

Designing Surveys to Investigate the Impacts of Wildfire Smoke on Human Health

by
Samuel Joel Attridge

A THESIS

submitted to
Oregon State University
Honors College

in partial fulfillment of
the requirements for the
degree of

Honors Baccalaureate of Science in BioHealth Sciences
(Honors Scholar)

Presented June 2nd, 2023
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Abstract approved: _____

Diana Rohlman

Wildfires are increasing in frequency. One area of research interest centers on the pollutants within wildfire smoke, including but not limited to particulate matter and polycyclic aromatic hydrocarbons. These chemicals are associated with exacerbation of respiratory, cardiovascular, dermatological, reproductive, oncological, gastrointestinal, and infectious conditions. As wildfires becoming increasingly prevalent, it will be important for researchers and clinicians to have access to surveillance tools that allow insight into how wildfire smoke exposure is affecting the health of certain populations. We developed a survey tool to characterize exposure to wildfire smoke and subsequent self-reported health outcomes. I first conducted a literature search to identify known and potential negative health outcomes associated with exposure to wildfire smoke. I found a total of 24 articles assessing a total of eight outcomes (cardiac, respiratory, dermatologic, gastrointestinal [GI], oncologic, gestational, COVID-19, and influenza). I used this information to conduct a literature search for survey tools. I used 10 surveys of eight outcomes (cardiac, COPD, asthma, smoking status, dermatological, GI, gestational, and recent infection) to develop a novel surveillance tool. The tool has 11 modules, 142 questions and is anticipated to take 40 minutes on average when self-administered.

Keywords: wildfire, pollution, PM_{2.5}, PM₁₀, PAH, survey

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APPROVED:

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I understand that my project will become part of the permanent collection of Oregon State University, Honors College. My signature below authorizes release of my project to any reader upon request.

Samuel Joel Attridge, Author

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Introduction

Wildfires present physical and chemical hazards to human health (Black et al., 2017; Marshall et al., 1998). Smoke from wildfires is a multicomponent mixture that can have a varying degree of health effects on exposed populations, potentially due to differences in composition (Rohlman et al., 2023). Wildfires can have devastating impacts on the communities they affect. Wildfire smoke already poses a heavy burden to communities around the globe, and may become even more of a burden in the future. The area burned per year by wildfires is likely to increase as anthropogenic climate change continues to raise the average annual temperature of Earth (Zhuang et al., 2021). Exposure to wildfire smoke can lead to increased morbidity and mortality (Agbeshie et al., 2022; Albery et al., 2021; Rohlman et al., 2023; To et al., 2021).

COMPOSITION OF WILDFIRE SMOKE

Smoke from wildfires is a toxic mixture of many compounds, including particulate matter (PM) of different sizes, such as PM_{2.5} and PM₁₀, polycyclic aromatic hydrocarbons (PAHs), and ozone (O₃) (Black et al., 2017). Vegetation that is dry may produce wildfire smoke with different chemical composition, or different ratios of PM_{2.5}, PM₁₀, PAHs, and O₃ (Zhang et al., 2013). For a full review of pollutants found in wildfire smoke, refer to (Black et al., 2017). Below, I discuss PM and PAHs.

PM_{2.5} is one of many pollutants released during biomass burning (Cleland et al., 2022). PM_{2.5} is particulate matter that is 2.5 microns (µm) or less in diameter. Among the compounds in PM_{2.5} are organic materials, minerals, elemental carbon, ammonia, and sulfate (Cao et al., 2018; Liu et al., 2020). PM_{2.5} from wildfire smoke commonly is composed of aliphatic acids and aromatic compounds (Liang et al., 2021).

PM₁₀, like PM_{2.5}, is classified by its diameter: 10 µm or less (Taheri Shahraiyini and Sodoudi, 2016). While PM₁₀ is less prevalent in wildfire-source smoke mixtures than PM_{2.5}, it still contains diverse toxicants (Künzli et al., 2006), such as carbonaceous compounds, crustal metals, and some elements, such as potassium (Ramirez et al., 2020).

Another prominent class of chemicals in wildfire smoke is polycyclic aromatic hydrocarbons (PAHs) (Ghetu et al., 2022). PAHs can exist in both the particle and vapor phases. PAHs are comprised of two or more benzene rings (cyclic hydrocarbons) that are covalently bonded (Abdel-Shafy and Mansour, 2016). Some of the prominent PAHs in wildfire smoke are pyrene and chrysene (Ghetu et al., 2022; Gorshkov et al., 2021). Other PAHs in wildfire smoke in the particle phase, such as benzo[a]pyrene, naphthalene, and benzene, are positively correlated with PM_{2.5} emissions in wildfire smoke (Hadley et al., 2021).

HEALTH IMPACTS OF WILDFIRE SMOKE

Many pollutants in wildfire smoke that are associated with negative human health outcomes such as respiratory, cardiovascular, dermatological, reproductive, oncological, gastrointestinal, and infectious disease (Künzli et al., 2006; Rohlman et al., 2023). For a comprehensive review of the health effects associated with exposure to wildfire smoke, refer to Black et al. 2017.

PM_{2.5} diffuses across the pulmonary epithelium into the bloodstream via the pulmonary capillaries (Pryor et al., 2022; Xu et al., 2020). Once in the blood, PM_{2.5} can cause oxidative damage to the vessels and myocardium that is associated with increased prevalence of atherosclerotic plaque and myocardial infarction in populations exposed (Gangwar et al., 2020). PM_{2.5} and PM₁₀ also can irritate the respiratory tract and exacerbate chronic respiratory conditions such as asthmas and chronic obstructive pulmonary diseases (COPDs) such as emphysema (Aguilera et al., 2021; Webber Mayris P. et al., 2009). Studies of associations with influenza virus infection and wildfire PM_{2.5} showed that increased ambient PM_{2.5} during wildfire smoke in summer is positively associated with rates of influenza infection during the following winter (Landguth et al., 2020)

Recent studies identified a negative correlation between concentrations of wildfire-source PM_{2.5} and birth outcomes such as decreased birth weight and pre-term birth, both of which are associated with negative neonatal outcomes such as increased rates of neonatal intensive care unit admission (Abdo et al., 2019; Ghosh and Wojtowycz, 2021).

PAHs contained within wildfire smoke are associated with oncologic and non-oncologic etiologies (Abdel-Shafy and Mansour, 2016; Mallah et al., 2022; Rengarajan et al., 2015). A study of cancer rates in wildland firefighters and civilians found higher rates of cancer in wildland firefighter populations that cannot be fully explained even when accounting for tobacco or nicotine smoking status (Oliveira et al., 2017). Several PAHs are carcinogens (Li et al., 2020; Sun et al., 2021). PAH exposure has also been associated with adverse respiratory health effects, with most research focusing on effects in juveniles (Goldizen et al., 2016; Liu et al., 2016; Miller et al., 2004).

PUBLIC HEALTH SURVEILLANCE DURING WILDFIRES

Several epidemiological studies attempted to associate exposure to wildfire smoke with various health outcomes (Künzli et al., 2006; Meo et al., 2021; Stowell et al., 2021; Wettstein et al., 2018; Youssouf et al., 2014). However, many studies are limited in the way they characterize exposure, or are limited by availability of data on health outcomes (e.g., reliance on hospital admittance records, ambulance data, or birth and death records).

As wildfires become more prevalent, it is necessary to understand the health effects across the population. Surveys are one way to characterize health effects across a population. For example, the National Institutes of Environmental Health Sciences (NIEHS) created the Disaster Research Response (DR2) program (Miller et al., 2016) to curate survey tools and other resources to better characterize exposures to pollutants following disasters.

Given the health concerns associated with the individual components of wildfire smoke, a survey tool that can characterize self-reported exposure and health effects, and could be rapidly disseminated following a wildfire smoke event, could be beneficial.

Therefore, I aimed to create a survey tool to be used as a surveillance tool by researchers and clinicians. I searched the primary literature for surveys evaluating specific health outcomes. I

evaluated these surveys against inclusion and exclusion criteria and then compiled them into a final survey tool.

Methods

I searched all available years of the primary literature to identify health effects associated with wildfire smoke. I searched the National Institute of Health Disaster Research Response Database (DR2) (Cao et al., 2018; Liu et al., 2020), Elsevier, Academic Search Premier, and Web of Science. I continued to search for new articles until the results saturated. I removed duplicate results.

