

A Breath of Fresh Air - Evaluating the risk perception of residents in British Columbia regarding wildfire smoke inhalation and smoke mitigation methods

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Abstract

Background

In recent years, there have been an increasing number of wildfire events. The effects of global climate change play a big role in the severity and length of these wildfire events. Prolonged periods of wildfire smoke in the air can negatively impact health by causing respiratory distress and exacerbating pre-existing conditions. Many regions have implemented smoke mitigation methods like community clean air shelters, but risk perception can influence whether or not these methods are effectively used. The purpose of this study is to evaluate the risk perception of residents in British Columbia regarding wildfire smoke inhalation and smoke mitigation methods.

Methods

A survey was distributed to residents living in British Columbia to evaluate their risk perception of wildfire smoke and use of smoke mitigation methods. The online survey was created with Survey Monkey, distributed via Facebook, Twitter, and Reddit, and took approximately five minutes to complete. The results were collected in Microsoft Excel and analyzed with NCSS statistical software.

Results

Chi-square tests showed a significant association between gender and the risk perception of inhaling wildfire smoke, exercising outdoors during a smoke event, going outside during an air quality advisory, and the decision to find a clean air space during a smoke event. There were some associations with age and geographical region as well. Results showed that most people practice some form of smoke mitigation, such as staying indoors, seeking refuge in a clean air space, and using masks and/or portable air filters.

Conclusions

Based on the results, gender has a significant impact on risk perception of wildfire smoke inhalation. Other demographics, such as age, geographical region, education, and ethnicity, did not display many significant associations. This study also identified that participants may have conflicting views about the protectiveness of a surgical/cloth mask during a smoke event. Most participants practiced some form of smoke mitigation method, like staying indoors.

Keywords: Wildfire smoke, smoke mitigation, clean air shelters, risk perception, British Columbia

Introduction

At the 2019 United Nations Climate Action Summit, Swedish environmentalist Greta Thunberg said it best: *“change is coming, whether you like it or not.”* The devastating effects of climate change are becoming more and more prevalent and can no longer be ignored. Infectious disease pandemics, loss of biodiversity, extreme weather events, and depletion of the ozone layer are just a few of the problems we face now. One such threat is forest wildfires, and societies need to adapt accordingly to these emerging changes.

Wildfire smoke inhalation has a detrimental effect on health due to microscopic particulates less than 2.5 microns in size, most commonly referred to as PM2.5. (BCCDC, 2019) PM2.5 is frequently referenced to in guidelines and air quality standards around the world. Public health initiatives need to prioritize vulnerable populations, which include pregnant women,

infants and young children, people with pre-existing health conditions, and the elderly. Furthermore, the goal of disseminating educational tools is to empower communities to respond effectively to wildfire smoke events on their own, before *and* during the actual event. By surveying the public about their knowledge of wildfire smoke inhalation, smoke mitigation methods, and their behaviours during a wildfire smoke event, conclusions can be drawn about significant knowledge gaps and where to allocate resources accordingly.

Literature Review

Health Effects of Wildfire Smoke

Acute exposure to fine and ultrafine particulates can cause adverse respiratory symptoms, like exacerbation of asthma and COPD, coughing, difficulty breathing, wheezing, and eye and nose irritation. (Stone et al., 2019)

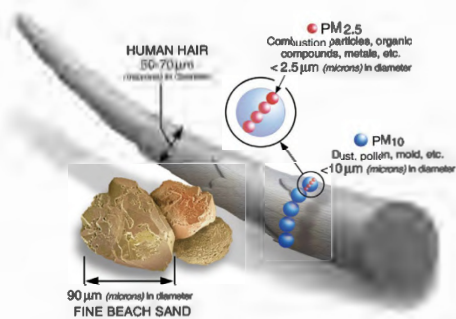


Figure 1. Size of PM_{2.5} (Bliss Air, 2019)

Long-term exposure of wildfire smoke in wildland firefighters has been studied, but studies on chronic exposure in the public are few and far between. Black et al. determined that lung function in wildland firefighters can return to baseline levels over a long follow-up period, but Stone et al. stated that it is difficult to compare a firefighter's occupational exposure to exposure experienced by the general public. (Black et al. & Stone et al., 2019) Kunzli et al. found that communities with long-term smoke pollution had increased reports of children with bronchitis and school absences, highlighting the fact that chronic exposure can lead to increases in hospital admissions, regardless of occupation. Studies suggest that wildfire smoke exposure is associated with cardiovascular disease, but there is insufficient evidence to link a consistent association between wildfire smoke and cardiovascular morbidity. The association is most consistent in North America, but it is important to take into account that cardiovascular disease is more prevalent in those study areas compared to others. (Barn et al., 2016)

