Health research priorities for wildland firefighters: a modified Delphi study with stakeholder interviews

Chelsea Pelletier 1, Christopher Ross,1 Katherine Bailey,1 Trina M Fyfe,2 Katie Cornish,3 Erica Koopmans3

ABSTRACT

Objectives The increase in global wildland fire activity has accelerated the urgency to understand health risks associated with wildland fire suppression. The aim of this project was to identify occupational health research priorities for wildland firefighters and related personnel. Design In order to identify, rank and rate health research priorities, we followed a modified Delphi approach. Data collection involved a two-stage online survey followed by semi-structured interviews. Setting British Columbia, Canada. Participants Participants included any current or past wildland firefighter or individuals engaged in related roles. There were 132 respondents to the first survey. Responses to the first survey were analysed to produce 10 research topics which were ranked by 75 participants in the second survey (response rate: 84%). Primary and secondary outcome measures The primary outcome was the identification, ranking and level of agreement of research priorities through a two-round online survey. We contextualised these findings through deductive and inductive qualitative content analysis of semi-structured interviews. Results The most important research priorities identified were (%) consensus: effects of smoke inhalation on respiratory health (89%), fatigue and sleep (80%), mental health (78%), stress (76%) and long-term risk of disease (67%). Interviews were completed with 14 individuals. Two main themes were developed from an inductive content analysis of interview transcripts: (1) understanding the dynamic risk environment; and (2) organisational fit of mitigation strategies. Conclusions Participants expressed a general concern with the unknown mental and physical health impacts of their jobs, including the long-term risk of morbidity and mortality. Future research must address knowledge gaps in our understanding of the health impacts of wildland fire and work to develop appropriate mitigation strategies while considering the needs of workers and unpredictable workplace environment.

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INTRODUCTION

Precipitated by climate change, accelerating wildland fire activity has extended fire seasons, increased demand for personnel and amplified the need to understand health impacts of wildland fire smoke for the public and those engaged in suppression efforts.1 2 Although there is variation across jurisdictions, wildland fire suppression typically includes a crew of frontline wildland firefighters working on a fireline, with support from related personnel such as air support (eg, water bombers), logistical coordination and operational management (eg, incident management teams). The role of a wildland firefighter is distinct from structural firefighting based on differences in smoke exposure, work structure and schedule, physical demands and other occupational hazards.3 A unique research focus, approach and priorities are needed for wildland firefighters.

Wildland firefighters are exposed to health hazards from inhalation of known air pollutants (eg, particular matter, carbon monoxide and polycyclic hydrocarbons) at levels near or above occupational exposure limits.4-6 Despite accelerating global wildland fire activity, knowledge on the health risks from occupational exposure to wildland fire is broad, inconsistent and insufficient to draw conclusions on health outcomes.7 8 To date, the majority of research on the health of wildland firefighters is focused on exploring acute effects of smoke exposure across a single shift or season, with most studies finding a...
engaged in wildland fire suppression. The purpose of this
development of appropriate mitigation strategies and
funding by organisations and governments, support the
coordinated and effective research plan, direct research
decision. Health research priorities are needed to ensure a
or other personnel involved in wildland fire suppres
health research priorities related to wildland firefighters
of cardiovascular disease and between wildland fire
fied associations between career length and occurrence
longitudinal trial. Cross-sectional studies have identified
this finding has yet to be confirmed in a prospective or
outside of the hazards from exposure to wildland fire
smoke, wildland firefighters are exposed to occupational
stressors due to the nature of the profession (eg, unpredict-
dictable extended deployments, trauma from seeing
homes or communities burned) and workplace culture
(eg, masculine dominance). Studies focusing on mental
health have identified an increased risk of post-traumatic
stress among wildland firefighters and increased suicide
risk. Fireline deployments have been associated with
fatigue resulting from poor sleep quality and quantity. Injuries are also commonly reported following work
as a wildland firefighter, related to fire complexity and
seasonal timing. Few studies have been published
evaluating strategies to reduce health risk. The broad
focus of these intervention strategies include prescribed
drinking interventions to support better thermal regula-
ion, mask wearing to reduce exposure to particulate
matter and enhanced skin hygiene (eg, showering,
laundering clothing) to reduce polycyclic aromatic
hydrocarbon exposure.

Health research priority setting is an important compo-
nent of participatory research approaches, can maximise
investments in research for funding organisations and
governments and help focus research efforts across broad
fields of study. Through research priority setting, people who stand to benefit the most from research,
known as stakeholders or knowledge users, can contribute
to the research process and direct research activities. In
relation to wildland fire, stakeholder voices include front-
line firefighters, people working in roles related to or
supporting direct fire suppression, occupational health
and safety policymakers and researchers. Health research
priority setting must be well defined in scope, inclusive
with broad representation, relevant to decision makers
and consider the specific research context.