I also tailored search terms to eliminate redundant results. I used the search terms respiratory survey wildfire smoke, asthma wildfire smoke survey, COPD exacerbation wildfire smoke survey, smoking respiratory wildfire smoke survey, flu cases wildfire smoke pollution association, COVID-19 wildfire increased association, wildfire smoke COVID-19 survey, COVID-19 wildfire increased incidence association, pregnancy wildfire smoke survey, cardiovascular outcomes wildfire smoke, cardiomyopathy wildfire, atopic dermatitis exacerbation wildfire smoke, adverse health outcome wildfire smoke, and cancer wildfire smoke exposure.

I excluded materials that were not in American English or peer-reviewed or were not available to the research team. I identified the primary pollutant addressed in the article and the year of publication. I used the health effects identified in the papers to search for existing surveys that were specific to those health outcomes. I obtained data on area burned per year (acres) from the National Interagency Fire Center (“NIFC Maps,” n.d.).

I identified surveys by key word searches (e.g., asthma survey) or from peer-reviewed studies that assessed a health outcome of interest. I split surveys that assessed multiple health outcomes into separate question sets, which I counted separately. Many surveys evaluated similar components of health or assessed the same health outcome. In cases where more than one survey focused on a given outcome, I selected one survey on the basis of established use (e.g., used predominantly in the discipline) or previous validation. In cases where I did not find a survey for a particular health outcome, such as cancer, I did not include the outcome in the final survey. I also included modules designed to collect social, economic, and demographic data and data on exposure to wildfire.

After I selected the surveys, I built a novel comprehensive survey tool that uses conditional branching questions and displays different modules or questions on the basis of the responses of the individual completing the survey.

Results

3.1 Adverse health outcomes associated with exposure to wildfire smoke

Wildfire smoke exposure was associated with eight adverse health outcomes. Twenty-four papers met my inclusion criteria. I grouped these 24 papers on the basis of eight outcomes associated with wildfire smoke exposure: cardiac, respiratory (asthma, COPD, and smoker status), dermatological, gastrointestinal [GI], oncologic, gestational, COVID-19, and influenza.

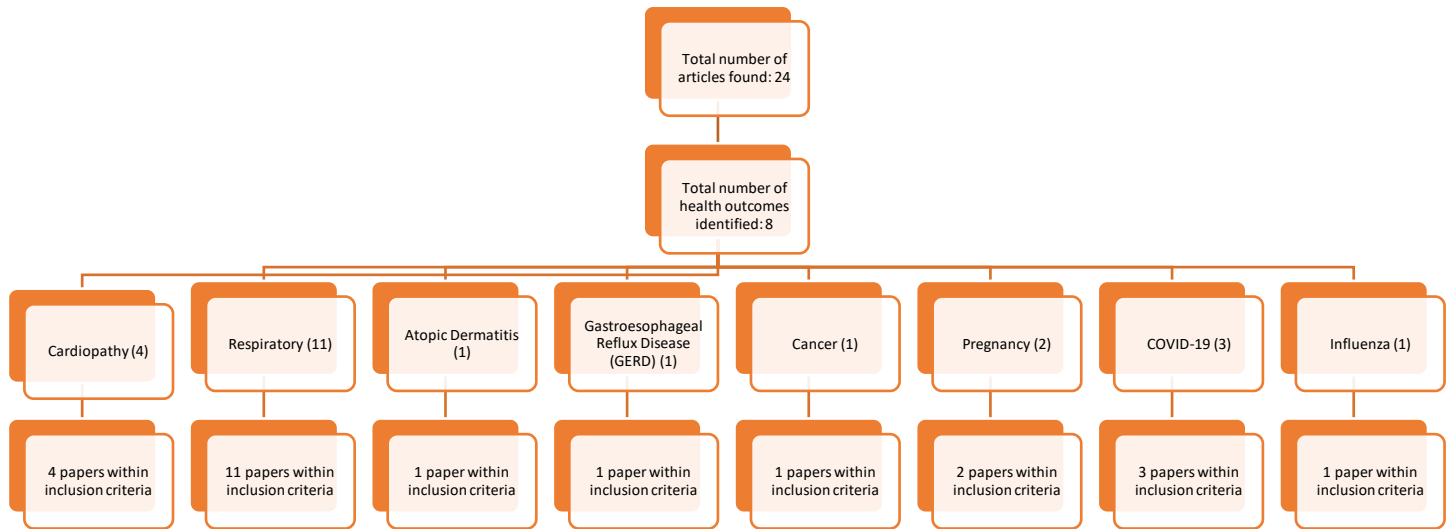


Figure 1: The total number of articles (24) were divided into eight separate health outcomes. 11 were found for respiratory, four were found for cardiomyopathy, three were found for COVID-19, two were found for pregnancy. Only one article was found for atopic dermatitis (AD), gastroesophageal reflux disease (GERD), cancer, and influenza.

These 24 papers were also found using search strings that were recorded in a literature list (see *Supplementary Materials*). Using Microsoft Excel, the number of papers found using each search string were compiled into a bar chart, which is displayed below (*Figure 2*).

Table 1:

Health Outcomes:	Papers (count):
COVID-19	3
Pregnancy	2
Cardiovascular	4
Respiratory (asthma, smoking status, COPD)	11
Atopic Dermatitis	1
GERD	1
Cancer	1
Influenza	1

Table 1: This table depicts the number of papers found (as a count) against primary health outcomes that they identified. If a paper identified multiple health outcomes, the paper was assigned to the primary health outcome which it identified. Respiratory and cardiovascular outcomes were the most represented in the literature search, whereas GERD, atopic dermatitis (AD) and influenza were the least represented.

The search strings used to locate the articles were also recorded to see if there were any trends in search terms versus results. In *Figure 2*, the yield of each search term as number of articles were plotted against each other.



Figure 2: The article yield (articles found) was recorded for each search strings; these yields were then plotted against each other to evaluate for possible trends. The search term with the highest article yield (articles found) was “respiratory wildfire smoke.”

Pollutants evaluated by these studies were also of interest in this study, as there are known health outcomes associated with specific pollutants. For each article meeting the inclusion criteria, the primary pollutant of interest was recorded. PM_{2.5} was found to be the pollutant most represented in our sample.

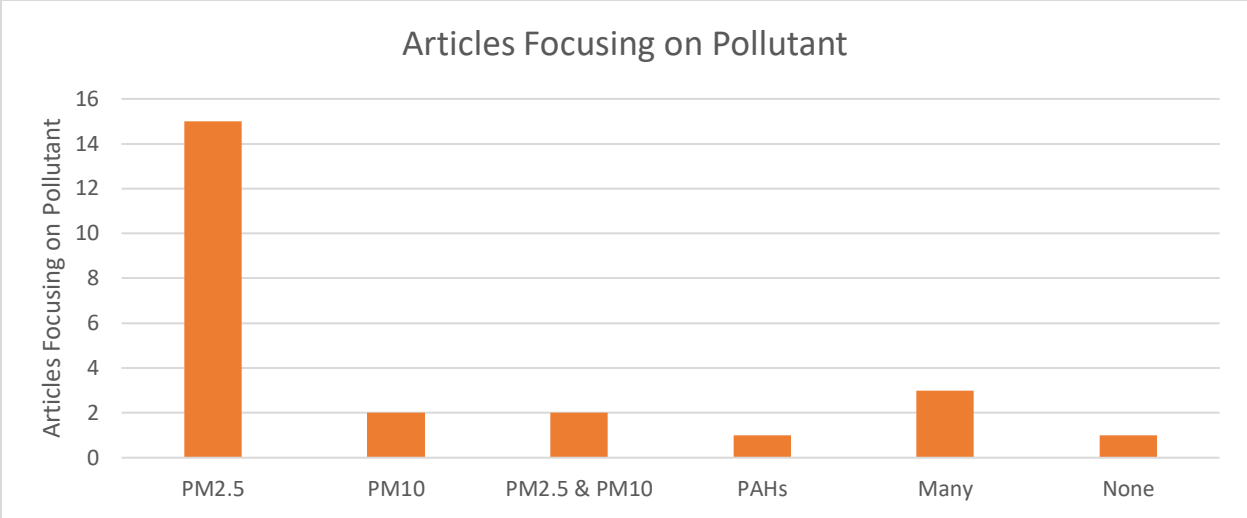


Figure 3: The number of articles focusing on certain pollutants was recorded and plotted against one another in a bar chart. Most articles focused on PM_{2.5}, with other articles focusing on PM_{2.5} in addition to other chemical classes, such as PM₁₀. One article is reported as focusing on “none,” as this article uses relative presence or absence of wildfire smoke in their analysis.