Wildfire smoke can also affect mental health. It can increase stress, feelings of isolation, and negatively impact existing mood and/or anxiety disorders. (Stone et al., 2019) As a matter of fact, there is a significant increase of emergency calls from seniors that have mood and/or anxiety disorders during periods of long-term smoke exposure. (Maguet et al., 2018) However, some literature reviews do not account for these mental health issues because they are not direct physical health consequences, so there could be an underestimation of health effects in those studies. (Liu et al., 2015)

Public Resources

The Air Quality Health Index (AQHI) is a public communication tool that measures air quality, assigns a numerical value to it according to health risk, and recommends protective actions during times of poor air quality. A limitation of this tool is that it is only found online, so individuals without internet access may not be able to view it. The AQHI also only provides a short-term forecast, generally up to twenty-four hours in advance.

In addition to these online resources, the Ministry of Environment issues Wildfire Smoke Advisories and Smoky Skies Advisories when smoke concentrations in a

region reach levels that adversely affect human health. Advisories and warnings can be accessed via television news outlets, mobile apps, newspapers, radio, public meetings, text messages, and online websites. (BCCDC, 2017)

Public Perception of Risk

In order to make effective decisions during wildfire smoke events, community perception of health risks must be taken into account. (Macey, 2008) Individuals that have strong environmental values may be more aware of the health risks associated with wildfire smoke, along with individuals that have health conditions that can be exacerbated by smoke inhalation. Demographic factors like gender, education, occupation, and ethnicity can also affect perception. One study found that women, African-Americans, and Hispanics tended to be more concerned about health risks compared to Caucasian respondents. (Maguet et al., 2018) Both Dix-Cooper et al. and Kunzli et al. agreed by stating that certain subgroups, such as women, persons with asthma, and persons with higher earning incomes, were more likely to stay indoors and listen to advisories during wildfire smoke events. Parents with young children were also more likely to listen to public service announcements and adopt preventative measures. (Dix-Cooper et al., 2014 & Golden, 2019) Some populations that

are less likely to hear advisories require targeted approaches. For example, distributing smoke advisories in different languages for people with English as their second language. (Dix-Cooper et al., 2014) It is also important to acknowledge that community perceptions shift over time. Initial concerns are high at the beginning of wildfire smoke events, but people become less concerned over time and resume normal activities, such as outdoor sports and exercise. This could be due to lack of awareness or the need to go outside during long periods of staying indoors. (Macey, 2008) One study even found that survey respondents viewed wildfire smoke as less dangerous than air pollution from other sources because it was 'natural'. (Liu et al., 2015)

Smoke Mitigation Methods

Home and community clean air shelters (HCAS & CCAS) can be used during wildfire smoke events by incorporating higher levels of filtration, portable or induct, during periods of poor air quality. The use of high efficiency particulate air (HEPA) filters can drastically reduce PM2.5 levels. Large air-conditioned spaces such as libraries, retirement homes, shopping malls, and community centres can be turned into CCAS, depending on feasibility. It is important to ensure that CCAS are easily accessible by

public transit, spacious enough to house large groups of people at once, and located in areas where local residents can't afford filtration systems for their own homes. (Allen et al., 2014) The City of Seattle has conducted a pilot program by establishing five high-tech CCAS as a response to previous summer wildfires. (Huang et al., 2019) Taking advantage of existing public buildings is an efficient approach, but not all buildings are equipped with the proper heating, ventilation, and air conditioning (HVAC) system required. (Barn et al., 2016) Additionally, smaller municipalities may be reluctant to provide CCAS due to lack of funding. (Maguet et al., 2019)

Filtering half facepiece respirators (FHFR) like N-95 masks can provide protection against wildfire smoke, *only* if fitted properly to the individual. Surgical masks are frequently used during wildfire smoke events, but are not properly designed to filter contaminated air. (Elliott & Rideout, 2014) Provincial guidelines include FHFR masks as a public health intervention, but realize that wearers might have a false sense of security and therefore resume regular outdoor activities. (Maguet et al., 2018) Elliott et al. added that there is limited evidence on FHFR use and its effectiveness as an individual-level mitigation method during wildfire smoke events. (Elliott & Rideout, 2014)