Research priorities have been established to advance
wildland fire suppression knowledge and for under-
standing the general public health impacts of wildland fire
smoke. We are not aware of any stakeholder-identified
health research priorities related to wildland firefighters
or other personnel involved in wildland fire suppress-
ion. Health research priorities are needed to ensure a
coordinated and effective research plan, direct research
funding by organisations and governments, support the
development of appropriate mitigation strategies and
ultimately improve health and well-being for all workers
engaged in wildland fire suppression. The purpose of this
project was to identify health research priorities for wild-
land firefighters and related personnel.

METHODS

This study is part of a larger project to establish health
research funding priorities for the British Columbia
Wildfire Service (BCWS) based on gaps in literature and
stakeholder priorities. The protocol for this project has
been previously published. To align with public health
guidelines on physical distancing during the COVID-19
pandemic, we did not conduct meetings with stakeholders
to discuss research priorities as indicated in our original
protocol. Instead, we conducted virtual semi-structured
individual interviews with a sample of survey respondents
to contextualise identified research priorities, and enable
breadth representation given COVID-19 public health
guidelines on travel and the realities of the wildland fire
season.

The Delphi method is a process to gather stakeholder
knowledge and experience and is commonly used to
identify occupational health research priorities. The Delphi process allows for the collection of opinions from
a variety of stakeholders followed by the presentation
of ideas back to participants in iterative ‘rounds’ until
consensus is reached. For this study, we have followed
a modified Delphi method involving a two-stage online
survey (SurveyMonkey) with follow-up semi-structured
interviews. We modified a traditional Delphi approach by
combining qualitative and quantitative data and by not
having an expert panel meeting to achieve consensus
following the multiple round survey. Instead, we used a
modified Delphi approach to obtain a ranked list of
research priorities by inviting a broad range of stake-
holder participants (eg, people with lived experience
as experts). Based on similar work to establish research
priorities using a modified Delphi approach, we established a priori to conduct two survey rounds and
determined consensus was achieved when at least 70% of
respondents indicated the research priority was ‘very
important’ or ‘extremely important’ during the second-
round survey.

Participants were eligible to participate if they were
current or past employees of BCWS (as frontline wildland
firefighters or in officer/managerial roles), researchers
or trainees with an interest in wildland fire or employed
in occupational health and safety. Both surveys included
a basic demographic questionnaire querying age, gender
and role as it related to wildland fire. Interview partic-
ipants were asked to identify their job role, but we did
not collect further demographic information (eg, age,
gender) to protect participant confidentiality. Given the
relatively small sample pool, limited number of women
working for the BCWS and sensitive nature of the project
in relation to the participants’ workplace, the identity of
some participants may be easy to deduce based on their
role and was thus not collected or reported. At the end of
each survey, participants could enter a draw to win one
of five $C50 Amazon gift cards. All interview participants
were offered a $C10 gift card to a food or retail vendor of
their choice.
Round 1: identifying research priorities
An invitation to participate in the first survey was circulated in March 2020 via email to BCWS employees, occupational health policy makers (identified through our BCWS partners) and researchers who had recently published in the field (eg, contact information available on websites or as corresponding author). Participants were asked to list up to 10 research priorities of concern for wildland firefighters and up to 10 research priorities for related personnel in two separate lists (see online supplemental file 1). We conducted an inductive qualitative content analysis of responses. Three members of the research team read and re-read open-field responses to identify codes and key concepts provided by participants. Codes were then grouped into categories sharing common features. Discussion was used to reach consensus on final research topics. The two job categories, wildland firefighters and related personnel, were collapsed for the second survey because the topics identified by participants were similar.

Round 2: rating and ranking research priorities
The second survey was sent in June 2020 to participants who completed the first survey and expressed interest in continuing their participation. In the second survey, respondents were presented with the research topics identified in survey 1 and asked to indicate the importance of each topic on a modified 5-point Likert scale ranging from “not at all important” to “extremely important” (see online supplemental file 2). To prevent bias resulting from question order, the order of research topics was randomised for each survey respondent.

To determine the relative importance of each research topic, respondents were presented with all research topics and asked to rank them from most important to least important. To calculate the weighted average, each research topic in the data set was multiplied by the rank-weight assigned by each participant before the final means were calculated. For example, a weight of 10 would be given to the respondents’ highest priority, 9 to the second highest priority and so on. This was repeated for each respondent’s ranked research priorities. The mean weighted average was calculated for each research topic. Participant responses were separated by job category (eg, wildland firefighter, aviation crew) to determine if there was any difference in identified research priorities based on role.