The year in which all of the articles were published was also assessed. Furthermore, we included data from the National Interagency Fire Center detailing the number of acres burned per year (“NIFC Maps,” n.d.). Number of articles per year was made into a bar chart and number of acres burned per year was superimposed on the bar chart as a line graph.

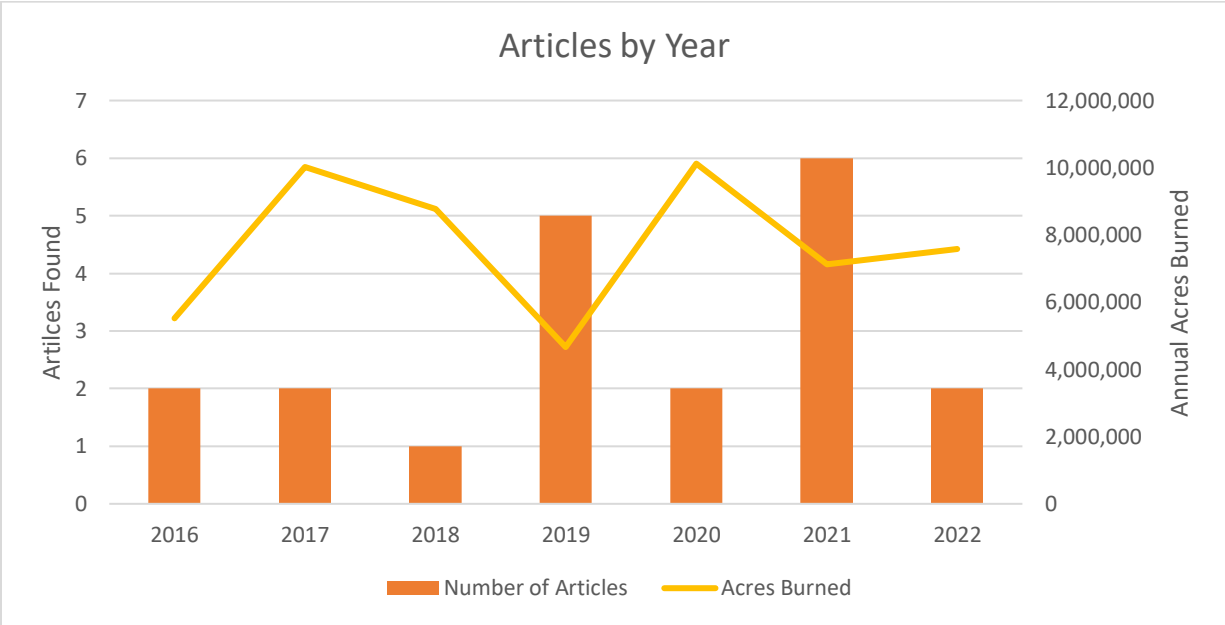


Figure 4: The number of articles published per year within the sample population were plotted against each other as a bar chart. Data from the National Interagency Fire Center (NIFC) detailing the number of acres burned per year in all 50 states of the US was obtained and plotted against the articles as a line graph. There were four articles published before 2016 that were excluded from this graph as these articles were not published in consecutive years.

3.2 Surveys

For the surveys selected for this study, a total of 18 survey question sets meeting the inclusion criteria were found. Surveys that assessed multiple health outcomes were split into separate question sets, which were counted separately. To reduce redundancy, surveys assessing similar or near-similar aspects were eliminated in favor of the most widely used survey by health professionals, which yielded a total of ten surveys represented in the final questionnaire. *Figure 5* and *Table 1* show the number of questionnaires identified and selected broken down by health outcome studied. Cancer was ultimately not represented in the final survey due to the chronicity of the condition and the survey's focus on acute health effects.

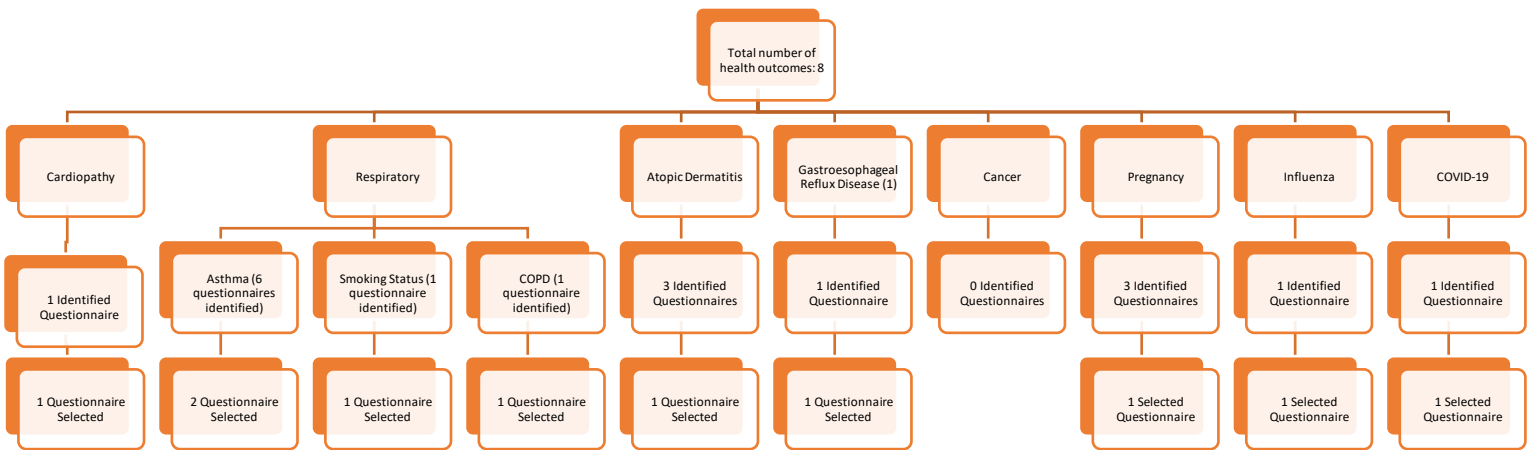


Figure 5: The total number of surveys identified (18) broken down by total number of health outcomes identified (8).

Table 2:

Survey	Health Outcome(s)	Access?	Selected?
Behavioral Risk Factor Surveillance System (BRFSS)	Asthma	1	0
Behavioral Risk Factor Surveillance System (BRFSS)	Pregnancy	1	0
Behavioral Risk Factor Surveillance System (BRFSS)	Demographic Information	1	1
Pregnancy, Infection, and Nutrition Study (PIN)	Pregnancy	1	1
London Measure of Unplanned Pregnancy (LMUP)	Pregnancy	1	0
Asthma Control Test (ACT)	Asthma	1	1
Childhood Asthma Control Test (CACT)	Asthma	1	1
American Thoracic Society Respiratory Questionnaire (ATS-DLD-78)	Asthma	1	1
Delfino Anti-Inflammatory Diary	Asthma	1	0
Atopic Dermatitis Control Test (ADCT)	Atopic Dermatitis	0	0
Atopic Dermatitis Questionnaire (ADT)	Atopic Dermatitis	0	0
Kansas City Cardiomyopathy Questionnaire (KCCQ-12)	Cardiopathy	1	1
GERD-Q	Gastritis/GERD	1	1
European Community Respiratory Health Survey (ECRHS)	Smoking Status	1	0
European Community Respiratory Health Survey (ECRHS)	COPD	1	1
European Community Respiratory Health Survey (ECRHS)	Asthma	1	0
Patient Oriented Eczema Survey (POEM)	Eczema	1	1
ECHO COVID-19 Survey	COVID-19	1	1
FLU-PRO	Influenza	1	1

Table 2: This table shows the surveys found by the study that assess the health outcomes identified in **Table 1**. Surveys are broken down by title, primary health outcome evaluated, whether or not there was access to the survey and associated documentation (0 = no, 1 = yes), and whether or not the survey was selected to be a part of the final survey product (0 = no, 1 = yes). The surveys and their health outcomes were used to create *Figure 6*.

The final ten surveys were then compiled into the Human Health and Wildfire Exposure survey. The survey has a total of 142 questions across 11 different modules. The survey tool was written in American English but contains a section for participants to specify whether or not they used a translator in the process of completing the survey. The survey tool collects demographic information (such as race/ethnicity) as well as health information pertaining to wildfire smoke exposure.

The full survey tool is available in the appendix.

