Pregnant women's experiences of extreme exposure to bushfire associated smoke: a qualitative study

ENVIRONMENTAL RESEARCH
HEALTH

PAPER

Pregnant women's experiences of extreme exposure to bushfire associated smoke: a qualitative study

Deborah Davis[1,2,*], **Katelyn Barnes**[2,3], **Rebecca Williamson**[3,4], **Alison M Behie**[5], **Christine Phillips**[3], **Rosalie Aroni**[3], **Celia Roberts**[4], **Ella Kurz**[1], **Danielle Schoenaker**[6,7,8] and **Christopher J Nolan**[3,9]

[1] School of Nursing and Midwifery, University of Canberra, Canberra, Australia
[2] ACT Government Health Directorate, Canberra, Australia
[3] School of Medicine and Psychology, College of Health and Medicine, The Australian National University, Canberra, Australia
[4] School of Sociology, College of Arts and Social Science, The Australian National University, Canberra, Australia
[5] School of Archaeology and Anthropology, College of Arts and Social Sciences, The Australian National University, Canberra, Australia
[6] School of Primary Care, Population Sciences and Medical Education, Faculty of Medicine, University of Southampton, Southampton, United Kingdom
[7] NIHR Southampton Biomedical Research Centre, University Hospital Southampton NHS Foundation Trust and University of Southampton, Southampton, United Kingdom
[8] School of Medical, Indigenous and Health Sciences, Faculty of Science, Medicine and Health, University of Wollongong, Wollongong, New South Wales, Australia
[9] Department of Endocrinology, The Canberra Hospital, Canberra, Australia
[*] Author to whom any correspondence should be addressed.

E-mail: Deborah.davis@canberra.edu.au

Keywords: bushfire, pregnancy, newborn, smoke inhalation, maternity care, wildfire, public health messaging

Supplementary material for this article is available online

OPEN ACCESS

RECEIVED
11 January 2023

REVISED
1 November 2023

ACCEPTED FOR PUBLICATION
16 November 2023

PUBLISHED
4 December 2023

Abstract

In 2019/2020, multiple bushfires burned across south-east Australia converging into unprecedented megafires that burned 5.8 million hectares. From October 2019–February 2020, 80% of Australians were affected by smoke from these fires, exposing them to dramatic increases of $PM_{2.5}$ in the air at an average level of ∼70 μg m3 per day, well above the World Health Organisation recommendation of ∼10 μg m3. Maternal exposure to $PM_{2.5}$ has been associated with negative birth outcomes and an increased rate of birth defects, yet there is a dearth of literature regarding how pregnant women deal with exposure to bushfire smoke. The aim of this study was thus to investigate how pregnant and postpartum women experienced severe bushfire smoke associated with the 2019–2020 bushfires in south-east Australia and the strategies they used to mitigate exposure to smoke for themselves and their unborn or newborn children. Forty-three women who were exposed to fire and/or smoke from the 2019–2020 bushfires participated in one-on-one semi-structured interviews via phone or videoconference. These women were selected purposively from a larger group of women who had elected to be interviewed. After interview, data were transcribed and thematically analysed using the four phases of disaster response (prevention, preparedness, response, recovery) as a frame. Overall, our results indicated that public health advice failed to meet the unique needs of this group. While many protected their properties appropriately and were reasonably well prepared for evacuation, they were unprepared for the disruption to vital services including power and communications. Women exposed to smoke inundation were unprepared for this outcome and self-initiated a variety of strategies. The support of community was also key to recovery. There is a clear need for specific recognition of the needs of pregnant women across all phases of disaster response, incorporating public health messaging, peer support, and access to resources.

1. Introduction

In the Australian summer of 2019/2020, multiple bushfires (also known as wildfires) in the south-east of the country converged, forming megafires which burned 5.8 million hectares and 21% of Australia's temperate

Figure 1. Smoke cloud approaching the suburb of Theodore from fires south-west of Canberra, 28 January 2020.

Figure 2. Street and car lights reflecting the heavy smoke layer in Canberra central city intersection, 2 January 2020.

forest [1]. While bushfire is a normal part of many Australian eco-systems, the duration, severity and scale of the megafire was unprecedented and triggered by intensifying anthropogenic weather patterns [2]. Accompanying the megafires was a smoke patch of enormous scale—generating a persistent smoke-charged vortex rising up to 35 km in altitude and measuring 100 km in diameter [3]. Not only did the atmospheric perturbation of this smoke cloud exceed that produced by the North American wildfires in 2017, it was on par with the strongest volcanic eruptions in the last 25 years [3] and further damaged the ozone layer [4]. Eighty per cent of Australians were affected by smoke and those in the south-east of the country experienced poor air quality between the months of October 2019 and February 2020 [3, 5] (see figures 1 and 2). While air pollution in Australia is usually very low, the measure of air pollution (particulate matter with a diameter less than 2.5 μm ($PM_{2.5}$)) was found to be $\sim$70 $\mu g\ m^{-3}$ per day during this period, sometimes reaching levels above 300 $\mu g\ m^{-3}$ [6], which is in sharp contrast to Australia's average levels of $\sim$8 $\mu g\ m^{-3}$ and the World Health Organisation recommended levels of $\sim$10 $\mu g\ m^{-3}$ [7]. This increase in $PM_{2.5}$ is greater than increases shown in previous bushfire sequelae from around the world, which report increases from $\sim$3.0 $\mu g\ m^{-3}$ to 34–57 $\mu g\ m^{-3}$ during the worst months of smoke exposure [8, 9].

