at using precise and transparent review methods when conducting (16, 17) and reporting this scoping review (18). A comprehensive approach using several appropriate databases without language restrictions improved the rigor of the review. Consistent with the purpose of a scoping review, we expanded the literature search from January 1983 until March 2020, so that more literature sources could be identified, and findings could truly reflect the state of knowledge. The search words were selected by the researchers and refined by an expert health librarian. In addition,

the reference lists of the included articles were forward searched. To reduce the risk of selection bias, this review utilized two independent reviewers to assess and identify potential eligible studies. Lastly, the use of Refworks and Covidence software supported meticulous documentation of screening decisions.

There were, however, some limitations of this scoping review. First, since this review did not pursue quality appraisal, we were not able to speak of the quality of the studies in the field assessing the classification accuracy of START, which could have resulted in inclusion of studies with comprised research quality and incomplete synthesis. Therefore, it is recommended that the findings should be used with caution and applied in research and practice after careful scrutiny. Second, 87.5% ($n = 28$) of the reviewed studies originated from developed countries which limits the extrapolation of findings to low- and middle-income countries. Third, the results of this scoping review may have been impacted by selective reporting within the included studies. While contacting the study authors could have helped clarify aspects of the simulation, triage assessment, or accuracy outcomes that were unclear or not reported, the objective of this review was to provide an assessment of studies assessing START accuracy based on what is reported in the available literature. Lastly, as with any review, there is a risk of publication bias, particularly among studies assessing the impact of novel interventions on triage classification accuracy.

CONCLUSION

Studies included in this scoping review provided satisfactory details on how their simulations were conducted. However, we found there is room for improvement in view of insufficient information regarding location where simulation exercises were performed, the type of disaster they were simulating, the source of the MCI event, the characteristics of the victims, whether or not participants had any prior experience with MCI triage, and potential source of bias. To further improve simulation-based assessment of triage systems, it is important that stakeholders are mindful of the complexity of subsystem interactions. It is recommended that if simulations are used for assessment purposes, they should be based in a systematic appreciation of the whole system. Future research could be more explicit about the knowledge upon which simulation training is based to allow for description of core theoretical and operational definitions, identification of the function of each component, promotion of similar construct measurement, reporting of findings in a common language, as well as replication and comparison of findings across studies. We recommend the use of reporting guidelines such as the "reporting guidelines for health care simulation research: extensions to the CONSORT and STROBE statements" (11). In particular, incomplete reporting of the reference standards and accuracy needs to be addressed and reported in future studies.

We recommend the development of a systematic review with meta-synthesis to assess overall accuracy, rate of under-triage, and rate of over-triage using the START method, as well as to obtain specific rates of accuracy for each of the four START categories: red, yellow, green, and black. A systematic review with meta-synthesis will allow the combination of results ensuring reliability across a number of studies, while assessing and minimizing bias. As a result, reliable and scientifically derived findings can be obtained for research and clinical practice.

DATA AVAILABILITY STATEMENT

The original contributions presented in the study are included in the article/**Supplementary Material**, further inquiries can be directed to the corresponding author.

AUTHOR CONTRIBUTIONS

UDW: research conceptualization, design of the research methodology, data curation, evidence screening, data extraction, data analysis, project administration, writing and editing the research protocol, and writing and editing the final manuscript. SWK: research conceptualization, design of the research methodology, data curation, evidence screening, data extraction, project administration, writing and editing the research protocol, and writing and editing the final manuscript. BHR: research conceptualization, design of the research methodology, funding acquisition, research supervision, writing and editing the research protocol, and writing and editing the final manuscript. SC: design of the research methodology and writing and editing the final manuscript. JMF: research conceptualization, design of the research methodology, funding acquisition, data analysis, writing and editing the research protocol, and writing and editing the final manuscript. All authors contributed to the article and approved the submitted version.

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New Life Through Disaster: A Thematic Analysis of Women's Experiences of Pregnancy and the 2016 Fort McMurray Wildfire

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Background: On May 3, 2016, residents of Fort McMurray Wood Buffalo, Alberta were evacuated due to an uncontrolled wildfire. The short-notice evacuation had destabilizing consequences for residents, including changes in routines, loss of control, and increased uncertainty. These consequences were especially detrimental to women who were pregnant or pre-conception during the evacuation. Pregnant and pre-conception women are particularly susceptible to a vast range of negative consequences during and post natural disasters, including elevated stress and higher incidence of pregnancy complications including gestational diabetes mellitus, pregnancy induced hypertension and C-section. The aim of this study was to understand the experiences, perceived stress and resilience of women who were pregnant during the wildfire. As well as to explore potential interventions to promote the health and enhance resilience of pregnant women and to assist in recovery after exposure to a natural disaster or other traumatic events.

Methods: A qualitative thematic analysis of 16 narratives penned by pregnant women and recounted in Ashley Tobin's compilations 93/88,000 and 159 More/ 88,000: Stories of Evacuation, Re-Entry and the In-Between was conducted.

Results: Analysis revealed five key themes: (1) experience of stress responses due to personal and external factors, (2) social connectedness and support as a facilitator of resilience, (3) performance of resilience-enhancing activities, (4) the roles of pregnancy and motherhood in the experiences of loss and resilience, and (5) the importance of home.