Section Title	# of Questions	Estimated Time to Complete
Demographic Information	8	4 minutes
Cardiac	12	3 – 10 minutes
Asthma	52	5 – 20 minutes
COPD	27	< 1 – 12 minutes
Smoking Status	6	< 1 – 4 minutes
Pregnancy	10	< 1 – 10 minutes
Gastrointestinal (GI)	7	< 1 – 7 minutes
Skin (Integumentary)	7	< 1 – 7 minutes
Recent Infection	5	< 1 – 5 minutes
Wildfire Exposure	6	4 – 8 minutes
Exit Survey	2	< 1 – 10 minutes
TOTAL	142	22 - 92

Table 3: The number of questions and estimated time to complete for each outcome module were recorded in this table. The section with the most questions and estimated to take the longest is the asthma module, and the module with the least amount of questions and is estimated to take the least amount of time to complete is demographic information. It is unlikely that a participant would complete the entirety of each module.

DISCUSSION

OUTCOMES & SEARCH STRINGS

Looking at the outcomes covered by the papers meeting our inclusion criteria, a majority were looking at associations with respiratory diseases. These included outcomes such as asthma exacerbation, COPD exacerbation, smoker vulnerability to wildfire smoke, and upper-respiratory infection (URI) excluding influenza and COVID-19 infection.

The search strings used to obtain each article from the internet were also recorded and analyzed to see which search terms resulted in the greatest number of articles found. Search strings such as “respiratory survey wildfire smoke” and “asthma wildfire smoke survey” returned a higher-yield of academic literature meeting our search criteria. This is aligned with the preponderance of literature focused on respiratory health as an outcome following exposure to wildfire smoke.

We believe there are many reasons as to why this is the case. First, wildfire pollution is likely to exacerbate chronic respiratory conditions, such as COPD and asthma (Reid et al., 2016). More research may be investigating respiratory outcomes as they appear to occur much earlier on in the scope of exposure to wildfire pollution. This is compared to other outcomes, such as cancer, which may not occur until 10-20 years after exposure in adults (Korsiak et al., 2022). Respiratory outcomes may be overrepresented in studies surrounding health outcomes associated with wildfire smoke exposure as individuals are exposed to wildfire smoke via inhalation. Pollutants from wildfire smoke, such as PM_{2.5} and PAHs are inhaled via the lungs (Xing et al., 2016), (Rengarajan et al., 2015), and are also able to cross the alveolar barrier into the blood stream via the pulmonary capillaries (Al-Saleh et al., 2013; Gerde et al., 2001; Thangavel et al., 2022).

While current research suggests that respiratory, cardiovascular, dermatological, gastrointestinal, oncological, and viral etiologies are exacerbated as a function of increased wildfire-source pollution, these outcomes are not routinely assessed, and there has not been a comprehensive wildfire smoke exposure survey tool to capture multiple symptoms. Such a survey tool may help evaluate the holistic effects of wildfire-source air pollution on public health.

My initial focus when building the survey tool was on physical health, which excluded impacts on mental health. However, current research also suggests that exposure to wildfire smoke is associated with negative changes in mental health such as increased incidence of PTSD, depression, and anxiety (Eisenman and Galway, 2022; Humphreys et al., 2022). Surveys such as the nine question Patient Health Questionnaire (PHQ – 9) quantify and assess the severity of depression symptoms (Kroenke et al., 2001). This survey should be included in the Human Health and Exposure to Wildfire Smoke survey developed here and was a considered topic to be included in the final survey.

POLLUTANTS OF INTEREST

Wildfire smoke is made up of a variety of constituents such as PM_{2.5} and PM₁₀, PAHs such as benzo[a]pyrene, and nitrous oxide (NO), among others (Black et al., 2017). A majority (62.5%)

of the articles primarily focused on PM_{2.5} as opposed to other constituents of wildfire smoke, such as PM₁₀, PAHs, ozone, nitrous oxide, etc.

One of the main reasons we believe this may be the case is due to the availability of data on PM_{2.5} concentrations. In the United States' specific case, PM_{2.5} and PM₁₀ are considered criteria air pollutants (CAPs) by the Environmental Protection Agency (EPA) (Suh et al., 2000). Due to this designation, daily rolling averages over a county are provided on the CDC website due to the agency's obligation to regulate the amount of chemical in the environment. Other pollutants, however, are designated as hazardous air pollutants (HAPs) (US EPA, 2015). The EPA does not record and provide data on such pollutants in the same way, making this data less readily available.

YEARS

The years of the articles meeting our inclusion criteria were recorded and plotted against the mean number of acres burned per year. Unstable factors in our globe's environment, such as anthropogenic climate change, are increasing the number of acres burned per year by wildfires (US EPA, 2016). As fires become bigger and more destructive, research into the health effects of exposure to wildfire smoke has likely becoming a more pressing point of interest for the environmental health sciences community. The median year that an article in this dataset was published in 2019, suggesting that research into the effects of wildfire smoke is experiencing a greater interest today.

Another interesting phenomenon pointed out by our study is the tendency of high publication years to fall on years preceded by significant wildfire destruction. For instance, 2020 saw a near-record breaking amount of acreage burned in the US, totaling to 10,122,336 acres burned ("Wildfires and Acres | National Interagency Fire Center," 2022). In 2021, six articles meeting our inclusion criteria were published, suggesting that interest in wildfire pollution-related research was more prevalent in this year than in others.

SURVEY

The final survey tool is designed to evaluate a wide range of outcomes including respiratory, infectious, dermatologic, cardiovascular, and embryologic effects of wildfire smoke exposure. It is designed to be completed by participants, that can self-report health symptoms they may be experiencing. The survey tool, which is designed to be disseminated electronically, is estimated to take on average, 40 minutes to complete. The goal of the survey is that it can be used by researchers, public health officials, and clinicians in evaluating how patients and/or populations are responding to a wildfire smoke-polluted environment.

LIMITATIONS

We were limited by survey options for some health outcomes. In some of the research, it is likely that data collection was so emergent that there were not strong associations between wildfire

smoke exposure and certain health outcomes. We could also be missing other health outcomes given that the field is still evolving.

Furthermore, not all surveys were available. Many studies would often mention using a survey and then not provide the questions they used.

CONCLUSION

This study conducted a literature search in order to determine what health outcomes are associated with exposure to certain chemicals in wildfire smoke. A total of 24 articles were found assessing a total of eight outcomes (cardiac, dermatologic, gastrointestinal (GI), oncologic, respiratory, infectious, gestational, and pulmonary). Using this information, a total of 10 surveys across seven outcomes were recorded (cardiac, pulmonary, dermatologic, gastrointestinal (GI), oncologic, gestational, COVID-19, and influenza). Using this information, a survey with 11 modules was created. The survey tool can be used alone, or in combination with environmental and/or personal sampling to better characterize wildfire smoke exposure and human health outcomes. As wildfire smoke becomes more prevalent with increased incidences due to climate change, it will be important for researchers, public health professionals, and clinicians alike to have the tools necessary to diagnose the health effects of exposure to wildfire smoke (US EPA, 2016).

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Supplemental Information I – Survey selection rationales

Behavioral Risk Factor Surveillance System (BRFSS): This survey assesses many health outcomes of interest, including asthma, smoking status, and pregnancy.

Asthma: For asthma, this survey was not chosen and a different survey was chosen in favor (ATS-DLD-78-A, ATS-DLD-78-C, ACT, and cACT).

Smoking Status: To evaluate smoking status, this survey’s smoking questions were chosen to evaluate the health outcome. This survey is used by the US government (Centers for Disease Control and Prevention) and was the only one of its kind found under the inclusion criteria that evaluated this outcome.

Pregnancy: For pregnancy, this survey was not chosen and a different survey was chosen in favor (PIN).

Pregnancy, Infection, and Nutrition Survey (PIN): This survey primarily assesses pregnancy as a health outcome. Because this survey was written/validated in English and was created as part of a peer-reviewed, primary research study, it met our inclusion criteria. This survey was selected due to it assessing a multitude of aspects of pregnancy, such as mental state (stress) and spotting/bleeding.

London Measure of Unplanned Pregnancy (LMUP): This survey assesses the desire of an individual/couple to become pregnant and/or the measure of “planned-ness” a current pregnancy was. While this survey modality was written and validated in English and was created using pertinent primary research, it was not chosen to be compiled into the final survey. It had a very narrow scope of what it was assessing (degree of planned-ness) and was validated only for use in cisgender, heterosexual couples (would not be useful for couples consisting of members of the LGBTQIAA+ community). Because the PIN had a wider scope of assessment and was not specifically focused on cisgender/heterosexual birth parent(s), the PIN was chosen in favor of this survey to assess pregnancy as a health outcome.