Cancelling or modifying outdoor events when air quality is poor is another smoke mitigation method. There is no associational evidence between cancelling outdoor events and health outcomes due to wildfire smoke, but an effect likely exists if event participants have access to an alternative location with cleaner air. Decreasing the duration of the event, changing locations, or postponing the event date are also alternatives. Educating the public about potential risk, providing alternatives, and allowing them to make their own informed decisions is also another option to consider. (Dix-Cooper & Elliott, 2014)

Methods and Materials

Complete Description of Materials Used

The materials used for this research project were a Macbook Air computer, Microsoft Excel 2019, Microsoft Word 2019, NCSS software, Facebook, Twitter, Reddit, and Survey Monkey. (2020)

Description of Methods Used

An online self-administered survey was distributed on January 25th, 2020 to residents living in British Columbia. The online survey was created by using Survey Monkey software and took approximately five minutes for participants to complete. It was distributed primarily via Facebook, Twitter, and Reddit. (2020) The survey link was

posted to Facebook groups and Reddit threads. It was also posted to specific community subreddits, such as the Kamloops, Prince George, and Kelowna subreddits.

The first question participants had to answer was whether they were a resident of British Columbia or not. The participants that answered 'No' were excluded from the study. Contact information was left in the consent form in case participants wanted to contact the principal investigator if they had any questions, comments, or concerns. There was the option of conducting the survey in person, over the telephone, or through mail, but these options weren't considered due to time restraints.

Inclusion and Exclusion

Residents living in British Columbia over the age of 18 were included in the study. Any participant other than a B.C. resident over the age of 18 were excluded.

Ethical Considerations

All surveys that involve human participants require ethics approval from the Research and Ethics Board (REB) at BCIT. The survey results were kept anonymous by disabling IP tracking on Survey Monkey. Some questions have a 'I don't know' or 'prefer not to answer' option in case the participant did not feel comfortable answering the question. A

consent form and cover letter were shown at the start of the survey. Participants were informed that survey participation is voluntary and that they could withdraw at any time without penalty or explanation. Data was stored in a secure password-protected computer in Canada. Ethical approval from the BCIT REB was obtained before the start of the survey, along with project supervisor approval.

Statistical Analyses and Results

Description of Data

Dichotomous binary, multichotomous nominal data, and ordinal data were collected. A total of 14 questions were asked. The first section consisted of demographic questions, which included age, gender, ethnicity, geographical region, and education. The second section included questions regarding wildfire smoke inhalation and smoke mitigation methods. Some questions had a 'I don't know' or 'prefer not to answer' option to eliminate random guessing and to provide a separate option for sensitive questions. For the analysis, the 'prefer not to answer' options were omitted due to the outlier effect. However, the 'prefer not to answer' options have been included in the descriptive data to show that those results were collected in the survey.

Null and Alternative Hypotheses

H₀ & H_a	Test Used	Result (p-value)	Conclusion
<p>H₀ : There is no association between gender and the risk perception of inhaling smoke during a wildfire smoke event in BC.</p> <p>H_a : There is an association between gender and the risk perception of inhaling smoke during a wildfire smoke event in BC.</p>	Chi-square test	0.00972	The p-value is < 0.05, therefore we reject the null hypothesis that there is no association between gender and the risk perception of inhaling smoke during a wildfire smoke event in BC and accept the alternate hypothesis. Acceptable alpha can be lowered from 0.05 to 0.01 to avoid a type 1 error.
<p>H₀ : There is no association between gender and the risk perception of exercising outdoors during a wildfire smoke event in BC.</p> <p>H_a : There is an association between gender and the risk perception of exercising outdoors during a wildfire smoke event in BC.</p>	Chi-square test	0.00299	The p-value is < 0.05, therefore we reject the null hypothesis that there is no association between gender and the risk perception of exercising outdoors during a wildfire smoke event in BC and accept the alternate hypothesis. Acceptable alpha can be lowered from 0.05 to 0.01 to avoid a type 1 error.
<p>H₀ : There is no association between gender and the decision to go outside during an air quality advisory in BC.</p> <p>H_a : There is an association between gender and the decision to go outside during an air quality advisory in BC.</p>	Chi-square test	0.00458	The p-value is < 0.05, therefore we reject the null hypothesis that there is no association between gender and the decision to go outside during an air quality advisory in BC and accept the alternate