Conclusion: Pregnant women have unique barriers that may negatively impact them during a natural disaster or other form of stressful event. They may benefit from assistance with navigating role transition during pregnancy, training in stress management strategies, and writing interventions to build resiliency and begin the process of recovery from trauma.

Keywords: stress, resilience, pregnancy, natural disasters, factors of resilience

INTRODUCTION

An unrelenting, unpredictable wildfire engulfed Fort McMurray Wood Buffalo (FMWB), Alberta in 2016, prompting the short-notice city-wide evacuation of approximately 88,000 people (1). Beginning on May 1, 2016, the fire remained uncontrolled until July 5, 2016, and burned nearly 570,000 hectares of land. An estimated $6 billion in commercial and personal damages resulted due to the destruction of approximately 2,400 homes and businesses (2). Residents in specific areas were able to return to their homes in June 2016, while others who lost their homes were unable to return until the spring of 2017.

The economic impact on the community was not the only destabilizing consequence residents of FMWB experienced. Residents received little warning in advance of the wide-scale evacuation, which resulted in significant disruption of routines, loss of control, and increased uncertainty, potentially increasing stress and anxiety (3). Despite the disruption, affected individuals must find a way to continue moving forward. In 2016, 55,595 babies were born in Alberta. While it is unknown how many of these women and infants were impacted by the FMWB wildfire specifically, pregnant women experiencing disasters are in a unique position, as unexpected traumas can impact their developing fetus (4).

Impacts of Disaster Exposure to Individuals

The outcomes of disaster exposure are immensely complex and may take months or years to conclude (5). Individuals exposed to disasters may experience increased observable stressors and develop subjective beliefs regarding cause and effects of the event (5). Research into impacts of natural disaster exposure consistently indicates increased disturbances in social and psychological well-being, frequently influenced by an individual's coping styles in response to stressful events (6). Women and children exposed to natural disasters experience increased stressors and a vast range of negative consequences including mental health concerns such as post-traumatic stress disorder (PTSD) (7–9).

Specific to FMWB, research by Moosavi and colleagues (10) found increased rates of probable PTSD, depression and anxiety as compared to self-reported prevalence prior to the wildfire in Fort McMurray Primary Care patients. Brown et al. (11) indicated similar increases in mental health concerns, with nearly half of student study participants meeting criteria for one or more probable diagnoses including depression, anxiety, PTSD or alcohol/substance abuse.

Natural disasters can disrupt an individual's occupational performance and ability to perform daily activities within their environment. Experiencing a natural disaster during pregnancy adds a layer of complexity. An environmental event may upset a pregnant woman's routines, roles, and occupations during a very significant and meaningful time. Additional barriers, such as limits to mobility in pregnancy, may enhance the challenges caused by an environmental event. As stress due to unexpected trauma during pregnancy can have long-term impacts that can compound across generations (4), reducing these negative consequences is of critical importance. When combined with the vulnerability of exposure to a natural disaster, the intersection between pregnancy and trauma creates a form of double jeopardization (12). As such, pregnant women who experience a natural disaster represent a vulnerable population, highlighting the importance of understanding women's experiences of pregnancy during traumatic events. Knowledge about how the women experienced stress and pregnancy throughout wildfire and evacuation can inform interventions to support women who have experienced trauma during pregnancy, as well as pregnant women who may experience a future traumatic event.

Prenatal Experience

While pregnancy and childbirth are incredibly significant, personal, and spiritual experiences (13), they cause changes in one's body, mind, relationships and routines and are associated with risks to a woman's physical, mental, and emotional well-being. Physical risks and complications include anemia, gestational diabetes mellitus, and hypertension (14). Mental health challenges can also arise. These health risks can impact the developing fetus, with the average rate of fetal deaths per 1,000 total births ranging from 7.5 to 8.1 in 2005–2014 (15). Preterm births during this same period were reported to occur in approximately 8 percent of live births, and very early births (prior to week 32) were found to make up 1.2 per 100 live births.

In addition to changes in physical appearance, women may also experience changes in their identity, roles and occupations (16), especially during their first pregnancy (17). Changes in relationships may also occur as a new understanding of self and the roles of others are developed (18). Pregnancy may facilitate greater intimacy in significant relationships or become a source of tension. Roles, occupations, and environments are important during pregnancy and are significant to understanding women's experiences of a natural disaster and their subsequent loss and grief. Pregnancy represents a transitional period (19), despite the continuation of daily routines and occupations (13). Engaging in normal routines and occupations, however, may become challenging during pregnancy and the post-partum period (19), with mobility and sleep becoming challenging. Experiencing a natural disaster during pregnancy can further alter an individual's occupational performance and their ability to perform daily activities. In addition to the changes in occupation that women experience during pregnancy, they also take on new occupations specific to pregnancy and birth, including preparing for delivery, transitioning to family expansion, and caring for the baby (19, 20).

Prenatal Maternal Stress and Child Development

Experiencing stress during pregnancy increases the risk of long-term effects to both mother and child (21–24). Research further indicates that parental trauma can be transmitted to offspring, with outcomes dependent on a complex interplay of biological, familial, and cultural systems (25). Pregnancy outcomes of women who experienced Hurricane Katrina showed a correlation between elevated stress and higher incidence of pregnancy complications including gestational diabetes mellitus, pregnancy

induced hypertension and C-section (26). Stress responses such as loss of sleep or appetite, which may affect maternal health, can also be attributed to environmental events (27).