The 2020 Royal Commission into the 2019/2020 bushfires [5] found 429 Australians may have died directly or indirectly as a result of smoke exposure. In addition, more than 3000 people were admitted to hospital for respiratory problems and 1700 presented for asthma. At the time of the fires, health authorities rapidly developed and disseminated public health information about smoke exposure such as staying indoors, reducing outdoor exercise, developing medical plans for those with respiratory conditions and monitoring air pollution levels [10]. There was particular emphasis on vulnerable populations, such as pregnant women, to protect themselves from smoke as the available evidence suggests maternal exposure to $PM_{2.5}$ adversely affects pregnancy and birth outcomes (for example, reduction in birthweight, increased incidence of preterm birth, increased incidence of birth defects and increased risk of gestational diabetes mellitus) [10, 11]. Evidence that air pollution during pregnancy can affect health of neonates is being shown through biomedical sampling studies [12]. Many Australians however, felt unprepared for the management of smoke exposure as well as uncertain about the extent of the health risks facing them [13].

Given climate scientists predict intensifying bushfire events like the Australian 2019/2020 fire season, it is vital to understand how pregnant women and mothers of newborns who face particular risk from extreme

smoke exposure experience and respond to smoke exposure. Through analysis of semi-structured interviews of women who were exposed to the 2019/20 Australian bushfires, we previously reported on the challenges they had accessing evidence-based information on how to protect themselves, and how family practitioners could better contribute during future events [14]. The aim of the current analysis was to understand their experiences dealing with extreme bushfire smoke exposure, and to explore the strategies they put in place to cope with and mitigate the smoke exposure risk posed to themselves and their unborn or newborn children.

2. Methods

Semi-structured qualitative interviews were conducted with 43 women who had been exposed to fire and/or smoke during the catastrophic bushfires of 2019–2020 in the region of south-east Australia, as previously reported [14]. Participants included women living in the bushfire-affected areas of southern NSW and the ACT, a region covering 180 000 square kilometres. The entire region was affected by pervasive smoke across December 2019–January 2020, and over a two-week period experienced ten major bushfires.

2.1. Participants

Participants were drawn from a larger longitudinal study into the effects of bushfire and bushfire smoke events on pregnant women, new mothers and their infants. Cohort participants were women who had a baby no older than 3 months or were at any stage of pregnancy on the 1 February 2020, or who became pregnant by the 30th of April 2020. The study was widely advertised by health sector members of the HealthANSWERS Research Partnership, on television and through women's groups. A purposive sample of 200 participants were invited by email to participate in a semi-structured interview. Purposive sampling was used to enhance geographic representation and capture a range of experiences across regional and urban contexts. Geographic representation was particularly important as those living in regional areas were more likely to be directly affected by bushfire and smoke, whereas those living in urban areas were more likely to be directly affected solely by bushfire smoke. All women who responded were interviewed. The research team met during data collection to discuss and refine the interview schedule and to monitor the point of data saturation. Data saturation was tentatively identified at 43 interviews. This is the point at which further gathering of data can reveal no new information or insights to aid in the analytic process of theme development.

2.2. Data collection

One-to-one semi-structured interviews were conducted by telephone or online conferencing platforms (due to COVID-19 restrictions) from August 2021 to December 2021. Interviews ranged in length from 30 and 70 min. Interviewers were provided a question guide and a protocol to follow in cases of distress caused by the interview. Interview questions were developed by the research team based on a literature review and the study aims to understand the health and wellbeing impacts of the bushfire and smoke on pregnant women, new mothers, and their babies. The development of the questions was an iterative process and questions were reframed after initial testing. The interview schedule was employed flexibly by the interviewers to ensure participants covered the topics of interest without unnecessary repetition, and in relation to their individual experiences. Basic demographic data was gathered, before participants were asked about their experiences of the bushfires and smoke. Questions included (i) key concerns at the time, (ii) how the bushfires and smoke affected their pregnancy, (iii) the type of maternity care they received, (iii) how the bushfires and smoke affected their antenatal and postnatal care and their ease of access, (iv) health information and advice they sought or received over this period, (v) the psychological impacts of the bushfires and smoke, and (vi) concerns about the impact of the bushfires and smoke on their baby's health (see supplementary data). Post interview reflective notes were completed by the researchers, including initial thoughts, challenges, and non-verbal context. Audio-recorded interviews were transcribed verbatim by a professional transcriber, de-identified, and imported into NVivo, a qualitative data analysis software tool. Names used to report data are pseudonyms.