			hypothesis. Acceptable alpha can be lowered from 0.05 to 0.01 to avoid a type 1 error.
<p>H₀ : There is no association between gender and the decision to find a clean air space during a wildfire smoke event in BC.</p> <p>H_a : There is an association between gender and the decision to find a clean air space during a wildfire smoke event in BC.</p>	Chi-square test	0.02850	The p-value is < 0.05, therefore we reject the null hypothesis that there is no association between gender and the decision to find a clean air space during a wildfire smoke event in BC and accept the alternate hypothesis. Acceptable alpha can be lowered from 0.05 to 0.01 to avoid a type 1 error.
<p>H₀ : There is no association between age and the risk perception of inhaling smoke during a wildfire smoke event in BC</p> <p>H_a : There is an association between age and the risk perception of inhaling smoke during a wildfire smoke event in BC</p>	Chi-square test	0.43315	The p-value is > 0.05, therefore we accept the null hypothesis that there is no association between age and the risk perception of inhaling smoke during a wildfire smoke event in BC and reject the alternate hypothesis.
<p>H₀ : There is no association between age and the risk perception of exercising outdoors during a wildfire smoke event in BC.</p> <p>H_a : There is an association between age and the risk perception of exercising</p>	Chi-square test	0.08419	The p-value is > 0.05, therefore we accept the null hypothesis that there is no association between age and the risk perception of exercising outdoors during a wildfire smoke event in BC

<p>outdoors during a wildfire smoke event in BC.</p>			<p>and reject the alternate hypothesis.</p>
<p>H₀ : There is no association between age and the decision to go outside during an air quality advisory in BC.</p> <p>H_a : There is an association between age and the decision to go outside during an air quality advisory in BC.</p>	<p>Chi-square test</p>	<p>0.07004</p>	<p>The p-value is > 0.05, therefore we accept the null hypothesis that there is no association between age and the decision to go outside during an air quality advisory in BC and reject the alternate hypothesis.</p>
<p>H₀ : There is no association between age and the decision to find a clean air space during a wildfire smoke event in BC.</p> <p>H_a : There is an association between age and the decision to find a clean air space during a wildfire smoke event in BC.</p>	<p>Chi-square test</p>	<p>0.03243</p>	<p>The p-value is < 0.05, therefore we reject the null hypothesis that there is no association between age and the decision to find a clean air space during a wildfire smoke event in BC and accept the alternate hypothesis. Acceptable alpha can be lowered from 0.05 to 0.01 to avoid a type 1 error.</p>
<p>H₀ : There is no association between geographical region and the risk perception of inhaling smoke during a wildfire smoke event in BC</p> <p>H_a : There is an association between geographical region and the risk perception of inhaling smoke during a wildfire smoke event in BC</p>	<p>Chi-square test</p>	<p>0.02640</p>	<p>The p-value is < 0.05, therefore we reject the null hypothesis that there is no association between geographical region and the risk perception of inhaling smoke during a wildfire smoke event in BC and accept the alternate hypothesis. Acceptable alpha can be</p>

			lowered from 0.05 to 0.01 to avoid a type 1 error.
<p>H₀ : There is no association between geographical region and the risk perception of exercising outdoors during a wildfire smoke event in BC.</p> <p>H_a : There is an association between geographical region and the risk perception of exercising outdoors during a wildfire smoke event in BC.</p>	Chi-square test	0.84746	The p-value is > 0.05, therefore we accept the null hypothesis that there is no association between geographical region and the risk perception of exercising outdoors during a wildfire smoke event in BC and reject the alternate hypothesis.
<p>H₀ : There is no association between geographical region and the decision to go outside during an air quality advisory in BC.</p> <p>H_a : There is an association between geographical region and the decision to go outside during an air quality advisory in BC.</p>	Chi-square test	0.34762	The p-value is > 0.05, therefore we accept the null hypothesis that there is no association between geographical region and the decision to go outside during an air quality advisory in BC and reject the alternate hypothesis.
<p>H₀ : There is no association between geographical region and the decision to find a clean air space during a wildfire smoke event in BC.</p> <p>H_a : There is an association between geographical region and the decision to find a clean air space during a wildfire smoke event in BC.</p>	Chi-square test	0.49265	The p-value is > 0.05, therefore we accept the null hypothesis that there is no association between age and the decision to find a clean air space during a wildfire smoke event in BC and reject the alternate hypothesis.