Objective prenatal maternal stress (PNMS) can affect the development of the baby *in utero* and have negative impacts on birth weight (24, 27). In an Australian study on birth outcomes following a bush fire, O'Donnell and Behie (22) found an increase in preterm births and babies born with low birth weight in comparison to previous years. PNMS has also been shown to impact childhood development. Research on the impacts of PNMS experienced by pregnant women during a flood was found to be negatively correlated with infant problem solving and personal-social skills at 6 months of age (23). Project Ice Storm (28), a research initiative following the Quebec ice storms of 1998, examined the long-term implications of prenatal exposure to a natural disaster on childhood development. PNMS was found to be related to decreased bilateral coordination and visual motor integration in children at five and a half years of age (21).

The impacts of maternal stress may be influenced by how the stress is perceived. Several studies have explored this relationship through examining the impacts of objective or subjective stress on both parent and child. Research by Cao et al. (21) found high maternal subjective distress was associated with greater negative impacts on motor function in children. Conversely, low subjective distress showed significant harmful effects when stress was high (21). Simcock et al. (23) found that objective maternal stress measures were more predictive of decreased problem-solving skills in infants at 6 months.

Based on research with rats, Yao et al. (4) suggested that experiencing a stressor, including exposure to natural disaster during pregnancy, may be predictive of chronic disease in later life. This study also found that prenatal stress compounded across generations and was a determinant in future maternal health (4). As stress due to unexpected trauma during pregnancy can have long-term impacts that compound across generations (4), reducing these negative consequences is of critical importance. Exposure to a natural disaster *in-utero* may affect infant and childhood development, create long-lasting impacts on well-being, and impact future maternal health of infant girls. Understanding the experience of coping with stress during pregnancy throughout the wildfire and evacuation can inform interventions to support women who have experienced trauma during pregnancy, as well as pregnant women who may experience a future traumatic event. These findings substantiate the importance of further research in this field.

Potential Intervention

Given the potential long-term physical and mental health outcomes trauma survivors and their offspring may encounter (25), it is imperative that potential interventions be explored. Chen et al. (6) found that elements of emotion-focused coping, including positive reframing, acceptance, and emotional support were protective factors, reducing the subjective distress for pregnant women in flood-related natural disasters. Writing interventions provide an adaptive method for navigating life transitions and coping with traumatic and stressful events and can portray features of emotion-focused coping throughout

narratives (29, 30). A meta-analysis on writing therapy found writing to be an evidence-based and efficient intervention for individuals experiencing post-traumatic stress (31). Horsch et al. (32) found that an expressive writing intervention was linked with decreased symptoms of depression and PTSD in mothers of preterm infants. Writing is efficient as it is cost-effective and does not require as much therapy time as other interventions (31, 32). Studies have demonstrated that the task of writing is an effective intervention during times of stress. In a meta-analysis on writing therapies, van Emmerik et al. (31) indicated writing was an efficient and evidence-based intervention for populations experiencing post-traumatic stress, with decreased symptoms of post-traumatic stress and depression resulting. At times expressive writing is an intervention prescribed for persons experiencing times of stress and at other times, they spontaneously take up writing as a way of recording their thoughts and feelings in the moment.

OBJECTIVE

This study sought to understand the experiences of women who were pregnant during or shortly following the Fort McMurray wildfire, particularly the perceived stress and resilience they experienced during the wildfire, evacuation and re-entry. This knowledge may help inform future interventions to enhance resilience, promote health, support post-traumatic growth and reduce the harmful effects of natural disasters and other traumatic stressors.

METHODS

A qualitative secondary analysis of expressive writing using thematic analysis was conducted examining narratives written by 16 women who were pregnant during the 2016 FMWB wildfire. The narratives were captured in two books compiled by Ashley Tobin – 93/88,000 (33) and 159 More/ 88,000: Stories of Evacuation, Re-Entry and the In-Between (34). Convenience sampling was utilized by the author to obtain the written entries. Thematic analysis (deductive and inductive) was conducted using methods adapted by Braun and Clarke (35). Graduate-level researchers transcribed the excerpts into NVivo 12. Data was coded and themes identified. All data was coded twice to increase consistency in the process and discrepancies were resolved through discussion. Emerging themes and patterns were analyzed, consolidated and refined and supporting quotes isolated.

RESULTS

Based on the analysis of the women's narrated experiences of pregnancy during the evacuation, five key themes emerged: (1) experience of stress responses due to personal and external factors, (2) social connectedness and support as a facilitator of resilience, (3) performance of resilience-enhancing activities, (4) the roles of pregnancy and motherhood in the experiences of loss and resilience, and (5) the importance of home. Further