2.3. Analysis

The study was exploratory and descriptive in nature and sought to gather rich data with participants who had direct experience of the phenomena under study, rather than seeking to confirm a particular theoretical or philosophical position. Data were analysed thematically using a descriptive approach with both inductive and deductive aspects to coding. Transcripts were read by the lead researcher (DD) who generated an initial set of codes by attaching a descriptive label to each meaning unit (a sentence or group of sentences conveying a message or concept relevant to the study). Descriptive labels were discussed with the research team who had conducted interviews and grouped with other labels conveying a similar idea to create descriptive themes. Following discussion and finalisation of the codes, the transcripts were coded. Four of the transcripts

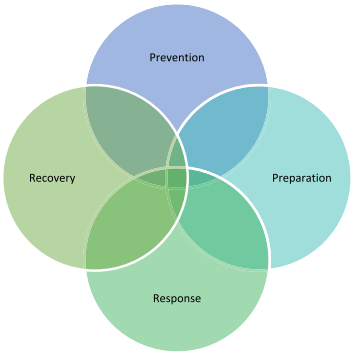

Figure 3. Comprehensive approach to emergency management framework. Adapted from [15]. CC BY 4.0.

were coded independently and subsequently reviewed to enhance rigour by checking for interpretative consistency. Coded data were then considered in the context of the Comprehensive Approach to Emergency Management framework which includes overlapping and cyclical phases of prevention, preparation, response, and recovery (see figure 3) [15].

Experiences of participants and identified strategies to cope with and mitigate impacts of smoke and fire exposure were grouped into each section of the framework. Application of the framework allows experiences and specific strategies to be viewed in the temporal context of disaster management. Furthermore, application of the framework supports insight for clinical and policy related supports that might be indicated to mitigate impacts of future fire or smoke events for pregnant women and babies.

3. Results

Forty-three women were interviewed, all of whom were impacted by bushfire smoke. Ten women were also fire-affected, meaning that they lived in an area that was directly at risk of bushfires. Some women were pregnant, and others had newborn babies. Four participants were within 3 months of becoming pregnant. Table 1 displays participant characteristics on 1 February 2020. Findings are presented under the themes that represented the phases of 'prevention and preparedness', 'response' and 'recovery' following Burns, Burns *et al* [16].

3.1. Prevention and preparedness

Many parts of Australia are prone to bushfire disasters. Public service campaigns have focused on preparedness, with those in prone areas urged to prepare their homes (clear gutters of leaf litter for example), have an escape plan and to consider the emergency (water, first aid kit) and essential items (such as documents) that need to be included in any evacuation. Many of the participants in areas that were fire-affected or at risk of bushfire in our study were reasonably well prepared for evacuation. For many, this was not the first experience of bushfire.

> *So, it was in the back of our heads that yeah, we could be in trouble if a grass fire started up near us. So, we did all the usual stuff, we had emergency … our go-bags ready. We talked about, you know, what to do … if there was a fire close by, yep. (Zoe)*

Pregnant women or families with newborns have specific needs however, that are generally not well catered for in public service information. This participant describes the value of information provided on social media.

> *I do remember someone put up on social media that if you had a, you know, a child under, say, six months, what to pack if you were having to go there [evacuate]. So, I remember thinking, oh, do we have all those things? Because I was trying to, obviously, exclusively breastfeed, but we did get a can of formula because I was worried that maybe because of the stress, my breast milk supply would go down.*

> *…it was kind of, like, a checklist of things that if you had to evacuate with a really small infant, make sure you have, you know, like, a good supply of nappies, formula, access to clean water, because if you had to formula feed. Yeah, so we did … I do remember, we bought formula, and we did buy bottled water during that period in case we did have to leave our home. (Anna)*

Table 1. Characteristics of participants.

Characteristic	Type	N	%
Age	21–30 years	<5[a]	
	31–40 years	37	86
	41–50 years	<5	
Ethnicity	Asian-Australian	8	19
	Anglo-Australian	34	79
	Unknown	<5	
Household	Single + child/children	<5	
	Partner	<5	
	Partner + child/children	42	98
Number of children	0	<5	
	1	16	37
	2	22	51
	3+	<5	
Fire effected	Pre-pregnancy	<5	
	During pregnancy	7	16
	Post-partum	<5	
Smoke effected[b]	Pre-pregnancy only	<5	
	During pregnancy	35	81
	Post-partum	<5	

[a] To protect participant's identity, <5 is used for any participant characteristic that is described in less than 5 participants.
[b] Of the women smoke effected during pregnancy, 5 conceived and 7 birthed during the smoke exposure period.

While participants were reasonably well prepared for evacuation, they were less well prepared for other impacts of the situation which included power outages, disruptions to transport, communication and supplies of petrol and other essential items. The impacts of these disruptions were more significant for women who were close to giving birth or caring for newborn babies. Power outages affected (among other things) refrigeration and the ability to sterilise infant feeding equipment and water.