Results of Descriptive Statistics

Figure 2 shows the location of participants. 30.15% of participants are from Thompson Okanagan, 28.64% are from Mainland/Southwest, 20.60% are from Vancouver Island/Coast, 8.54% are from Cariboo, 7.29% are from the Kootenays, 3.05% are from the North Coast, and 0.25% preferred not to answer.

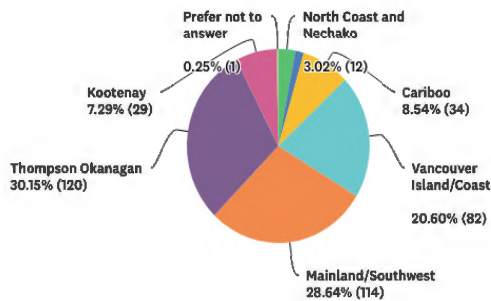


Fig 2. Geographical location of survey participants

Figure 3 shows the age of participants. Most of the participants lie within the 19-29 years range or the 30-39 years range. This could primarily be due to the fact that social media was used to gather participants for the survey.

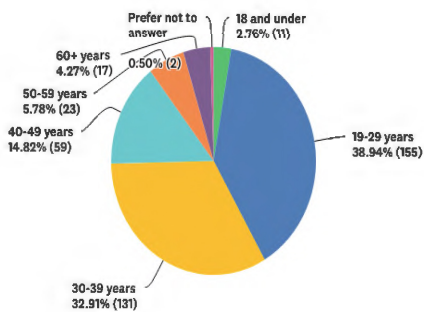


Fig 3. Age of survey participants

Figure 4 shows the gender of survey participants. 39.39% of participants are female while 55.30% of participants are male. 3.03% preferred not to answer. 2.27% identified as another gender that wasn't listed.

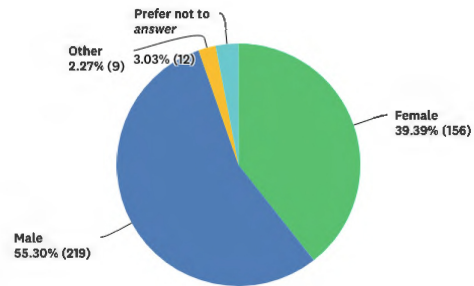


Fig 4. Gender of survey participants

Figure 5 shows the ethnicity of survey participants. 71.97% answered Caucasian, while 15.40% answered Asian/Pacific Islander. The graph shows Black/African American and Hispanic/Latino categories, but they were removed in the statistical analysis because they are outliers.

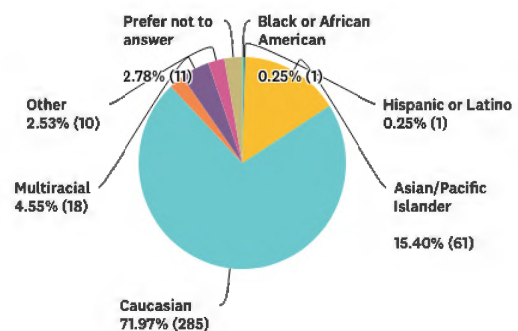


Fig 5. Ethnicity of survey participants

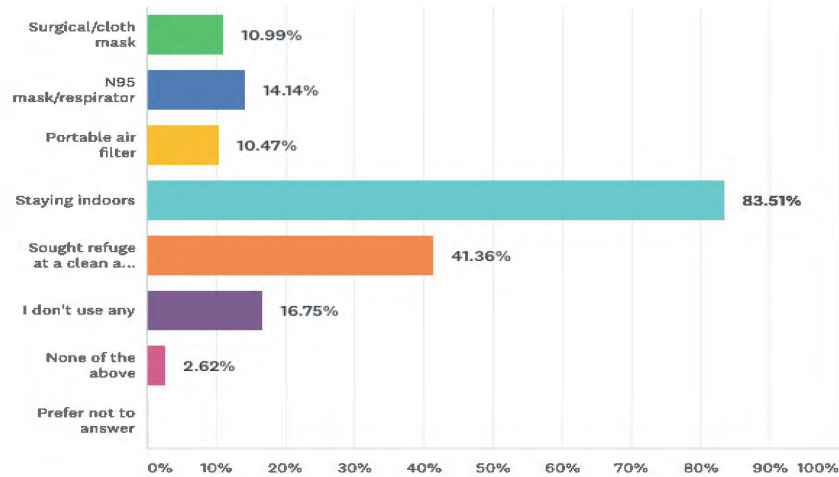


Fig 6. Smoke mitigation methods of survey participants

Figure 6 shows the smoke mitigation methods that are used by the survey participants. The most popular methods were staying indoors, seeking refuge at a clean air space, and using some form of a cloth mask or N95 respirator. 16.75% responded that they don't use any mitigation method at all. 2.62% responded that they don't use any of the above methods.