Themes	Findings and supporting quotations
1.1 Stress Responses were unique to the individual, but a shared experience.	Experiencing significant emotional responses.
	"The fire is all around us. It's like we were watching a movie or were stuck in a nightmare. It's like our whole world is falling down on us. We can feel the heat from the fire at our house and ash is falling from the sky. We're all in shock and can't move."
	"They told me to head to [company], and I would be able to at least get an EMT… to assist me. I just started to cry… in total disbelief of what was happening. It seemed unreal."
	"Being under mandatory evacuation meant to me that I had to pack my stuff and get the hell out of there. I closed the windows, turned off the fans and AC, and grabbed the weirdest mix of stuff ever in my bag. I dumped the contents of our safe into my suitcase, the oddest mix of clothes with no underwear or socks, my secret cash stash, some water, a knitting project, a flask of water, and my husband's birthday presents."
	"As we started to get closer to town, it hit me. This is real life. My sister-in-law called back and said, "Don't panic, stay calm. We can't have you go into labor." I was doing fine until that call. I completely lost it."
	Loss of sleep and focus.
	"We were all so tired but couldn't sleep. Thinking about all the things we left behind and would never see again."
	"I thought I was OK. I was worried about my husband, I had dreams where he was being burned alive along with my unborn baby. He never stopped working and I didn't get to speak to him properly until May 5th. I was just glued to my phone and the TV, like a zombie."
	Pregnancy/labor complications.
	"My OBGYN finally explained to me that extreme stress can cause a baby to stop growing. There are medical terms that I researched and googled like crazy. Intrauterine growth restriction, placental insufficiency, small for gestational age."
1.2 Common fears were experienced.	Separation from family/significant others.
	"That moment I had to leave my daughter + husband behind so I could get to Albian Sands quicker, it made me feel sick."
	"I freaked out. I was pregnant and alone with my daughter, literally running for my life down Abasand hill. My husband was at work trying desperately to come to us. I felt there was a possibility I may never see him again until eternity."
	Losing their home and possessions.
	"While waiting in line, I break down bawling my eyes out and my fiancé says "Are you okay? What's wrong?". Through my tears I say, "That could be the last time we see our home. We have a 19-month-old little girl, I'm 31 weeks pregnant and right now we may be homeless."
	"As we are coming up Beacon Hill I couldn't even look out the window. I'm sitting there thinking "what if we don't get to go back? I forgot so much stuff!" This is our home we could be losing along with thousands of other people."
	"That's when everything sank in. Will I see my home again? I didn't grab any baby items! I just had my baby shower!!"
	Transportation.
	"We all make the decision to try and head south once we get the chance. We knew north would not have enough accommodations for everyone and that we definitely wouldn't have enough gas to get us there."
	"As I was figuring everything out, I realized I had only 88 km to the tank. What if I get stuck in traffic? How would I get out of here?"
	"We headed down the one way on the wrong side of the road toward the camps. The highway was gridlocked. I can remember my husband saying, "One quick shift of the wind + were all wiped out." Pure terror set in as we waited in traffic for 2 hours."
	The well-being of the baby.
	"We weren't sure what our plan was yet but it didn't take long to decide the new smoky conditions wouldn't be great for our 48-hour old baby."
	"The first night, I was in so much pain from my C-section and was still trying to come to terms with what we just went through. I spent the night knelt on the floor hunched over the bed, crying, trying to sleep, and worried that something was going to happen to my baby."
1.3 Pregnancy possessed an additional barrier to evacuation.	Pregnancy was an added complication during evacuation.
	"She'd asked if I could get on a flight and at first was told 'Sorry, she's too pregnant to fly…' CUE meltdown number two. How on Earth was I going to have a baby in a CAMP?!"
	"[Driving 6.5km] took us 45 mins, that's when I noticed something felt different the pains in my back + stomach were getting closer I started to watch the clock…I called my husband and told him we needed to stop and talk to the RCMP, at this time noticing everything around us was on fire Husband: no we can't stop here. Me: Yes my contractions are 4 mins apart! Husband: No your joking right?! Are you sure?"

descriptions of themes with supporting quotes are found in **Tables 1**–**5**.

Theme 1: Experience of Stress Responses Due to Personal and External Factors

Throughout the fire and evacuation, women experienced varied stress responses during and/or following the event, including significant emotional reactions and lack of sleep.

"The fire is all around us. It's like we were watching a movie or were stuck in a nightmare. It's like our whole world is falling down on us. We can feel the heat from the fire at our house and ash is falling from the sky. We're all in shock and can't move." [P165].

Several women also experienced pregnancy complications potentially related to heightened stress such as intrauterine growth restriction, C-section, and preterm births.

Themes	Findings and supporting quotations
2.1 Support from significant others facilitated resilient attitudes.	Significant others as a source of support. *"I closed the door and instantly started crying. I was 8 months pregnant. I had no idea what to pack so I took a step back and thought to myself...I need to call my husband so he can come home and help me."* *"My husband helped me through each day as I battled my emotions. He was simply amazing <3 But it's still hard."* Connection with loved ones as a stress reducer. *"As soon as I seen my sister we both started to cry, I was happy to be somewhere safe and with family."* *"[My husband] abandoned his vehicle and walked the rest of the way to us through the thick smoke. When I finally saw him walking through the smoky parking lot at the hospital, it was better than my wedding day. I could breathe again. I felt safe. With flames all around us I wasn't scared. I knew he would keep us safe."*
2.2 Support from others/ community facilitated resilient outcomes.	Acts of kindness as sources of support. *"The workers...were all staring at me and felt so sorry this was happening while I was in labor. They were very nice and offered us their rooms, and even offered to take our pets and look after them for the night."* *"Two guys asked us if we needed help with our bags. We told them we didn't have a ticket + were on standby. They immediately handed both of us their tickets, then helped us carry our bags to the plane. Whoever these two strangers are...thank you, from the bottom of my heart."* Provision of needs as sources of support. *"We had so many offers for places to stay, food, and even the doctor that checked the baby offered us to stay with her family!"* *"People were helping us in any way they could! A kind man in Spruce Grove took my mom and sister out shopping, and a sweet old lady handed us money after hearing our story. I was in awe of all the compassion."*

"My OBGYN finally explained to me that extreme stress can cause a baby to stop growing. There are medical terms that I researched and googled like crazy. Intrauterine growth restriction, placental insufficiency, small for gestational age." [P228].