> *…I can't remember when we lost power, I should look it up. So, we lost power quite a bit, which was obviously a big impact when it was very hot, like, I was worried about [baby], and even food and stuff being unrefrigerated and things like that. (Carol)*

> *I think we lost power on New Year's Eve, and we lost it for three days. So, because we had to have the doors and windows shut because of the smoke, obviously, and then it was very hot. Like, that worried me with the baby, but he was really good. He was a bit unsettled, I think at the New Year's Eve one, like, he was pretty cruisy, so it wasn't that big a deal. And he was breastfed, so that was a plus. And because we couldn't find milk or bread and things like that for a while, that was a worry. My sister-in-law had weaned her baby, like, a couple of weeks before, so she was considering putting … we were trying to give milk to her and just make sure they had bottles and things like that. (Carol)*

The mega fires of the summer of 2019–2020 were unprecedented with many more individuals affected by smoke and poor air quality than fire. Public service messaging has focussed mostly on preparedness for the potential for fire while preparedness for smoke inundation is not addressed (although general guidelines were prepared by the Australian National University [10]). This may be more difficult to prepare for.

Participants in our study described how they attempted to seal their homes against smoke inundation and scrambled to find air purifiers which had sold out at all local retail stores.

> *And so, I got on the phone to friends to see if we could get an air purifier, and I managed to get one in Melbourne because I had a friend down there who was going to drive up, so she went and got it for me. My parents managed to get one in Perth because I had a friend flying over from Perth, so*

[10] https://nceph.anu.edu.au/phxchange/communicating-science/how-protect-yourself-and-others-bushfire-smoke.

we managed to get air purifiers. And we duct-taped our front door shut and had wet towel towels under everywhere and had the airlock into the garage. (Helena)

Provision of information specific to pregnant women and families with babies would be helpful to enable women and families to make informed decisions (to stay in smoke affected areas or evacuate for example) and to take steps that might limit exposure as much as possible.

I think I was worried about the baby, but at the same time, we just didn't have an option to … I don't know. What could we do? I guess I didn't have any information about anything. (Isabelle)

Well, yeah, I guess, looking back, we didn't really have any information given to us about how smoke can affect unborn babies or anything like that. So that would have been … yeah, the reason I didn't think much about it was because I wasn't told any information about it. But yeah, like, it is probably a fairly significant thing to be breathing in bushfire smoke for a month or two. (Sophie)

Women also noted that even when that advice was provided, some of the resources to support protection, such as P2 masks, were often not available. This suggests there are systemic problems beyond just inadequate public health messaging, including getting vulnerable groups access to safety equipment and needed resources.

I think, like, probably more clear guidelines about, I guess, what not to … I mean, it's easy to say with hindsight there should be clear guidelines about what to do, but it's an unprecedented situation. … and then even just, like wearing masks, like, you know, P2 masks weren't available, or it was, like, do you wear them or not? Like, I guess maybe clear information around mask-wearing, … whether that's recommended in those circumstances and whether that's available and things like that. (Clare)

Australia is a country prone to bushfire and participants were well versed in preparing homes for bushfire events and for evacuation. They were less well prepared to manage smoke inundation, disruption to essential services and to account for the specific needs of pregnancy or newborns.

3.2. Response

Participants in fire affected areas had a variety of experiences which included defending properties by actively fighting fires, staying in place on stand-by to evacuate, or evacuating to centres or homes of friends or relatives. One pregnant woman describes her experience on a rural property:

… and he would send me to go do a lap around the yard and the house and the sheds just to make sure everything was okay, that there was no fire getting close. And it did, it got very close to the house there, and I was stomping on fire in my farm boots, and I still have my boots, and the bottom of the soles are melted from where I was putting out the fire and throwing buckets of water. And I had to take, like, I had to go into the house a couple of times because the smoke was so thick, but it's not like the house was not smoky, because the smoke alarms were going off like crazy. And the smoke was so … this is where I remember the smoke being the worst. It was so bad and windy; it was changing different directions. (Hazel)

Another mother with a newborn baby related her experience of the smoke:

The smoke was so thick. Like, especially on New Year's Eve, when it got really bad. It was burning the inside of your nostrils, the heat and the smoke, it was just thick in the air. You could feel, like, the dirt inside your mouth. I just didn't want him [newborn] to breathe it all in. …

We would look up and there'd just be, like, leaves spiralling and, like, burnt stuff and smoke, and I think I was just worried about him breathing that in. (Bonny)

In evacuation centres or in the homes of families and friends, people were working together, often pooling limited resources to provide for the necessities.

But it was quite a good time in the community, in some senses, like, there was a lot of help and, like, like people would walk around and see you had a baby and they'd be, like "Do you need nappies? Do you need this?" and people were helping each other out. (Carol)

But in terms of food, there was … yeah, food and water were okay. We kind of had community … I guess it was the community thing. I think if we were on our own it would have been different… everybody kind of came together and helped each other out. (Isabelle)

Telecommunication is an essential service, the importance of which comes to the fore in disaster situations. The ability to be informed was seen by participants as crucial to their decision making and safety.