Asthma Control Test (ACT)/Childhood Asthma Control Test (cACT): This survey assesses an individual’s control over their asthma symptoms. This survey was written and validated in American English and was also developed using traditional scientific research methods. Due to the short nature of the survey, the easy conversion of answers to a numerical value, and its compliance with our inclusion criteria, this survey was selected to be a part of the final survey. This was also chosen alongside the ATS-DLD-78-A and the ATS-DLD-78-C.

American Thoracic Society Respiratory Questionnaire (ATS-DLD-78): The ATS-DLD-78A and C are self-administered, comprehensive questionnaires that assesses one’s history of asthma symptoms, use of medication, as well as the condition of current asthma symptoms. This survey was developed using primary research and was written and validated in American English. This survey was selected alongside the ACT/cACT to evaluate asthma symptoms.

Delfino Anti-Inflammatory Diary: This survey was written as a part of a study assessing the effects of air pollution on childhood asthma symptoms and how anti-inflammatory medications (such as albuterol) can modulate this effect. This survey was written and validated in American English. While this survey passes our inclusion criteria, it was not chosen to be a part of the final survey in favor of the ATS-DLD-78A/C and ACT/cACT

Atopic Dermatitis Control Test (ADCT): This survey assesses the severity of atopic dermatitis (AD) symptoms. While it was developed using primary research and was written and validated in American English, it is not freely available. For this reason, it was not selected to be a part of the final survey. The Patient Oriented Eczema Questionnaire (POEM Q) was selected to assess integument-related symptoms.

Atopic Dermatitis Questionnaire (ADT): This survey assesses the severity of atopic dermatitis (AD) symptoms. While it was developed using primary research and was written and validated in American English, it is not freely available. For this reason, it was not selected to be a part of the final survey. The Patient Oriented Eczema Questionnaire (POEM Q) was selected to assess integument-related symptoms.

Kansas City Cardiomyopathy Questionnaire (KCCQ-12): The survey we chose to be a part of the final product was the Kansas City Cardiomyopathy Questionnaire (KCCQ-12). This survey was chosen due to the fact it was the only survey assessing this health outcome that was found using our research methods. This survey was validated for use in the United States and was supported by clinical research as a means of assessing cardiopathy.

GERD-Q: The GERD-Q is a comprehensive questionnaire that assesses the severity of gastroesophageal reflux disease (GERD) symptoms. This survey was written and validated in American English, was developed using primary research. For these reasons, it is within our inclusion criteria. This survey was selected to be a part of the final survey to assess gastrointestinal symptoms as a health outcome.

European Community Respiratory Health Survey (ECRHS): This survey was constructed using primary research, and was written and validated in American English. This survey assesses multiple respiratory health outcomes:

COPD: This survey partially assesses chronic pulmonary obstructive diseases (COPD) such as emphysema. As this survey hits our inclusion criteria and is used by health professionals worldwide, it was selected to assess exacerbation of COPD symptoms as a result of exposure to wildfire smoke.

Asthma: For asthma, this survey was not chosen and a different survey was chosen in favor (ATS-DLD-78-A, ATS-DLD-78-C, ACT, and cACT).

Extension for Community Healthcare Outcomes (ECHO) COVID-19 Questionnaire: This survey was created by the CDC to assess COVID-19 symptoms using the most up-to-date research. The survey was written, created, and validated in American English and is open access to the public through PhenX toolkit. This survey was selected to be a part of the final survey to assess COVID-19 symptoms.

Influenza Patient Reported Outcome (FLU-PRO) Diary: This survey was created to assess influenza symptoms and was validated in a research study. The questionnaire was written in American English. As there were no other empirically-validated surveys assessing influenza symptoms, we chose the FLU-PRO to assess them in the final survey.

Patient Oriented Eczema Questionnaire (POEM): This survey assesses the severity of eczema symptoms and flare-ups. This survey was written and validated in American English and was developed using primary research. For these reasons, it is within our inclusion criteria. This survey was selected to be a part of the final survey to assess integumentary disease (such as AD) as a health outcome.

HUMAN HEALTH AND EXPOSURE TO WILDFIRE SMOKE SURVEY

MODULE 1. DEMOGRAPHIC INFORMATION

1. Study ID: _____
2. Name: _____
3. Age: _____
4. Racial Identity and Ethnic Identity¹
 - Racial Identity (select 1 or more options)
 - White
 - Black/African American
 - American Indian or Alaskan Native
 - Asian
 - Native Hawaiian and/or Other Pacific Islander
 - Race(s) Not Listed (if so, please identify on the line below, separate multiple identities with commas)
 - Race: _____
 - Ethnic Identity (select 1 or more options)
 - Hispanic
 - Non-Hispanic
 - Ethnicity/(ies) Not Listed (if so, please identify on the line below, separate multiple identities with commas)
 - Ethnicity: _____
5. Gender Identity and Sexual Orientation²
 - Gender Identity (select 1 or more options)
 - Male
 - Female
 - Non-Binary
 - Agender
 - Genderfluid
 - Genderqueer

¹ Jensen, E., Jones, N., Orozco, K., Medina, L., Perry, M., Bolender, B., Battle, K., 2021. Measuring Racial and Ethnic Diversity for the 2020 Census. United States Census Bureau. URL (accessed 1.25.23).

² Suen, L.W., Lunn, M.R., Katuzny, K., Finn, S., Duncan, L., Sevelius, J., Flentje, A., Capriotti, M.R., Lubensky, M.E., Hunt, C., Weber, S., Bibbins-Domingo, K., Obedin-Maliver, J., 2020. What Sexual and Gender Minority People Want Researchers to Know About Sexual Orientation and Gender Identity Questions: A Qualitative Study. Arch Sex Behav 49, 2301–2318. <https://doi.org/10.1007/s10508-020-01810-y>

- Other/Non-Specified (if so, please identify on the line below, separate multiple identities with commas)

- Other: _____

- Sexual Orientation (select 1 *or more as needed*)

- Straight
 - Lesbian
 - Gay
 - Bisexual
 - Pansexual
 - Asexual/Aromantic
 - Queer

- Other/Non-Specified (if so, please identify on the line below, separate multiple identities with commas)

- Other: _____

6. Marital Status

- Married
- Divorced
- Widowed
- Separated
- Never Married
- Member of an Unmarried Couple
- Other/Not Listed

7. What is the highest grade and/or year of education that you completed?

- Never attended school or only attended kindergarten
- Grades 1 – 8 (some of elementary, and/or some of middle school)
- Grades 9 – 11 (completed some of High School)
- Grade 12 and/or GED (High School graduate)
- 1 – 3 year(s) of college/technical school (some college/technical school)
- 4 or more years of college (college graduate)
- Other

8. What is your total annual household income considering all sources?

- Less than \$10,000
- \$10,000 - \$14,999
- \$15,000 - \$19,999
- \$20,000 - \$24,999
- \$25,000 - \$34,999
- \$35,000 - \$49,999
- \$50,000 - \$74,999
- \$75,000 - \$99,999
- \$100,000 - \$149,999
- \$150,000 - \$199,999
- More than \$200,000

MODULE 2. CARDIAC MODULE³

1. Do you have a prior history of heart disease (cardiomyopathy)? This includes conditions such as congestive heart failure (CHF), coronary artery disease (CAD), and heart attack (MI).
 - Yes
 - No
2. Are you over the age of 65 years?
 - Yes
 - No

If you answered yes to either Cardiac Module questions 1 or 2, please proceed to module CM.1. If you answered no to both questions 1 and 2, you may continue to the Asthma Module.