The women also shared stressors and fears related to the event included separation from family members or significant others; fear of losing their homes; fears of losing possessions; fears of running out of gas; waiting in traffic; and well-being of their baby. These stressors and fears often highlighted the women's values, such as connection with family, safety of their children, and protection of their homes, representing uncontrollable circumstances external to the individual.

"We headed down the one way on the wrong side of the road towards the camps. The highway was gridlocked. I can remember my husband saying, "One quick shift of the wind + were all wiped out." Pure terror set in as we waited in traffic for 2 hours." [P97].

Frequently, interactions between pregnancy and the environment served as an additional barrier to evacuation as women experienced difficulties including limited physical capabilities, the need for washroom facilities, or fatigue. While not atypical to pregnancy, these limitations created additional challenges for women during evacuation. Proximity to labour added additional uncertainty and stress (see **Table 1**).

"She'd asked if I could get on a flight and at first was told 'Sorry, she's too pregnant to fly...' CUE meltdown number two. How on Earth was I going to have a baby in a CAMP?!" [P64].

Theme 2: Social Support Was a Facilitator of Resilience

Connection with loved ones was an important facilitator of resilience as women received support from family and significant others during and after the evacuation process, with one participant writing,

"My husband helped me through each day as I battled my emotions. He was simply amazing <3 But it's still hard." [P81].

Writing expressed the value of relationships and togetherness with family members and spouses or partners. Whereas separation from significant others was a source of fear and stress, reunions with loved ones eased stressful emotions (see **Table 2**). Connection and support from the community was also an important facilitator of resilience during women's experiences of the fire and evacuation. Pregnant women received assistance from service providers and health care workers who examined and offered escorts to help women reach safety quickly. The women also were offered compassion and kindness from others, with one woman and her family being allowed into a camp after it was full. One new mother with a one-day old baby shared:

"Two guys asked us if we needed help with our bags. We told us we didn't have a ticket + were on standby. They immediately handed both of us their tickets, then helped us carry our bags to the plane. Whoever these two strangers are...thank you, from the bottom of my heart." [P116].

Strangers made significant personal sacrifices from allowing participants to move in front of them in traffic or giving up flight tickets to ensure safety was reached. Women experienced generosity from others through donations and offers of places to

Themes	Findings and supporting quotations
3.1 Gratitude and thankfulness were expressed.	Thankfulness for hospital staff, first responders, and other service providers. *"Thank you from the bottom of my heart to the emergency staff at the [hospital], especially the PICU ward, and the respiratory staff for helping our sweet boy in his fight"* *"The kitchen was filled with staff working overtime trying to ensure everyone got a good meal...- thank - you [company name]!"* *"Thank you to the emergency crews for leaving your families to save our city."* *"We would like to also thank all the emergency personnel from all around Canada for helping our city when we needed it most."* Gratitude for kindness from strangers. *"I get out of my SUV and ask the guy behind me. Please can my husband jump ahead of you, I'm worried being 3 days overdue we need to be together. He said "of course". Thank you whoever you are - the man from Tower Rd hauling your camper."* *"Even though this day will always be engraved in our memories, the kindness and generosity of strangers and the true efforts of our first responders will never be forgotten. There are no words to express our gratitude and love for you all."* Gratitude for significant others. *"And to my husband; thank you for being my rock, my strength, my shoulder to lean on and my person to hug. Thank you for keeping our family safe".* *"I will be forever grateful to my family and my husband for keeping me calm and for getting us to safety."* Thankfulness for positive outcomes. *"Although being loaded on a city bus 5 hours after a c-section with newborn twins wasn't ideal - I will always be grateful for the care we were given and part of me will always wonder how much worse it might have been if I had been evacuated at 38 weeks pregnant with breech twins and gone into labor."*
3.2 Circumstances were framed positively.	Positive feelings toward outcomes. *"We lost all of our material possessions that day but in the months to follow we were blessed far beyond what we could have imagined."* *"We were one of the lucky ones that didn't lose our home. I thank god every day for: keeping everything we have worked so hard for and everyone safe, for not going into labor due to all the stress, and that my fiancé was on night shift that day because without him I'm not sure how our story would've turned out."* Positive feelings in difficult situations. *"It wasn't the best living arrangement but it could have been worse too."* *"Our daughter will have a crazy birth story to tell when she gets older!"* Pride in community resilience. *"It is amazing to see how strong our city has been since the Beast, and the compassion we've all received...It makes me so proud to say that Fort McMurray is my home."* *"I am proud to say that I love the community that I live in. I will always be Fort McMurray strong."*

stay. Women expressed feeling cared for and overwhelmed by the community support.