Round 3: semi-structured interviews
Semi-structured interviews allowed the opportunity for participants to provide a nuanced description of identified research topics and to identify specific projects within each umbrella topic. Eligible interview participants were at least 18 years of age and had completed both surveys. We aimed for diversity in our sample based on length of time working in a wildland fire-related role and across different job categories (eg, researchers, wildland firefighter).

Interviews were conducted by two research team members over Zoom videoconference or telephone. One researcher took detailed field notes and the other facilitated the interview using a semi-structured interview schedule. Interviews were between 22–49 min in length (average: 34 min). The interview schedule (see online supplemental file 3) included open-ended questions about work-related health concerns, potential mitigation strategies and research questions or specific projects for each of the top five ranked research priorities.

Interviews were transcribed verbatim by a study team member. Field notes were used during analysis to provide additional contextual information. Analysis was conducted in two phases using a qualitative content analysis by two team members. First, we took a deductive approach to provide examples and nuanced description of each of the research topics identified in the survey. A structured categorisation matrix was created for the top five research topics based on ranking and consensus. The interview transcripts were coded for correspondence with each research topic (category); only data aligning to the matrix (eg, matched to a category or research topic) was chosen for the deductive phase of the analysis.

Data within each category was examined to determine if any subcategories were necessary. Items not explicitly aligned to one of the pre-identified research topics were analysed using an inductive approach to identify additional themes. Inductive open coding was completed to ensure we comprehensively represented content communicated by participants and to understand issues discussed by participants not directly related to the pre-identified research topics.

Patient and public involvement
Patients were not involved in this study.

RESULTS
Participants
Survey 1 was completed by 132 participants (92 men and 40 women; table 1). We are unable to calculate a response rate for the first survey because the invitation to participate was primarily circulated through a BCWS mailing list. Survey 2 was sent to 89 potential participants and completed by 75 respondents (response rate: 84%, 48 men and 27 women). Interviews were conducted with 14 participants: 7 current or prior wildland firefighters, 3 researchers or trainees and 4 people with administrative or officer roles.

Research priorities
More than 900 research areas were suggested from participants in survey 1 which were organised into 10 categories or research topics ranked by participants in survey 2. Consensus was achieved on 5 of the 10 research topics (figure 1). Understanding and mitigating effects of smoke inhalation on respiratory health (89% consensus), fatigue and sleep (80% consensus) and mental health (78% consensus) were
the research topics with the greatest consensus. While consensus was not reached across the entire cohort of respondents regarding the priority of long-term risk and prevalence of disease other than respiratory (67% consensus across entire sample), within the subset of wildland firefighters and aviators, there was 81% consensus on the priority of the topic. Additionally, for the research topic camp conditions, there was consensus (74%) within the subset of zone and control staff.

When looking at the weighted rank of each research priority, the pattern was consistent with the research priorities achieving consensus, with two notable differences. Work structure and organisational culture was the fifth topic to satisfy the consensus requirement of a rating greater than 70%; however, it had the sixth highest weighted average. Long-term risk and prevalence of disease other than respiratory was ranked fourth by participants when considering the weighted average; however, it did not reach consensus (67%; table 2). The role of a respondent did not appear to influence the ranking of research priorities. Four of the top five areas of research as identified through the weighted average (Understanding and mitigating effects of smoke inhalation on respiratory health, fatigue and sleep, mental health and stress) also have consensus ratings greater than 70%; therefore, any further research in these four areas would be addressing priority areas as identified by stakeholders.

**Interview findings**

In general, interview participants agreed with the ranked list of research priorities. Based on a deductive analysis, we generated areas of focus (subcategories) for three of the top five-ranked research topics (table 3). For some research topics, no subcategories were developed.

From the inductive interview analysis, we developed two overarching principles as themes relevant to every research topic:

**Understanding the dynamic risk environment**

Participants described the importance of understanding health risk and exposure across different roles. For example, people who work in office environments do not face the same exposures:

> the office stuff or the staff that are there, I don’t think they have the same concerns around smoke exposure and physiological toxins. (P8, researcher)
This different exposure may translate to different health research priorities. For instance, auxiliary staff who are typically students hired during the summer wildland fire season (May to August) may not be as concerned with long-term health risk when compared with people who work in wildland fire-related roles for their entire career:

if we’re looking at an older population of firefighters, whether that be more the career wildland firefighters, I think the health priorities, the health shifts a bit. Um, in that, I’d be more concerned about a mixture of cardio-respiratory factors. Um, whether or not long-term exposure to wildland smoke might be related to later in life—like, um, uh, like lung pathologies or you know, if there’s any risk factors for cardiovascular disease. (P6, researcher)