CM.1

1. How much have symptoms such as shortness of breath or fatigue limited your ability to *shower and bathe*? (*limit = decrease*)
 - Extremely limiting
 - Quite a bit limiting
 - Moderately limiting
 - Slightly limiting
 - Not limiting
 - Does not apply

³ Green, C.P., Porter, C.B., Bresnahan, D.R., Spertus, J.A., 2000. Development and evaluation of the Kansas City Cardiomyopathy Questionnaire: a new health status measure for heart failure. *J Am Coll Cardiol* 35, 1245–1255. [https://doi.org/10.1016/s0735-1097\(00\)00531-3](https://doi.org/10.1016/s0735-1097(00)00531-3)

2. How much have symptoms such as shortness of breath or fatigue limited your ability to **walk distances greater than or equal to one block on level ground?** (*limit = decrease*)
 - Extremely limiting
 - Quite a bit limiting
 - Moderately limiting
 - Slightly limiting
 - Not limiting
 - Does not apply

3. How much have symptoms such as shortness of breath or fatigue limited your ability to **jog or walk quicker than a normal pace?** (*limit = decrease*)
 - Extremely limiting
 - Quite a bit limiting
 - Moderately limiting
 - Slightly limiting
 - Not limiting
 - Does not apply

4. Over the past 2 weeks, how many times did you have swelling in your feet, ankles, or legs when you woke up in the morning?
 - Every morning
 - 3 or more times a week, but not every day
 - 1-2 times a week
 - Less than once a week
 - Never over the past 2 weeks

5. Over the past 2 weeks, on average, how many times has fatigue limited your ability to do what you wanted?
 - All of the time
 - Several times a day
 - At least once a day
 - 3 or more times a week but not every day
 - 1-2 times a week
 - Less than once a week
 - Never over the past 2 weeks

6. Over the past 2 weeks, on average, how many times has shortness of breath limited your ability to do what you wanted?
 - All of the time
 - Several times a day
 - At least once a day
 - 3 or more times a week but not every day
 - 1-2 times a week
 - Less than once a week
 - Never over the past 2 weeks

7. Over the past 2 weeks, on average, how many times have you been forced to sleep in an upright position (i.e. in a chair) with at least 3 pillows to prop you up because of shortness of breath?
- Every night
 - 2 or more times a week, but not every night
 - 1-2 times a week
 - Less than once a week
 - Never over the past 2 weeks
8. Over the past 2 weeks, how much has your heart failure limited your enjoyment of life (enjoying hobbies, activities, socialization, etc.)?
- It has extremely limited my enjoyment of life
 - It has limited my enjoyment of life quite a bit
 - It has moderately limited my enjoyment of life
 - It has slightly limited my enjoyment of life
 - It has not limited my enjoyment of life at all
9. If you had to spend the rest of your life with your heart failure the way it is right now, how would you feel about this?
- Completely dissatisfied
 - Mostly dissatisfied
 - Fairly satisfied
 - Mostly satisfied
 - Completely satisfied
10. How much does your heart failure affect your lifestyle? Please indicate how your heart failure may have limited your participation in **hobbies and recreational activities** over the past 2 weeks.
- Extremely limiting
 - Quite a bit limiting
 - Moderately limiting
 - Slightly limiting
 - Not limiting
 - Does not apply
11. How much does your heart failure affect your lifestyle? Please indicate how your heart failure may have limited your participation in **working at a job or around the house** over the past 2 weeks.
- Extremely limiting
 - Quite a bit limiting
 - Moderately limiting
 - Slightly limiting
 - Not limiting
 - Does not apply

12. How much does your heart failure affect your lifestyle? Please indicate how your heart failure may have limited your participation in **visiting family and friends that do not live in your home** over the past 2 weeks.

- Extremely limiting
- Quite a bit limiting
- Moderately limiting
- Slightly limiting
- Not limiting
- Does not apply

MODULE 3. ASTHMA MODULE

1. Do you have a history of asthma (chronic, allergic, occupational, exercise-induced, etc.)?
 - Yes
 - No

If you answered yes to question 1, please proceed to module R.1. If you answered no to both questions 1 and 2, you may skip to the COPD module.

R.1

ATS DLD 78⁴

1. Do you usually have a cough?
 - Yes
 - No

2. Do you usually cough as much as four to six times a day, four or more days out of the week?
 - Yes
 - No

3. Do you usually cough at all on getting up or first thing in the morning?
 - Yes
 - No

4. Do you usually cough at all during the rest of the day or at night?
 - Yes
 - NO

If you answered yes to any of the above questions (1, 2, 3, or 4), continue on to the next questions. If you answered no to all of the above questions, continue to question 7.

⁴ Ferris, B.G., 1978. Epidemiology Standardization Project (American Thoracic Society). The American review of respiratory disease 118, 1–120.

5. Do you usually cough like this on most days for 3 consecutive months or more during the year?
- Yes
 - No
6. For how many years have you had this cough?
- < 1 year
 - 1 – 5 years
 - 6 – 15 years
 - 16 – 30 years
 - 31 + years
7. Do you usually bring up phlegm from your chest
- Yes
 - No
8. Do you usually bring up phlegm like this as much as twice a day, four or more days out of the week?
- Yes
 - No
 -
9. Do you usually bring up phlegm at all on getting up, or first thing in the morning?
- Yes
 - No
10. Do you usually bring up phlegm at all during the rest of the day or at night?
- Yes
 - No

If you said yes to questions 5, 6, 7, 8, 9, or 10, continue to answer questions 11 and 12. If you answered no to questions 5, 6, 7, 8, 9, and 10, continue to question 13.

11. Do you bring up phlegm like this on most days for three consecutive months or more during the year?
- Yes
 - No
12. For how many years have you had trouble with phlegm?
- < 1 year
 - 1 – 5 years
 - 6 – 15 years
 - 16 – 30 years
 - 31 + years
 -

13. Have you had periods or episodes of increased cough and phlegm lasting for 5 weeks or more each year?
- Yes
 - No

If you answered yes to question 13, continue to question 14. If you answered no to question 13, skip to question 15.

14. For how long have you had at least 1 such episode per year
- < 1 year
 - 1 – 5 years
 - 6 – 15 years
 - 16 – 30 years
 - 31 + years

15. Does your chest ever sound wheezy or whistling when you have a cold, occasionally apart from colds, or on most days/nights?
- Yes
 - No

If you answered yes to question 15, continue to question 16. If you answered no to question 15, skip to question 17.

16. For how many years has this been present?
- < 1 year
 - 1 – 5 years
 - 6 – 15 years
 - 16 – 30 years
 - 31 + years

17. Have you ever had an attack of wheezing that has made you feel short of breath?
- Yes
 - No

If you answered yes to question 17, continue to question 18. If you answered no to question 17, skip to question 21.

18. How old were you when you had your first such attack?
- Since birth
 - 1 – 5 years
 - 5 – 10 years
 - 10 – 20 years
 - 20 – 40 years
 - 40 – 65 years
 - 65 + years

19. Have you had two or more such episodes?

- Yes
- No

20. Have you ever required medicine or treatment for these attacks?

- Yes
- No
- Does not apply

21. Are you troubled by shortness of breath when hurrying on the level or walking up a slight incline that is known to be caused by a respiratory or cardiovascular disease?

- Yes
- No

If you answered yes to question 21, continue to question 22. If you answered no to question 21, continue to question 26.

22. Do you have to walk slower than people of your age on the level because of breathlessness?

- Yes
- No

23. Do you ever have to stop for breath when walking at your own pace on the level?

- Yes
- No

24. Do you ever have to stop for breath after walking about 100 yards (or after a few minutes) on the level?

- Yes
- No

25. Are you too breathless to leave the house or breathless on dressing or undressing?

- Yes
- No
- Does not apply

Questions 26-30 are from the ACT ADULT⁵

26. In the past 4 weeks, how much of the time did your asthma keep you from getting as much done at work, school, or around the house?
- All of the time
 - Most of the time
 - Some of the time
 - A little of the time
 - None of the time
27. During the past 4 weeks, how often have you had shortness of breath?
- More than once a day
 - Once a day
 - 3 to 6 times a week
 - Once or twice a week
 - Not at all
28. During the past 4 weeks, how often did your asthma symptoms (wheezing, coughing, shortness of breath, chest tightness, or pain) wake you up at night or earlier than usual in the morning?
- 4 or more nights a week
 - 2 or 3 nights a week
 - Once a week
 - Once or twice
 - Not at all
29. During the past 4 weeks, how often have you used your rescue inhaler or nebulizer medication (such as albuterol)?
- 3 or more times per day
 - 1 or 3 times per day
 - 2 or 3 times per week
 - Once a week or less
 - Not at all
30. How would you rate your asthma control during the past 4 weeks?
- Not controlled at all
 - Poorly controlled
 - Somewhat controlled
 - Well controlled
 - Completely controlled

⁵ Nathan, R.A., Sorkness, C.A., Kosinski, M., Schatz, M., Li, J.T., Marcus, P., Murray, J.J., Pendergraft, T.B., 2004. Development of the asthma control test: a survey for assessing asthma control. *J Allergy Clin Immunol* 113, 59–65. <https://doi.org/10.1016/j.jaci.2003.09.008>

MODULE 4. COPD MODULE⁶

1. Do you have a history of chronic obstructive pulmonary disease(s) (COPD)? These include chronic bronchitis and emphysema.
 - Yes
 - No

If you answered yes to question 1, please proceed to module R.2. If you answered no to both questions 1 and 2, you may skip to the Smoking Status module.