Theme 3: Performance of Resilience-Enhancing Activities

Women described engaging in resilience-supporting behaviours. Across the narratives, they commonly wrote of practicing gratitude and framing circumstances positively. Women expressed gratitude for those who assisted them during the evacuation as well as during labour and delivery. They were thankful to the first responders who fought the fire, and to the individuals who provided support after the event.

> "[T]he kindness and generosity of strangers and the true efforts of our first responders will never be forgotten. There are no words to express our gratitude and love for you all." [P165].

Women expressed gratitude for significant others and extended families who kept them grounded during the evacuation and the aftermath. Furthermore, they identified positive aspects of the experience, for example, recognizing

> "Our daughter will have a crazy birth story to tell when she gets older!" [187].

Finally, the pregnant women expressed pride and solidarity with their community (see **Table 3**), reflecting on their pride in how the citizens of FMWB successfully navigated difficult circumstances.

Theme 4: The Roles of Pregnancy and Motherhood in the Experiences of Loss and Resilience

The women identified disruption of transitional changes into new or unique roles, occupations, and interactions with the environment related to pregnancy as a result of the wildfire. Many of the women also noted that pregnancy was a time of excitement and anticipation, indicating

> "I decided that morning [May 3] to start bouncing on an exercise ball cause I was anxious to meet my little man" [P67].

Others additionally noted that ordinary routines were also required, including caring for children, household tasks, and

TABLE 4 | Theme 4: The roles of pregnancy and motherhood in the experiences of loss and resilience.

Themes	Findings and supporting quotations
4.1 Pregnancy was a time of anticipation.	Pregnancy is an exciting time. *"We were scared as first time parents, but so excited for our new adventure."* Pregnancy as a time of preparation. *"May 1st - I spent the day getting all the last minute details finished. I was due to have our baby girl on May 5th so I knew there wasn't much time left to get everything done. I was organizing her nursery and I was nesting so much that I spent hours scrubbing the grout on the bathroom floor. I just wanted everything perfect for when we brought our first born home from the hospital."*
4.2 Women performed mothering occupations and routines.	Importance of regular routines. *"I was two days shy of 36 weeks pregnant while I was making dinner for my husband + 2-year-old on the day of May 3rd when people started to voluntarily evacuate from certain areas of the city."* *"I started with my morning routine of getting our 4-year-old ready for preschool."*
4.3 Women experienced loss/ disappointment in relation to roles of being pregnancy/ mother.	Feelings of loss regarding the expectations of new motherhood. *"As a new mom, I didn't get to take my baby home. I didn't get to experience that first night at home with the newborn."* *"We decided to drive through the night South toward Saskatoon. 3 adults, 2 dogs and a 3-day-old baby all crammed into the SUV. Definitely not how I had imagined my first days postpartum."* Feelings of grief for perceived failure in fulfilling their role as a mother. *"I feel guilty. I couldn't protect my beautiful little baby girl and I failed her when she needed me most to be strong and fine and to hold it together despite everything going on around us. When people make comments about her size, although she is growing and completely healthy, but still petite for her age, I am reactive because it reminds me of my first failure to protect her and keep her safe. My first experiences as a mother are guilt and helplessness that I could not do a better job in protecting her."* Grief over the loss of life. *"I hear people tell their stories of loss, loss of home, loss of items. Some have property damage. As I sit and listen to all these stories, I am weeping on the inside for the loss of my baby. No amount of insurance money or Red Cross funds will fix my loss."* A loss of pregnancy/labor roles with the experience of miscarriage. *"I asked for no pain medications for the DNC because I wanted to feel the pain of labor."* *"As November 21st approaches, I can't help but dwell on this day as it would have been my due date. I would trade spots in the blink of an eye to have my home burnt down if it meant I was still pregnant."*
4.4 Women experienced loss of pregnancy/ mothering occupations.	Concern over abilities to provide for their babies needs. *"As we learned our stay in Edmonton would be longer than planned, I got so depressed and all I could do was cry. I was stressed about not having anything for the baby."* *"The nurse looked at us + told us our baby girl will be here today...Besides being happy, we were scared she was early. We didn't have anything for her. Not sure what our house situation was gonna be But Ready or not, here she comes!"* Disruption of new occupations related to being a mother. *"I never imagined I would be changing my twin sons' dirty diapers on a city bus. That is probably one of my most vivid memories of the evacuation. I remember thinking that the first day of my babies' life shouldn't be like this"*
4.5 Giving birth brought fulfillment to pregnancy role.	Birth as a sense of meaning contrasting uncertainty and loss. *"After 9 hours of labor & 1.5 hours of pushing our little [baby] arrived @ 3:21 PM. He was so perfect. Everything was perfect."* *"My family finally arrived around 12:30 PM on May 4th – which was perfect timing. My beautiful son was born at 1:32 PM."*
4.6 Women adapted mothering roles and occupations.	Roles and occupations were fulfilled. *"We drenched towels and covered our son's car seat in an attempt to repel any possible smoke that may come into the vehicle."* *"May 5th up for 24 + hours I needed to rest, but priority #1 car seats for the kids, new baby clothes, diapers etc. we had nothing for the baby"* *"I wake up our daughter and try to calmly continue our same routine because I don't want her to be scared. I'm already scared enough for the both of us...The faint smell of smoke is in the air, so I rush to turn our central air off. I didn't want our daughter to smell it."* Resourcefulness in adapting to new circumstances. *"We didn't have a crib or bassinet for the baby to sleep in, so we did the only thing we could think of - made a bed for her out of a dresser drawer...Its funny how you spend so much time preparing for a baby, getting everything ready, and at the end of the day all we needed was a safe place to sleep, food to eat, we had each other, and we were safe."*

external employment. However, these roles and occupations were disrupted by the wildfire, as women expressed feelings of loss and disappointment regarding what they had hoped to experience as a mother and for their new baby.

