

## Occupational exposure and health of wildland firefighters: protocol for a systematic review

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### Abstract

The frequency of forest fires has increased in recent years. This phenomenon has led to an increase in the difficulty of fighting them and an increase in the occupational exposure of firefighters. This study aims to carry out a systematic review protocol to obtain information on firefighters' occupational exposure on the fire front. A protocol was carried out following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses: PRISMA Statement guidelines. There were no age, gender or publication date restrictions for including articles within the scope of firefighter samples. The study aimed to understand all the risks to which firefighters are exposed when fighting forest fires and their relationship with the onset of occupational diseases. Thus, all studies with laboratory or real-time monitoring, using samples of firefighters, and which carried out evaluations that made it possible to identify exposure risk factors and their relationship with occupational activity were included. This list makes it possible to verify all the studies carried out up to the date of the review on this subject and to guarantee a contribution to improving knowledge in this area of research.

## 1. INTRODUCTION

There are many occupational hazards to which firefighters are exposed on the fire ground. Sometimes, it is difficult to identify most of them. Few studies are known that evaluate firefighters' occupational exposure on a fire front. This becomes a difficulty in assessing the different occupational risks involved in forest fires, which hinders the development of measures to mitigate these risks (Groot et al., 2019; Koopmans et al., 2020). The context of a forest fire has great demands on those working in its vicinity. Like other work environments, forest fires require analysis and assessment of occupational exposure that puts the safety and health of firefighters at risk, potentially leading to situations of accident, serious illness, or even death. The health impacts closely related to forest fire emissions are mortality and morbidity from cardiorespiratory

causes. Note that the emissions released increase influence the onset of asthma and chronic obstructive pulmonary disease (COPD) (Barbosa et al., 2022; Youssouf et al., 2014).

Real-time health monitoring systems for firefighters are being developed to ensure health and safety in the field. However, these systems have yet to be applied in significant risky activities with variables that provide sufficient information for evaluating the health status of firefighters during the execution of their actions and the characterisation of the occupational exposure associated with them (Carvalho et al., 2014).

Currently, scientific studies are more focused on assessing smoke exposure (Miranda et al., 2010; Navarro, 2020; Reinhardt & Ottmar, 2004), the respiratory health impacts associated with this exposure (Adetona et al., 2011; Hejl et al., 2013; Koopmans et al., 2022) and the cardiovascular load related to the activity (Sol et al., 2018; West et al., 2019). Despite this, the association between firefighters' occupational exposure and the onset of occupational diseases is still minimal. It is essential to highlight that this association is complex because most firefighters are volunteers, indicating that they perform other occupational activities.

This systematic review protocol proposes a review to describe the studies conducted to assess firefighters' occupational exposure in wildland firefighting. This is intended to categorise the risk of firefighters and the relationship with health impact. To this end, this review aims to identify parameters that are assessed in real-time in field and laboratory studies. This review protocol contributes to analysing and investigating new components associated with firefighters' exposure at the fire front and its relationship with health impacts and occupational disease.

## 2. METHODOLOGY

### 2.1. Protocol and registration

The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) Statement was the methodology adopted for this systematic literature review. The research strategy was developed based on the extension for Protocols (PRISMA-P) and extension guidelines for scoping reviews (Moher et al., 2009; Page et al., 2021; Shamseer et al., 2015). The protocol of review was registered on PROSPERO with ID CRD42023456338.

### 2.2. Eligibility criteria

#### *Type of Studies*

It will only be considered research articles published in indexed peer-reviewed journals. Conference papers, book chapters and literature review articles will be excluded.

#### *Context*

Field and simulated-scenario articles with an assessment of firefighters' occupational exposure in the forest were selected. Environmental assessments on occupational exposure were also considered.

#### *Participants*

All studies were included considering firefighters in active service, regardless of affiliation, position, or contractual relationship (professional or volunteer). There were no age or gender restrictions.

#### *Assessment Methods*

Field and laboratory studies focused on forest fires and studies with all types of assessments of firefighters and their work environment to characterise occupational exposure were accepted. In addition, articles that did not sample firefighters but focused on statistical treatment of pre-existing data to evaluate firefighters' occupational exposure in forest fires or the incidence of work-related illness were included.

## Language

Only articles in the English language were selected because it is a language that guarantees scientific quality and is used in Q1 and Q2 quartile journals.

## 2.3 Information sources

The search focused on the SCOPUS, Web of Science, Pubmed, Science Direct and Academic Search Complete databases. There were no date restrictions on the selection of articles. The selection of articles was divided into three stages. The first stage involved searching the database and eliminating all duplicates. In the second stage, all the studies that did not assess firefighters' occupational exposure at the front were eliminated by analysing the abstracts. Finally, in the last stage, the included articles are analysed, and information is collected on the assessment of occupational exposure and occupational diseases.