> *It was really just keeping track of what was going on. So, all the information that was put out by emergency services and by government and things, that was really what helped with just keeping track of all of that. (Alison)*

Telecommunications, however, can be severely impacted during disasters such as bushfires. Many in the fire affected areas lost power (thus ability to charge devices), mobile phone reception, and internet.

> *We went for 21 days without phone signal at home, which was really scary because the fire was still burning, we didn't know where it was. (Bonny)*

Social media proved useful when this was accessible because it provided current information in a situation that was evolving rapidly. It is significant in the case below that this social media community was organised around the shared experience of mothering:

> *So, I don't know, maybe, if I didn't have my first child, I might not have had those connections in that community, because that was one of the things when the fire came through when we had to first evacuate was that when I woke up at four, actually, before I looked at the fire app, I had messages from the mums' group saying, "We're in [place], and we're leaving now." And so, all the messages, and then that's the same when evacuating, and in terms of evacuating [Suburb], the reason that we did leave straight away is because some people had and they're saying, "We're on the road to Canberra now, and we're stuck. We can't move. We've got 1, 2, 3 kids in the back, and we are stuck in traffic with smoke and there's a fire breaking out." And so then from that, it was better than having any news, Messenger. [Laughs] It was kind of, like, brings us all together. And it continues now, like, in all kinds of situations, we're the first ones to know. [Laughs]. (Isabelle)*

For those in fire affected areas, making decisions about staying or leaving, being safe from fires and accessing essentials like food and water were priorities. This is illustrated by this participant as she reflects on her experience of the fires and the potential impact of smoke exposure on her pregnancy.

> *Ultimately, that could be a decision I made to maybe the detriment of my own health and my unborn child's health at the time, but at that time, there were much higher, greater priorities, life priorities I had to deal with. And that's just the harsh reality of those circumstances. (Hazel)*

There was a lack of public health information available at the time about smoke exposure specific for pregnant women and babies. Most families took pragmatic steps to avoid the smoke as much as possible.

> *[Pause] I don't remember anything specifically. I suppose I just was very pragmatic about, you know, we just had to get through it and avoid smoke as much as possible. Yeah, I think getting out clear public messaging, like, early would really help in that kind of circumstance. (Stacey)*

These steps included wearing face masks and staying indoors as much as possible. It was however difficult to avoid smoke exposure because it infiltrated most homes.

> *… yeah, I'll never forget that weird feeling of walking out into our loungeroom and it was really smoky. (Keira)*

Families attempted to seal their homes by taping around doors and windows, and some were able to purchase air purifiers, though these quickly sold out at stores. Some women spent days at a time secluded in a bedroom for example, to avoid smoke exposure.

> *At night, particularly when it got really heavy, we rolled up towels and put it against the door. Like, we usually have those windbreaker sausage type things anyway, but we just packed the little cracks under the door with wet towels or damp towels to see if we could stop it that way. And we taped up around our front doors, where we could feel some air coming in sometimes. We just had to seal the house as best that we could. (Evelyn)*

> *I locked myself back in my bedroom and monitored the air quality through the air filter, probably for maybe the next five days or something. Again, only leaving to go to the bathroom and eat until my husband and daughter came home and the air quality had improved a bit. Oh, and I always wore a mask when I left the house at that point. (Denise)*

A response that proved to be most useful to women in smoke affected areas was the use of air quality apps. For many over this time it became a new norm to check air quality information online before making decisions about venturing outdoors.

> *Yeah, yeah. We checked that every day to see what it was like. Because my husband's a runner … well, my husband and I are both runners, I wasn't running at that point because I just had a caesarean, but we would check that each day whether it was okay for him to go out, go for a run, or just even if we were going to go out and doing anything. And because I know we've got monitoring stations in, there's one quite near where we live, and then there's a couple more throughout ACT. And we were checking those each day to see what it was like. (Carly)*

These findings highlight the importance of local information to inform individual decisions to stay or leave during bushfire events. It also points to the need for public health information to better target the needs of pregnant women and families with newborns. However, the women were proactive with initiating self-care practices.

3.3. Recovery

The mega fires of 2019–2020 were followed closely by the COVID-19 pandemic, impacting recovery of individuals and communities affected. Reflecting on recovery and the factors that had a positive impact, most participants highlighted supportive partners, family, and friends.

> *This support from my husband. Yeah, he was very reassuring, and the support from my parents, they were very supportive, you know, reminding me that I was doing a good job and just take one day at a time and make sure I was eating and drinking and just doing all the basics right. (Anna)*

The experience of pregnancy and being a mother at home with a new baby can be isolating. Those with new babies at this time, especially first-time mothers, mourned the loss of an anticipated experience of socialising with other new parents and potentially developing a new social network appropriate to their new social circumstance. Those with established social networks highlighted the key role these networks played in their recovery.