R.2

1. Do you have... (pick 1 or more options)
 - COPD
 - Chronic bronchitis
2. Have you been experiencing wheeze or a “whistling” noise in your chest upon exhaling any time in the last year/12 months?
 - Yes
 - No

If you answered yes to the above question, please answer questions 1 - 5. If you answered no, please skip to question 6.

3. Have you been at all breathless when the wheezing noise was present?
 - Yes
 - No
4. Have you had this wheezing or whistling when you were **not** ill with a respiratory illness (cold with cough, sore throat, or chest pain)?
 - Yes
 - No
5. How old were you when you first had wheezing or whistling in your chest?
 - Since birth
 - 1 – 5 years
 - 5 – 10 years
 - 10 – 20 years
 - 20 – 40 years
 - 40 – 65 years
 - 65 + years

⁶ Burney, P.G., Luczynska, C., Chinn, S., Jarvis, D., 1994. The European Community Respiratory Health Survey. Eur Respir J 7, 954–960. <https://doi.org/10.1183/09031936.94.07050954>

6. How frequently have you had wheezing or whistling in the last 12 months?
- Every day
 - At least once a week, but not every day
 - Occasionally (less than once a week)
7. Have you woken up with a feeling of tightness in your chest any time in the last year/12 months?
- Yes
 - No
8. Have you had an attack of shortness of breath that came on during the day when you were at rest at any time in the last year/12 months?
- Yes
 - No
 -

If you answered yes to question 7, please answer question 8. If you answered no to question 7, please skip to question 9.

9. How old were you when you first experienced recurrent attacks of shortness of breath that came on during the day while resting?
- Since birth
 - 1 – 5 years
 - 5 – 10 years
 - 10 – 20 years
 - 20 – 40 years
 - 40 – 65 years
 - 65 + years
10. Have you had an attack of shortness of breath that came on following strenuous activity at any time in the last year/12 months?
- Yes
 - No
11. Have you been awoken by an attack of shortness of breath any time in the last year/12 months?
- Yes
 - No
12. Have you been woken by an attack of coughing at any time in the last 12 months?
- Yes
 - No

13. How often have you experienced bouts or spasms of coughing in the last 12 months?

- Less than once a month
- Every month, but less than every week
- Every week, but not every day
- Every day

14. Do you usually cough first thing in the morning, during the day, or at night in the winter?

- Yes
- No

If you answered yes to question 13, answer question 14. If you answered no to question 13, skip to question 16.

15. Do you cough like this on most days for as much as three months each year?

- Yes
- No

If you answered yes to question 14, answer question 15. If you answered no to question 14, skip to question 16.

16. How many years have you had this problem for (coughing as much as three months out of the year)

- Younger than 20 years
- 20 – 40 years
- 40 – 65 years
- 65 + years

If you answered yes to question 16, answer question 17. If you answered no to question 16, skip to question 19.

17. Do you usually bring up any phlegm from your chest first thing in the morning, during the day, or at night, in the winter?

- Yes
- No
-

If you answered yes to question 17, answer question 18. If you answered no to question 17, skip to question 20.

18. Do you bring up phlegm like this on most days for as much as three months each year?

- Yes
- No

If you answered yes to question 18, answer question 19. If you answered no to question 18, skip to question 20.

19. How many years have you had this problem (of bringing up phlegm from your chest on most days for as much as three months each year)?
- Younger than 20 years
 - 20 – 40 years
 - 40 – 65 years
 - 65 + years
20. In the last 12 months, have you had any episodes or times when your symptoms (such as cough, phlegm, or shortness of breath), were a lot worse than usual?
- Yes
 - No
 - I do not experience symptoms such as these

If you answered yes to question 20, answer question 21. If you answered no to question 20, skip to question 26.

21. Have you any episodes or times when your symptoms (such as cough, phlegm, or shortness of breath) were a lot worse than usual when you noticed signs of wildfire smoke (smelt like smoke outside, hazy conditions, darker than it would normally be during that time of the day, etc.)?
- Yes
 - No

If you answered yes to question 21, answer questions 22 - 25. If you answered no to question 21, skip to question 26.

22. During that period of wildfire smoke, how many times have these episodes occurred?
- No times
 - 1 time
 - 2 – 3 times
 - 3 – 6 times
 - 7 + times
23. During that period of wildfire smoke, how many times have these episodes forced you to seek medical attention, such as seeing your PCP or calling a nurse/doctor advice line?
- No times
 - 1 time
 - 2 – 3 times
 - 3 – 6 times
 - 7 + times
 - I am unable to seek medical attention at this time (due to location, financial strain, insurance, etc.)

24. How many times was your therapy changed after these episodes.
- No times
 - 1 time
 - More than one time
 - I do not receive therapy
 - I am non-compliant with my therapy (I do not do my therapies as prescribed by my doctor or respiratory specialist)
 - I do not receive treatment at this time due to extenuating circumstances (such as location, financial aid, transportation, etc.)
25. How many times have you visited a hospital casualty department, emergency room, or have spent a night admitted to a hospital after these episodes?
- No times
 - 1 time
 - More than one time
 - I cannot seek advanced medical treatment (due to location, financial aid, transportation, etc.)
26. Do you ever have trouble with your breathing?
- Yes
 - No

If you answered yes to question 26, answer question 27. If you answered no to question 26, skip to the Smoking Status module.

27. Do you have this trouble... (pick the single option that applies best to you)
- Continuously so that your breathing is never quite right
 - Repeatedly, but it always gets completely better
 - Only rarely

MODULE 5. SMOKING STATUS MODULE⁷

1. Have you smoked at least 100 cigarettes (more than ~ 5 packs) in your entire life?
 - Yes
 - No

2. Do you now smoke cigarettes every day, some days, or not at all?
 - Every day
 - Some days
 - Not at all

⁷ Pierannunzi, C., Hu, S.S., Balluz, L., 2013. A systematic review of publications assessing reliability and validity of the Behavioral Risk Factor Surveillance System (BRFSS), 2004–2011. BMC Medical Research Methodology 13, 49. <https://doi.org/10.1186/1471-2288-13-49>

If you answered yes to questions 1 and/or anything other than “not at all” for 2, please continue to answer questions 3 – 6. If you answered no/not at all to both questions 1 and 2, continue to the Pregnancy module.

3. Do you now use e-cigarettes or other electronic “vaping” products every day, some days, or not at all?
 - Every day
 - Some days
 - Not at all

4. How old were you when you first started to smoke cigarettes regularly?
 - Younger than 18 years
 - 18-25 years
 - 26-64 years
 - 65 + years
 - I have never smoked cigarettes.

5. How many packs per day (PPD) do you smoke?
 - Less than a pack
 - 1 pack
 - 2 packs
 - 3 + packs
 - I do not currently smoke/I have never smoked cigarettes.

6. During the most recent period of wildfire, did you quit (cessate) smoking cigarettes or vape/e-cigarette due to respiratory symptoms such as shortness of breath, cough, wheeze, etc.?
 - Yes
 - I smoked less cigarettes/e-cigarettes/vape than I normally would have (due to shortness of breath, cough, etc.)
 - No

MODULE 6. PREGNANCY MODULE⁸

1. Do you have functional reproductive organs (such as a uterus and ovaries) that allow you to *carry* a baby to full term?
 - Yes
 - No

⁸ Evenson, K.R., Herring, A.H., Wen, F., 2012. Self-Reported and objectively measured physical activity among a cohort of postpartum women: the PIN Postpartum Study. *J Phys Act Health* 9, 5–20. <https://doi.org/10.1123/jpah.9.1.5>

If you answered yes to question 1, answer questions 2. If you answered no to question 1, skip to the GI module.

2. Have you recently received a positive at-home pregnancy test (urine HCG) or told by your doctor (urine or blood HCG, ultrasound) that you may likely be pregnant?
 - Yes
 - No

If you answered yes to question 2, answer questions 3 - 10. If you answered no to question 2, skip to the GI module.