Discussion

Results revealed significant associations between gender and risk perception. Even with lowering the alpha to 0.01 to account for any alpha errors, there were statistically significant p-values that fell under 0.01. (Heacock, 2019). For example, there was an association between gender and the risk perception of exercising outdoors during a wildfire smoke event in B.C., with a p-value of 0.00299. These results imply that there is a significant association between gender and risk perception, and approaches that target gender may be more effective than targeting any other demographic.

Numerous chi-square tests were run to test the hypotheses between risk perception and practices with demographic factors, such as ethnicity, education, geographical region, and age. Most of these results were not statistically significant. A larger representative sample is required to accurately test the null and alternate hypotheses. This could be due to the fact that certain demographics were not representative of the true population. For example, the majority of participants who took the survey were Caucasian and relatively young, which could have an effect on the results.

Participants were asked whether they were more willing to go outside during a smoke event if they were wearing a cloth mask. The results were divided, with approximately 13% that strongly disagreed, 30% that disagreed, 30% that neither agreed nor disagreed, 23% agreed, and 2% that strongly agreed. These results suggest that there are divided perceptions about how protective a cloth mask is, and that more education is needed about the effectiveness of such masks.

Many survey participants used some form of smoke mitigation method. The most commonly used methods were staying indoors, so community clean air spaces may be effective during periods of poor air quality. Most survey participants based their decision to go outside based on air quality advisories. Participants agreed with the idea of visiting a clean air space during a wildfire smoke event. This shows that the general public are aware, or at least slightly aware, of the health risks that wildfire smoke poses and that they should heed warnings and take preventative measures.

Limitations

One limitation of this research study was only involving participants with access to internet and/or social media, which could have skewed the results. It is a possibility that people with access to the internet and are

well-versed in social media platforms are more well-informed and have a greater wealth of resources at their disposal, which might have affected their risk perception of wildfire smoke and the types of smoke mitigation methods they used. Another limitation was only offering the survey in English. Those who cannot read or speak English might have differing perceptions of risk compared to the population that was gathered for the survey.

Knowledge Translation

Based on the results of the study, there is a need for more public education about the risks of wildfire smoke inhalation and effective ways to mitigate smoke inhalation. The British Columbia Centre for Disease Control has already developed information fact sheets for the general public, but there may be members of the public that do not know how to search for the information or they do not have access to internet. Vulnerable populations like pregnant mothers and elderly people should also be targeted. Information in the form of physical brochures, flyers, or pamphlets can be provided in community centres, long-term care facilities, and even prenatal classes. Results of this survey can advocate for community clean air shelters that provide temporary relief during wildfire smoke events. These clean air shelters should be

large enough to hold many people and be sources of useful information and entertainment. Suitable examples include recreational centres, shopping malls, libraries, retirement homes, or any other public building that fit the above criteria. They should be easily accessible by active transport (ie: walking or cycling) and transit, and located in a heavily-populated area. Municipalities should invest in these clean air spaces and place them in heavily populated city centres that are easily accessible by active transport or transit systems.

Future Research

Although an online survey was conducted for this specific research project, there was a chance that other groups may have been left out unintentionally. Future research topics include:

- What is the risk perception of at-risk populations (ie: the elderly, pregnant mothers) regarding wildfire smoke inhalation?
- What is the knowledge level of Facility, Maintenance, and Operations (FMO) Managers of public and private buildings regarding wildfire smoke preparedness?

Conclusions

Based on the results of the survey, residents in British Columbia perceive wildfire smoke inhalation as generally risky, and there was a

significant association between gender and risk perception. From the results of this study, the general public has some idea of smoke mitigation and prevention, so health organizations should focus on specific initiatives and education, such as community clean air shelters and clarifying the effectiveness of cloth masks against wildfire smoke. The practical significance of these results show that the general public is willing to use clean air shelters and that their implementation should be considered in future emergency responses.

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Competing Interests

The author declares that they have no competing interests.

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