> *So, I guess if I was a first-time mum, if I was pregnant with my first child, I would have not had the support or that outlet I get to communicate. Yeah, if people need just to hang out or have a chat, like, there's always somebody around to go to the beach or whatever…*
>
> *Interviewer: What are some of the kinds of tangible things, like, what happened that made you feel that sense of community?*
>
> *Well, kind of a bit lame, but Messenger. [Laughs] Messenger has brought, like, especially in terms of parents and mums, we joke that, like, my partner's, like, "What does the mum crew know without this situation?" [Laughs] Like, we know what's going on in the community, because we all talk and tell each other what's happening and whether, you know, if we want to just have our kids hang out, and it's not exclusive to anybody, it's whoever has kids and wants to come. (Isabelle)*

Personal support and sense of community emerged as key factors in promoting recovery from this bushfire disaster.

4. Discussion

This paper describes the perceptions and experiences of pregnant and postpartum women before, during and after the Australian mega-bushfire event of 2019–2020 including the discrete strategies they employed to mitigate the effects of smoke and fire. Participants in this study relied on their social supports and community networks for information in all phases of the bushfire event given the absence of specific public health and clinical advice for pregnant women and babies. This in part reflects the absence of disaster response planning for the needs of pregnant women and women with babies.

Bushfires underscore the fragility of community and rural health infrastructure. In the 2019/20 bushfires, 65 000 people were internally displaced across Australia [17]. Clinics burned down, electronic health records were non-functional, and medication supply chains broke down [18]. Rural Australia had a pre-existing critical shortfall in health personnel [19], and thus many women faced the bushfires and the prolonged smoke emergency needing to rely upon self-care. The World Health Organization has stressed the importance of self-care interventions as critical elements on universal health coverage, particularly during environmental crises and displacement [20]. Our findings demonstrate that many women undertook self-care practices, from monitoring to self-treatment, to protect themselves and their infants. Self-care practices in this context refers to self-initiated actions such as purchasing air purifiers, isolating away from the smoke, evacuating themselves to sites not affected by smoke, wearing masks, and undertaking their own research. Public health messages should aim to support women's self-care as well as care by health workers. In

this way, self-care practices will be better integrated into public health response, and professional advice from health workers will be better informed.

Public service messaging about evacuation from locations at risk of engulfment by fire is part of the Australian bushfire response [21]. The underlying assumption of such messaging is that it provides people with advice enabling them to be prepared to take action speedily to minimize loss of life and maintain optimal health in difficult circumstances, especially when panic and indecision may make that difficult to achieve [5]. Our participants acknowledged the utility of such messaging and their reliance on it in their preparations for possible evacuation. However, their comments suggested that there was a lack of information specific to pregnant women or women with young children and this made it more difficult for them to feel, or be, adequately prepared, particularly in the midst of experiencing a heightened sense of risk [22]. The impact of the fires on both traditional lines of communication and household amenities (relied upon to provide care for newborns) made it difficult for the participants to act with the same level of certainty in decisions about their personal crisis/disaster management preparations. To better assist pregnant women, and women with infants prepare and respond to bushfire events, communication should be condition- and age-specific, and disseminated through multiple channels, including social media. This could include for example, lists of items to include when evacuating with a newborn or infant.

The women in our study reported that advice to avoid smoke was difficult to implement. Houses were porous, with smoke coming through windows and doors [10]. Advice to use air purifiers inside and P2 masks outside was difficult to follow as air purifiers and masks rapidly sold out, with no specific prioritising of pregnant women, people in public housing, or people with limited financial resources [23]. There were no identified safe, low-smoke environments for women in highly porous housing. In future, to assist women in their response to bushfire events, public health responses should consider prioritising supply of air purifiers and P2 masks to pregnant, post-partum and breastfeeding women, and establish safe public spaces.

The US Centers for Disease Control and Prevention has produced safety messaging for pregnant, postpartum and breastfeeding women during natural disasters such as hurricanes, floods and wildfires [24]. The messaging addresses preparation for a disaster (focusing on evacuation), and specific advice for the response and recovery phases of emergency management, which also addresses structural considerations. We recommend that targeted planning modelled upon this approach be developed for women in advance of bushfires.

The women in this study described complex and nuanced approaches to protecting the health of the foetus or newborn in the absence of fit-for-purpose messaging for pregnant women. A key strategy was the use of peer support using social networks in both the response and recovery phases of bushfire emergency management. Peer support has been well-described in the aftermath of environmental disasters [25, 26] mainly focusing on psychosocial support [27]. In our study, peer support was also sought through a community of mothers in the midst of the disaster—for example, on the timing of evacuation, or how to mitigate the impacts and intrusion of smoke. This strategy relied upon pre-existing social networks, and therefore would not have been available to women who did not have access to social media, or who had limited facility in English. Our study suggests that there is a need to have specific social media outreach in disasters to pregnant women and women in early pregnancy, through trusted community organisations and potentially social media [28, 29].