It is also important to understand and explore risks across multiple seasons because the unpredictability in fire activity may contribute to different health risks:

We think of those big fire seasons, 2017, 2018, even 2015, and like the work component is very fatiguing, but um, it’s also very engaging. And then we have slower seasons like this one [2020] and we may not think of it as harder on our mental health, because we’re not doing as much. But I do think it actually creates different challenges for people. So, I think that’s something that we need to be aware of— even though we’re not on fires, there are stressors associated with the job and it might actually be harder for people because they [do not] have that active engagement in what we see as really fulfilling work. (P4, wildland firefighter)

It really depends on the year. Because some, uh, some seasons they’re so busy, and some seasons they’re so slow. There’s going to be like different, there’s different things people care about in each, kind of different, when things are busy. (P1, wildland firefighter)

Finally, the unpredictable work structure and schedule imposes barriers and challenges to conducting research:

I mean our unpredictable work schedule could be tough for research, but the way you guys have been sending out like the surveys that we do on our own time has been awesome. Like, if we can just sit down and just take 20 min, then by all means. But if you need to like come into our workplace and try to organize that research is a bit tougher. (P3, wildland firefighter)

Organisational fit of mitigation strategies

Participants emphasised any mitigation strategy be worker-centred, reflect worker priorities and needs, and be developed with employees. This was reflected in participants discussing that management may not always have a feel for what it is like to work on the front-line and any mitigation or management strategy not aligning with organisational realities would have minimal uptake.

people are so resistant to like any change, any, and I think it’s a part of that whole disparity between management – like this is something else management’s pushing down, oh they have no concept, like just ignore it...like that whole dynamic of like, just like, people sitting in office, and us like grinding out there. (P5, wildland firefighter)

Relatedly, participants discussed how organisational culture and resistance to change could present a barrier to implementing mitigation strategies:

the biggest challenge I come across is like the ‘this is the way we do things’ kind of attitude. (P8, researcher)

And then the organizational culture about, sort of a can-do organization and you know, we can, we get a
| Research topic (category) | Areas of focus (subcategory) | Examples of meaning unit (quotes) |
|---------------------------|------------------------------|----------------------------------|
| Understanding and mitigating effects of smoke inhalation on respiratory health | Development of appropriate mitigation strategies | “it’s demoralizing sometimes being out there and not having a mask when you see, [like] … Police officers, or other agencies that are assisting us with different things, like not even really in the smoke, and wearing like large masks to protect their health, so. Um, I think it’s definitely valuable to continue looking into that and to continue pushing to get us some, um, sort of lung protection. Cause, you, you [sic] definitely feel it., Like after fire season your lung capacity is, um, it’s [sic] not what it was at the beginning of the season” (P1, wildland firefighter) |
| Fatigue and sleep | | “I think most firefighters are pretty aware that it’s not good to be breathing in what we’re breathing in, but we’re just at this standstill of what it seems like finding the right PPE that’s appropriate for the job. So, I think research sort of on that more practical side on what, like what apparatus is going to work for us would be really important at this stage” (P4, wildland firefighter) |
| | | “You know, actual things other than like bring a mask, like if wearing mask is the only way, great. But also, beyond wearing a mask, which I think would take a while to find the right mask and the right buy in, what are the real facts, don’t do it? It’s like if you’re doing it, what’s the distances, like a lot of information about, people will be around smoke[sic], probably not wearing masks at some point. What are ways to mitigate, or like mitigate some of those things in alternate ways?” (P5, wildland firefighter) |
| | Understand exposure | “like the smoke inhalation, like what does that look like? Like what particulates, how much, like exposure, which kind of smoke you’re putting in, like how, what factors influence that, like what you’re actually doing and how can you like minimize that” (P5, wildland firefighter) |
| | Determine optimal amounts of sleep | “the obvious one that stands out to me, that like, you know, I notice a lot more on the line, is that sort of long-term exposure piece to smoke. Um, it would probably be like fine particulate matter. Cause, there’s a lot of times where, you know, in the later stages of a fire we are looking for smoke and looking for heat, and on our hand and knees in very, very [sic] fine ash with no PPE and um, and I think that probably proposes like a significant health risk. Um, I know it’s been documented in other fields that kind of any really fine particulate matter like that is detrimental to your lungs, and we just go in with zero PPE and zero information about it” (P14, wildland firefighter) |
| | Understand impacts of long-term fatigue | “what is the optimal amount, amount of sleep that like a firefighter should be getting? Or what is the optimal amount of rest in order to fully, like, kind of reset our minds and reset our bodies, uh to get ready for that next fourteen-day deployment. I don’t know, like fourteen to three just seems like it was pulled out of the air, so, um, I’d be curious to know like what, what is the proper amount of rest that we should be getting” (P1, wildland firefighter) |
| | | “the quality of sleep, the length of shifts and whether or not they’re able to achieve—or obtain—quality sleep while they’re in the field, and whether or not that is, um, impacting on their safety while working” (P6, researcher) |
| | | “when you have, have 8 hours off between shifts, including you know going home, cooking a meal, taking a shower, all things that you do at home, so that adds up over time. So yeah, I think it’d be interesting to see how that would affect um kind of like overall fatigue, long term fatigue” (P2, wildland firefighter) |
lot done—yes—we can take care of things, and this is the way we’ve always done it. And uh, yeah, it’s certainly an organization, I think. The—yeah—so just sort of pushing through that organizational culture. (P13, administrative/office role)