"We decided to drive through the night South towards Saskatoon. 3 adults, 2 dogs and a 3-day-old baby all crammed into the SUV. Definitely not how I had imagined my first days postpartum." [P107].

For new mothers, the fire and evacuation acted as a barrier to performing and savouring new mothering occupations. In addition to disappointment in expectations, the wildfire and evacuation acted as a barrier to engaging in mothering roles

Themes	Findings and supporting quotations
5.1 The concept of home was valued.	Women valued the concept of home. *"I will never be able to put into words how grateful I am for all first responders. The fire came close, but thank you for saving our home, + our memories."* *"At 1030 AM on May 5, our baby BOY was born!!! And we can also say we were fortunate enough to bring him home 54 days later."*
5.2 Women experienced fear and loss surrounding place of home.	Loss of expected experiences. *"As a new mom, I didn't get to take my baby home. I didn't get to experience that first night at home with the newborn."* *"I was so scared, confused and emotional. Our baby was less than a day old. We should be home."* Fear of losing homes. *"I could not fathom the idea of leaving our home at that moment of my broken life leaving...if I left...it was as if everything that I knew to be true was now false. But we finally left our home in the early evening on May 3rd"* *"We then lock the door and reluctantly left - the house we'd finally finished".*
5.3 Significance of homecoming.	Homecoming restored the valued environment of home. *"July 1st, we came back to our home in Fort McMurray with our now 2-month-old son. I remember walking inside and going straight to his room. Everything was just how I left it. I just sat there and held him and cried. This is your room. This is our home. Welcome home, again, sweet boy."* Women felt strong emotions upon coming home. *"As we made our journey home on June 2nd. I was flooded with raw emotions again...sadness + anger."* *"July 1st finally came, and it was the best day ever! I was going home to be with my husband. The drive was quiet. The drive coming into town was full of tears. I was so happy to be home, but so sad for those who lost their homes."*

and occupations, which exacerbated experiences of stress, lack of control, or grief as women sought to provide for their babies' needs. The disrupted environment resulted in barriers to carrying out mothering roles and occupations during the postpartum period. A small number of women noted experiencing a miscarriage during or following the events of the fire.

> "As November 21st approaches, I can't help but dwell on this day as it would have been my due date. I would trade spots in the blink of an eye to have my home burnt down if it meant I was still pregnant." [81].

While it is unknown whether the fire was a cause of the miscarriage, these narratives express tragic losses amidst their experiences of the wildfire related to the lost life and roles. Despite the loss and grief, many of the narratives also related stories of birth, acceptance, homecoming, and demonstrated resilience. These stories bring a sense of restoration with women regaining valued roles, occupations and environments as amidst grief and loss many of the women gave birth, contrasting the horror in the fire and evacuation. Women exhibited resilience in adapting to high-stress environments while maintaining roles and routines of motherhood.

> "May 5th up for 24 + hours I needed to rest, but priority #1 car seats for the kids, new baby clothes, diapers etc. we had nothing for the baby" [P252].

They emphasized the roles of provision and protection, finding creative ways to provide for their children's needs (see **Table 4**).

Theme 5: The Importance of "Home"

The significance of home was an important theme that demonstrated how women valued and interacted with their environment, as they experienced feelings of fear and loss during

the evacuation and experienced resolution in coming home and connecting the concept of home with memories. Mothers frequently narrated the loss of being able to bring their baby home from the hospital, after preparing to do so commenting

> "I was so scared, confused and emotional. Our baby was less than a day old. We should be home." [P116].

Many women experienced fear that they may not see their homes again, bringing a sense of displacement. During homecoming, women experienced strong, predominantly positive emotions, sometimes mingled with fear and anger.

> "July 1st finally came and it was the best day ever! I was going home to be with my husband. The drive was quiet. The drive coming into town was full of tears. I was so happy to be home, but so sad for those who lost their homes." [P66].

For many of the women, coming home seemed to be indicative of circumstances settling. Birth and homecoming often provided a sense of resolution to these events, restoring anticipated roles and routines (see **Table 5**).

DISCUSSION

This study aimed to explore the experiences of women who were pregnant during or shortly following the traumatic 2016 wildfire, with a specific focus on perceived stress and resilience shown through expressive writing. Exploration of the experiences of pregnant women during and following an unexpected traumatic event may provide increased knowledge of how pregnant women experience and respond to stress. Seeking to understand factors of stress and resiliency, along with the roles and occupations important in pregnancy can inform recovery interventions and support resilience-building in prenatal populations in the future.