This study offers an in-depth exploration of the experiences of an under-represented and vulnerable group during a severe bushfire event. Interviews were conducted 18–24 months after the event which provided emotional distance from the experience for participants. This period of time may have introduced the potential for recall error; however, a bushfire is a major, frightening and unusual event, typically recalled through 'flashbulb memory' [30]. Flashbulb memories are usually recalled vividly despite time from the event; the closer one is to the event the more likely the event is to be recalled accurately [31].

In summary, while the role of health professionals in similar future situations remains critical, the recent wildfire experience suggests that communication between patients and health workers may be compromised by damage to hard infrastructure and telecommunications. In light of this prospect, we advocate development of three important strategies. The first is strong engagement of health professionals in the development of the targeted public health messaging to ensure it provides sufficiently detailed information that is effective and usable. The second is partnering with women to develop emergency self-care strategies and self-care agency to support implementation of the strategies [32]. The third is to support and facilitate peer connection between women.

5. Conclusion

Being exposed to smoke is serious. More research is needed on smoke exposure so people have a better chance to avoid smoke without leaving the area (in mega fires leaving is often not possible, especially when

pregnant). Plans are needed to improve the self-care, peer support of pregnant and postpartum women in these situations. Partnering clinicians and public health practitioners should be producing targeted messages, which recognise diversity in context and health needs during bushfire events.

Data availability statement

The data cannot be made publicly available upon publication because they contain sensitive personal information. The data that support the findings of this study are available upon reasonable request from the authors.

Acknowledgments

We acknowledge the Mother and Child 2020 study team members and study participants who contributed their valuable time to this study. This project was conducted with the support of the HealthANSWERS research partnership including Southern NSW Local Health District, Murrumbidgee Local Health District, Illawarra Shoalhaven Local Health District, University of Canberra, Australian National University, and University of Wollongong.

Funding

The Mother and Child 2020 study has received funding from the Australian National University College of Health and Medicine, the Finley River Fund, and the Fiji Alumni of the Australian National University.

Ethical statement

Ethical approval was Granted by The ACT Health Human Research Ethics Committee in February 2021 with a reference number of 2021.ETH.00001 ACT HREC.

The Mother and Child 2020 study has received funding from the Australian National University College of Health and Medicine, the Finley River Fund, and the Fiji Alumni of the Australian National University.

ORCID iDs

Deborah Davis https://orcid.org/0000-0002-2041-1064
Katelyn Barnes https://orcid.org/0000-0001-5891-1331
Rebecca Williamson https://orcid.org/0000-0003-1486-446X
Alison M Behie https://orcid.org/0000-0002-7436-3694
Rosalie Aroni https://orcid.org/0000-0003-2945-0403
Danielle Schoenaker https://orcid.org/0000-0002-7652-990X
Christopher J Nolan https://orcid.org/0000-0002-6964-3819

References

[1] Boer M M, Resco de Dios V and Bradstock R A 2020 Unprecedented burn area of Australian mega forest fires *Nat. Clim. Change* **10** 171–2
[2] Deb P, Moradkhani H, Abbaszadeh P, Kiem A S, Engström J, Keellings D and Sharma A 2020 Causes of the widespread 2019–2020 Australian bushfire season *Earth's Future* **8** e2020EF001671
[3] Khaykin S *et al* 2020 The 2019/20 Australian wildfires generated a persistent smoke-charged vortex rising up to 35 km altitude *Commun. Earth Environ.* **1** 1–12
[4] Damany-Pearce L, Johnson B, Wells A, Osborne M, Allan J, Belcher C, Jones A and Haywood J 2022 Australian wildfires cause the largest stratospheric warming since Pinatubo and extends the lifetime of the Antarctic ozone hole *Sci. Rep.* **12** 12665
[5] Commonwealth of Australia 2020 Royal commission into national natural disaster arrangements *Report* (available at: https://naturaldisaster.royalcommission.gov.au/publications/royal-commission-national-natural-disaster-arrangements-report) p 594
[6] Graham A M *et al* 2021 Impact of the 2019/2020 Australian megafires on air quality and health *GeoHealth* **5** e2021GH000454
[7] IQAir 2022 Air quality in Australia (available at: www.iqair.com/au/australia)
[8] Candido da Silva A M, Moi G P, Mattos I E and Hacon S D 2014 Low birth weight at term and the presence of fine particulate matter and carbon monoxide in the Brazilian Amazon: a population-based retrospective cohort study *BMC Pregnancy Childbirth* **14** 309
[9] Abdo M, Ward I, O'Dell K, Ford B, Pierce J R, Fischer E V and Crooks J 2019 Impact of wildfire smoke on adverse pregnancy outcomes in Colorado, 2007–2015 *Int. J. Environ. Res. Public Health* **16** 3720
[10] Williamson R, Banwell C, Calear A L, LaBond C, Leach L S, Olsen A, Phillips C, Walsh E I and Zulfiqar T 2022 'I didn't feel safe inside': navigating public health advice, housing and living with bushfire smoke *Crit. Public Health* **33** 1–11
[11] Evans J, Bansal A, Schoenaker D A, Cherbuin N, Peek M J and Davis D L 2022 Birth outcomes, health, and health care needs of childbearing women following wildfire disasters: an integrative, state-of-the-science review *Environ. Health Perspect.* **130** 086001
[12] Rodney R M *et al* 2021 Physical and mental health effects of bushfire and smoke in the Australian capital territory 2019–20 *Front. Public Health* **9** 682402