DISCUSSION

Following best practice guidelines for research priority setting,27 28 the aim of this project was to identify health research priorities for wildland firefighters and related personnel. Five research topics achieved consensus across
the entire sample: understanding and mitigating effects of smoke inhalation on respiratory health, fatigue and sleep, mental health, stress and work structure and organisational culture. A sixth research topic, long-term risk and prevalence of disease other than respiratory, nearly reached consensus (81%) among people involved in direct fire suppression. Designing and conducting research to understand the cumulative impacts of multiple seasons of wildland fire exposure is a considerable challenge and the long-term health impacts of wildland firefighting are poorly understood, although we do note ongoing work by the US National Institute for Occupational Safety and Health. In British Columbia, many front-line wildland firefighters are post-secondary students hired as auxiliary employees during the summer (May to August) wildland fire season. The transient and mobile workforce creates considerable challenges to evaluating risk related to morbidity and mortality outcomes over multiple seasons. Similarly, the unpredictability of a given fire season means generating consistent evidence or measuring changes in health outcomes across any one season is challenging due to the variable exposure. For example, some participants mentioned unique challenges during less active fire seasons such as a different mental health toll from not being able to engage in work they enjoy and find meaningful. Thus, while some fire seasons may be ‘quieter’ in terms of fire activity and respiratory health risk (eg, lower smoke exposure), they may impose a different mental health risk. While our research priorities can be used to support researchers to make decisions on prioritising collective research efforts, findings also suggest the need for sustainable, flexible research infrastructure to adapt and understand variable risk environments.

Limitations
The email invitation to participate was sent in March 2020. This was done to ensure data collection was not impacted by the busiest point in the fire season (typically June to August in British Columbia). Because of this, many auxiliary/seasonal staff had not yet started work and may be under-represented in our sample. Participants were asked to list their top 10 research priorities for wildland firefighters and related personnel separately in the first survey. Based on very similar research topics identified for both job categories and suggestions by participants in the open field question, we collapsed the two job categories for the stage 2 survey. This may have reduced our ability to tease out specific research topics for related personnel and identified research priorities are likely more applicable to wildland firefighters. Occupational health policymakers and researchers were identified by convenience sampling through our partnership with BCWS and by extracting contact information from recently published papers in the field, which may have limited the breadth of stakeholder participant perspectives.

CONCLUSIONS
This project represents the first attempt to develop a comprehensive set of research priorities for wildland
Wildland fire exposure and health: A framework for action.

Firefighters and related personnel. Our process included a broad range of stakeholders, from frontline staff to those working in occupational health and safety policy, with national and international representation. Stakeholders consistently identified the need for research to understand the physical and mental health risks of wildland firefighting, and how this risk may lead to long-term morbidity and mortality across multiple fire seasons or an entire career. Appropriate, feasible mitigation, prevention and/or management strategies are urgently needed to address health concerns for workers directly or indirectly engaged in wildland fire suppression.

Contributors CP lead study conception and design, data collection, analysis and manuscript writing, and is the guarantor of this work. CR was involved in the development, distribution and analysis of online surveys, and assisted in preparation of the manuscript. KB supported interview data collection, transcription, interview analysis and preparation of the manuscript. TMF, EK and KC provided critical feedback on data collection, study design, assisted with survey and interview analysis. All authors participated in the interpretation of the results, provided critical revision of and approved the final manuscript.

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ORCID iD Chelsea Pelletier http://orcid.org/0000-0002-8009-8014

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