3. Do you feel calm right now?
 - 1 = Not at all
 - 2 = Somewhat
 - 3 = Moderately so
 - 4 = Very much so
4. Do you feel secure right now?
 - 1 = Not at all
 - 2 = Somewhat
 - 3 = Moderately so
 - 4 = Very much so
5. Do you feel tense right now?
 - 1 = Not at all
 - 2 = Somewhat
 - 3 = Moderately so
 - 4 = Very much so
 -
6. Do you feel strained right now?
 - 1 = Not at all
 - 2 = Somewhat
 - 3 = Moderately so
 - 4 = Very much so
 -
7. Do you feel at ease right now?
 - 1 = Not at all
 - 2 = Somewhat
 - 3 = Moderately so
 - 4 = Very much so
8. Do you feel upset right now?
 - 1 = Not at all
 - 2 = Somewhat
 - 3 = Moderately so
 - 4 = Very much so

9. How worried are you about possible misfortune right now?
- 1 = Not at all
 - 2 = Somewhat
 - 3 = Moderately so
 - 4 = Very much so
10. Has your doctor told you that you are suffering from high blood pressure (also called gestational hypertension), diabetes (also called gestational diabetes), or other pregnancy-related complication as a result of this pregnancy?
- Yes
 - No

MODULE 7. GASTROINTESTINAL (GI) MODULE⁹

1. Do you have a history of chronic heartburn, diagnosed by doctors as gastroesophageal reflux disease (GERD) by doctors?
- Yes
 - No

If you answered yes to question 1, answer questions 2 - 7. If you answered no to question 1, skip to the Skin module.

2. How often did you have a burning feeling behind your breast bone (heartburn) over the last week?
- No days
 - 1 day
 - 2 – 3 days
 - 4 – 7 days
3. How often did you have stomach contents (liquid or food) moving upwards to your throat or mouth (also known as regurgitation or emesis)?
- No days
 - 1 day
 - 2 – 3 days
 - 4 – 7 days
4. How often did you have a pain in the center of the upper stomach (possibly called “epigastric” pain by your doctor)?
- No days
 - 1 day
 - 2 – 3 days
 - 4 – 7 days

⁹ Jones, R., Junghard, O., Dent, J., Vakil, N., Halling, K., Wernersson, B., Lind, T., 2009. Development of the GerdQ, a tool for the diagnosis and management of gastro-oesophageal reflux disease in primary care. *Aliment Pharmacol Ther* 30, 1030–1038. <https://doi.org/10.1111/j.1365-2036.2009.04142.x>

5. How often did you have nausea?
 - No days
 - 1 day
 - 2 – 3 days
 - 4 – 7 days

6. How often did you have difficulty getting a good night's sleep because of your heartburn and/or regurgitation?
 - No days
 - 1 day
 - 2 – 3 days
 - 4 – 7 days

7. How often did you take additional medication for your heartburn and/or regurgitation, other than what the physician told you to take (over-the-counter medications like TUMS or Rolaids)?
 - No days
 - 1 day
 - 2 – 3 days
 - 4 – 7 days

MODULE 8. SKIN (INTEGUMENTARY) MODULE¹⁰

1. Has your doctor ever told you that you have atopic dermatitis (AD), or red, scaly rashes that appear seemingly at random and in many different parts of the body?
 - Yes
 - No

If you answered yes to question 1, answer questions 2 - 8. If you answered no to question 1, you may skip to the Recent Infection module..

2. Over the last week, on how many days has your skin been itchy because of your eczema?
 - No days
 - 1 -2 days
 - 3 -4 days
 - 5 – 6 days
 - Every day

¹⁰ Charman, C.R., Venn, A.J., Williams, H.C., 2004. The patient-oriented eczema measure: development and initial validation of a new tool for measuring atopic eczema severity from the patients' perspective. Arch Dermatol 140, 1513–1519. <https://doi.org/10.1001/archderm.140.12.1513>

3. Over the last week, on how many nights has your sleep been disturbed because of your eczema?
 - No days
 - 1 -2 days
 - 3 -4 days
 - 5 – 6 days
 - Every day

4. Over the last week, on how many days has your skin been bleeding because of your eczema?
 - No days
 - 1 -2 days
 - 3 -4 days
 - 5 – 6 days
 - Every day

5. Over the last week, on how many days has your skin been weeping or oozing clear fluid because of your eczema?
 - No days
 - 1 -2 days
 - 3 -4 days
 - 5 – 6 days
 - Every day

6. Over the last week, on how many days has your skin been cracked because of your eczema?
 - No days
 - 1 -2 days
 - 3 -4 days
 - 5 – 6 days
 - Every day
 - No days

7. Over the last week, on how many days has your skin been flaking off because of your eczema?
 - No days
 - 1 -2 days
 - 3 -4 days
 - 5 – 6 days
 - Every day

MODULE 9. RECENT INFECTION MODULE^{11,12}

Question 1 is from the ECHO COVID-19 Questionnaire. Questions 2-5 were questions that were similar or shared between the FLU-PRO and the ECHO COVID-19 Questionnaire.

1. Did you have viral symptoms like fever, cough, or diarrhea during the most recent period of wildfires?
 - Yes
 - No
2. Have you received a positive COVID-19 or influenza test during the most recent period of wildfires?
 - Yes
 - No

If you answered yes to question 1 or 2, answer questions 3 - 5. If you answered no to question 1, skip to the final module.

3. Have you experienced fever, chills, cough, shortness of breath, sore throat, headache, muscle/body aches, runny nose, gastrointestinal distress, or loss of smell/taste?
 - Yes
 - No
4. Did you require medical care for either COVID-19 or influenza such as an appointment with a doctor or treatment with medication?
 - Yes
 - No
5. Were you hospitalized as a result of COVID-19 or influenza infection during the most recent period of wildfires?
 - Yes
 - No

MODULE 10. WILDFIRE EXPOSURE¹³

1. In the last two weeks, did you smell smoke outside or see that there was low visibility due to smoke?
 - Yes

¹¹ PhenX Toolkit: Covid19 [WWW Document], n.d. URL <https://www.phenxtoolkit.org/covid19/source> (accessed 5.13.23).

¹² Han, A., Poon, J.-L., Powers, J.H., Leidy, N.K., Yu, R., Memoli, M.J., 2018. Using the Influenza Patient-reported Outcome (FLU-PRO) diary to evaluate symptoms of influenza viral infection in a healthy human challenge model. *BMC Infectious Diseases* 18, 353. <https://doi.org/10.1186/s12879-018-3220-8>

¹³ Kirsch, K.R., Feldt, B.A., Zane, D.F., Haywood, T., Jones, R.W., Horney, J.A., 2016. Longitudinal Community Assessment for Public Health Emergency Response to Wildfire, Bastrop County, Texas. *Health Secur* 14, 93–104. <https://doi.org/10.1089/hs.2015.0060>

- No

If you answered yes to question 1, continue to question 2. If you answered no to question 1, skip to question 3.

2. How many days over the last two weeks was this the case?
 - One day
 - Two to three days
 - Three to five days
 - Five to seven days
 - Seven to twelve days
 - Every day
3. Did you use any of the following protective actions when going outdoors? (Select all that apply)
 - Stayed indoors more
 - Reduced time exercising outside
 - Used a respirator such as an N95 or KN95 when going outside
 - I did not use any protective actions when going outside
4. Did you use any of the following protective actions when indoors? (Select all that apply)
 - Installed or used HEPA filters
 - Installed or used commercial HEPA or HVAC system
 - Installed or used a home-made HEPA filter with a box fan
 - Used a respirator such as N95 or KN95 when indoors
 - Kept windows closed
 - Moved to a space with cleaner air
 - I did not use any protective actions when indoors
5. How often do you think you are exposed to unhealthy air quality from wildfire smoke in any given year?
 - Less than one day in a year
 - One to three days per year
 - Three to five days per year
 - More than five days per year
 - More than two weeks per year
 - Don't know/Doesn't apply
6. Have you burned any food or been in the vicinity of anyone burning food within the last two weeks?
 - Yes
 - No

MODULE 11. EXIT SURVEY

1. Did you understand all of the questions you were asked to answer in this survey?

- Yes
- No

i. If you answered yes, please say what confused you and why:

2. How did you answer the questions in this survey today?

- I speak and read English and filled out this survey myself
- I speak and read English and **someone else** filled out this survey for me
- I do not read English, but I speak English. **Someone else** filled out this survey for me
- I do not read or speak English. Someone is **interpreting** for me and filling out this survey for me

Supplemental Information III – Citations for Articles Meeting Inclusion Criteria

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