[13] Funk W E, Montgomery N, Bae Y, Chen J, Chow T, Martinez M P, Lurmann F, Eckel S P, McConnell R and Xiang A H 2021 Human serum albumin Cys34 adducts in newborn dried blood spots: associations with air pollution exposure during pregnancy *Front. Public Health* **9** 730369
[14] Davis D, Roberts C, Williamson R, Kurz E, Barnes K, Behie A M, Aroni R, Nolan C J and Phillips C 2022 Opportunities for primary health care: a qualitative study of perinatal health and wellbeing during bushfire crises *Fam. Pract.* **40** 458–64
[15] Queensland Fire and Emergency Services 2018 Queensland prevention, preparedness, response and recovery disaster management guideline (Queensland Government) (available at: www.disaster.qld.gov.au/dmg/Pages/DM-Guideline.aspx)
[16] Burns P L, Douglas K A and Hu W 2019 Primary care in disasters: opportunity to address a hidden burden of health care *Med. J. Aust.* **210** 297–9
[17] Du Parc E and Yasukawa L 2020 The 2019/20 Australian bushfires: from temporary evacuation to longer-term displacement (Internal Displacement Monitoring Centre) p 25 (available at: www.internal-displacement.org/sites/default/files/publications/documents/Australian%20bushfires_Final.pdf)
[18] Lal A, Patel M, Hunter A and Phillips C 2021 Towards resilient health systems for a more extreme climate: insights from the 2019/20 Australian bushfire season *Int. J. Wildland Fire* **30** 1–5
[19] Australian Institute of Health and Welfare 2018 Australia's health (Australian Institute of Health and Welfare) p 570 Australia's health series no. 16; Cat. No. AUS 221 (available at: www.aihw.gov.au/getmedia/7c42913d-295f-4bc9-9c24-4e44eff4a04a/aihw-aus-221.pdf)
[20] Hopkins J and Narasimhan M 2022 Access to self-care interventions can improve health outcomes for people experiencing homelessness *BMJ* **376** e068700
[21] Sharp E A, Thwaites R, Curtis A and Millar J 2013 Factors affecting community-agency trust before, during and after a wildfire: an Australian case study *J. Environ. Manage.* **130** 10–19
[22] Beyene T *et al* 2022 The impact of prolonged landscape fire smoke exposure on women with asthma in Australia *BMC Pregnancy Childbirth* **22** 919
[23] Williamson R, Banwell C, Calear A L, LaBond C, Leach L S, Olsen A, Walsh E I, Zulfiqar T, Sutherland S and Phillips C 2022 Bushfire smoke in our eyes: community perceptions and responses to an intense smoke event in Canberra, Australia *Front. Public Health* **10** 793312
[24] Centers for Disease Control and Prevention 2022 Reproductive Health in Emergency Preparedness and Response (Division of Reproductive Health (available at: www.cdc.gov/reproductivehealth/emergency/index.html)
[25] Castellano C 2021 Applications of peer support in disasters: connecting in times of disaster *Int. Rev. Psychiatry* **33** 677–81
[26] Giarratano G P, Barcelona V, Savage J and Harville E 2019 Mental health and worries of pregnant women living through disaster recovery *Health Care Women Int.* **40** 259–77
[27] Ogie R, Moore A, Wickramasuriya R, Amirghasemi M, James S and Dilworth T 2022 Twitter data from the 2019–20 Australian bushfires participatory and temporal variations in social media use for disaster recovery *Sci. Rep.* **12** 16914
[28] Wendling C, Radisch J and Jacobzone S 2013 The use of social media in risk and crisis communication (OECD Publishing, OECD Working Papers on Public Governance) p 42 (available at: www.oecd-ilibrary.org/content/paper/5k3v01fskp9s-en)
[29] Atkinson S, Kim C and Lee J Y 2021 Facebook as an official communication channel in a crisis *Aust. J. Emerg. Manage.* **36** 92–98
[30] Brown R and Kulik J 1977 Flashbulb memories *Congition* **5** 73–79
[31] McGaugh JL 2013 Making lasting memories: remebering the significant *Proc. Natl. Acad.Sci. USA* **110** 1042–7
[32] Narasimhan M, Allotey P and Hardon A 2019 Self care interventions to advance health and wellbeing: a conceptual framework to inform normative guideance *BMJ* **365** 1688