Factors of Stress and Resilience

Despite the added complication of pregnancy, participants displayed resilient mindsets and referenced emotion-focused coping through problem solving, gratitude, asking for and accepting help, and maintaining expected roles. Participants indicated they received immense support by others in the community. It was noted in the narratives that they believed this occurred due to their pregnancy. This finding warrants further exploration into the protective factors of community resilience, particularly in terms of prevention of long-term impacts resulting from PNMS. Connection with friends and family, emergency personnel, and supportive community members provided a buffer from elements of stress.

Roles and Occupations

The person, occupation, and environment all impact a mother's ability to participate in roles and occupations important in motherhood, with stress and self-efficacy being critical to the transition (19). Roles and occupations in pregnancy, birth, and motherhood were important themes that emerged in women's descriptions of the Fort McMurray wildfire, with women noting that the fire acted as a barrier to fulfilling mothering roles and occupations. During a natural disaster, elements within the person, occupation, and environment are subject to disruption and unpredictability, challenging a mother's role participation and occupational performance. Experiencing stress and trauma during pregnancy impact a mother's roles and occupations. As such, understanding the change or loss in roles and occupations are critical for supporting women following unexpected trauma during pregnancy.

Self-Selected Intervention

The act of writing has been shown to help individuals process traumatic events. In this study, we examined the writings that women shared about their experiences of the evacuation from Fort McMurray and re-entry into the community. While it was impossible to connect with the women who chose to contribute to the book, it is possible to infer from their written text that they used this opportunity to share their thoughts and feelings about their experiences regarding their pregnancies and they were impacted by the wildfire. Through writing, they were also able to explore both the difficult emotions and situations caused by fire and evacuation as well as hopeful and positive outcomes, providing an outlet to process their experiences. Writing may have also provided the women with an outlet to explore important roles, environments, and occupations in pregnancy and birth and to process grief.

Recommendations

Building resilience in pregnant women prior to experiencing trauma is one approach to reducing the harmful impacts of prenatal maternal stress. Prenatal education may provide an opportunity to teach expectant parents resilience strategies that can be drawn upon during a traumatic event. The FMWB wildfire created a stressful and unpredictable context in which pregnant women experienced significant stress responses. Community and familial support in transitioning roles and routines as disasters unfold is vital to ensuring pregnant women experience as minimal disruption as possible, and this support was frequently documented in the women's narratives.

Coping mechanisms including planning or asking for help were discussed in several narratives, however, physiological stress management behaviors, including breathing or grounding exercises, were rarely discussed. While lack of inclusion does not confirm that these behaviors were not accessed, increased focus on stress management methods may be beneficial during prenatal education. This recommendation supports women through changes during the perinatal period in addition to unexpected stressful or traumatic events. Tragea et al. (36) found significant decreases in perceived levels of stress following implementation of a six-week stress management program for prenatal women, indicating that such strategies may act as a protective factor against harmful effects of stress during pregnancy. An increased ability to cope with stress may help in building resilience in pregnant women. Because natural disasters and other forms of traumatic stress are often unexpected, education on stress management may be beneficial as a widespread intervention for women during the prenatal period. Given the negative effects of stress on birth and childhood outcomes, it is important to support adaptive and healthy ways of responding to stress to build resilience in mothers. Education and health promotion on adaptive coping styles may be beneficial for prenatal women who may experience stress during pregnancy.

Areas for Future Research

While the risks for women and children facing prenatal stress and trauma are well documented, more research is needed to identify effective interventions to support populations who have experienced an environmental disaster. Current research indicates PNMS impacts childhood development, demonstrating the need for research into proactive resilience-building is critical to assist pregnant mothers with managing stressors and offset potential risks to their infants. Additionally, as women who have experienced a traumatic event may face challenges due to effects of prenatal stress, such as difficulty in adapting to the role of motherhood, research in this area is of critical importance.

Limitations

There were several limitations to this research study. The data used was not collected by the research team, leaving many aspects of data collection unknown, including when women wrote the narratives following the wildfire. The data contains a small sample size, representing a small number of evacuees. Participants were self-selected, as individuals volunteered to contribute to the writing project. Furthermore, due to the anonymity, researchers were unable to seek participant feedback after analysis was completed. As a result, the findings cannot be generalized to all women who were pregnant during the Fort McMurray Wood Buffalo wildfire.

CONCLUSION

Experiencing a natural disaster significantly influences an individual's occupational participation and their ability to recover

from the associated trauma. Pregnant women have unique barriers that may negatively impact them during a natural disaster or other forms of stressful event. Support to pregnant women could be offered through assistance with role transition and enabling mothering occupations and routines. Education on stress management and adaptive coping along with facilitating exploration and processing of traumatic experiences through writing interventions can also be used to build resiliency and aid in recovery from traumatic events.

DATA AVAILABILITY STATEMENT

The datasets presented in this article are not readily available because writing excerpts used in the data analysis were taken from the books 98/88,000 and 159 more/88,000: Stories of Evacuation, Re-entry and the In-between. Requests to access the datasets should be directed to 98/88,000

and 159 more/88,000: Stories of Evacuation, Re-entry and the In-between.

AUTHOR CONTRIBUTIONS

AP, SB-P, JO, and DO contributed to conception and design of the study. KT coded the writing excerpts and wrote the first draft of the manuscript. KT, AP, and SB-P performed the thematic analysis. AP, CM, JO, DO, and SB-P wrote sections of the manuscript. All authors contributed to manuscript revision, read, and approved the submitted version.

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