## 2.4 Search

The keywords will be combined using the Boolean Connectors "AND" and "OR", as shown in [Table 1](#). The first screening will be done by selecting articles based on title, abstract and keyword fields.

**Table 1.** Set of keywords in databases

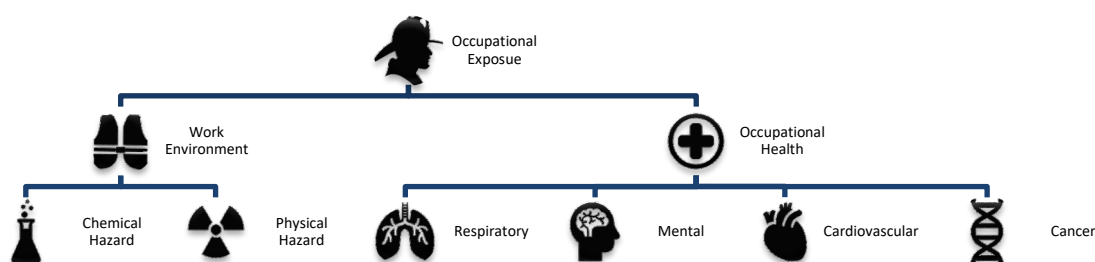
Database	Keywords
Scopus	((("Firefighters OR Fireman") AND ("Forest Fire" OR "Wildland fire") AND (Fatigue OR "Physiological Response" OR "Physiological Monitoring" OR Stress OR "Occupational Exposure" OR "Occupational Health" OR "Occupational Hygiene" OR "Work Injuries" OR "Professional Diseases" OR "Cognitive Function" OR "Occupational Safety" OR "Effort Subjectivity"))
Web of Science	"Firefighters"(All Fields)"or "Fireman"(All Fields)"and "Forest Fire"(All Fields)"or "Wildland fire"(All Fields) and "Fatigue (All Fields)"or "Physiological Response"(All Fields) or "Physiological Monitoring"(All Fields) or "Stress" (All Fields) or "Occupational Exposure"(All Fields) or "Occupational Health" (All Fields) or "Occupational Hygiene"(All Fields) or "Work Injuries"(All Fields) or "Professional Diseases"(All Fields) or "Cognitive Function" (All Fields) or "Occupational Safety" (All Fields) or "Effort Subjectivity (All Fields)
Pubmed	(((((firefighter) OR (fireman)) AND (Forest Fire)) OR (Wildland fire)) AND (Fatigue OR "Physiological Response" OR "Physiological Monitoring" OR Stress OR "Occupational Exposure" OR "Occupational Health" OR "Occupational Hygiene" OR "Work Injuries" OR "Professional Diseases" OR "Cognitive Function" OR "Occupational Safety" OR "Effort Subjectivity"))
Science Direct	((("Firefighters OR Fireman") AND ("Forest Fire" OR "Wildland fire") AND (Fatigue OR "Physiological Response" OR "Physiological Monitoring" OR Stress OR "Occupational Exposure" OR "Occupational Health" OR "Occupational Hygiene" OR "Work Injuries" OR "Professional Diseases" OR "Cognitive Function" OR "Occupational Safety" OR "Effort Subjectivity"))
Academic Search Complete	("Firefighters" "or "Fireman") AND ("Forest Fire OR "Wildland fire") AND ("Fatigue" OR "Physiological Response" OR "Physiological Monitoring" OR "Stress" OR "Occupational Exposure" OR "Occupational Health" OR "Occupational Hygiene" OR "Work Injuries" OR "Professional Diseases" OR "Cognitive Function" OR "Occupational Safety" OR "Effort Subjectivity)

Articles will be screened, and all the studies applied to animals or sick individuals will be excluded. In addition, studies focused on environmental and occupational exposure to forest fires will be included. The question raised in this review will be considered by analysing the included studies using an Occupational Safety and Health approach. The included studies will be highlighted in occupational safety and health through a work environment assessment approach using biomarkers or workload characterisation. The

articles in the occupational health section will focus on detecting work-related diseases. In the information-gathering process, the necessary data to assess occupational exposure and identify the exposure levels found by different authors about forest fires will be systematised and synthesised.

## 2.5 Data items

The selected articles should be divided into two categories, Occupational Health and Work Environment, according to the exposure assessments made by the researchers. Considering the themes and data discussed, the same article might simultaneously be included in multiple categories. These categories are shown in Figure 1, where the classification is defined according to the study approach. The risk factor and the relationship with the disease's onset determine the occupational exposure categorisation. According to the results, further categorisation could be developed.



**Figure 1.** Variables to categorization of occupational exposure

## 2.6 Risk of bias assessment

To assess the risk of bias, the study quality assessment tool developed by the National Heart, Lung and Blood Institute (NHLBI), Quality Assessment Tool for Observational Cohort and Cross-Sectional Studies, was applied (National Heart, Lung, 2021). A quality classification is proposed to determine the articles' weight and degree of evidence in the review. This weight is determined using the following classification from Figure 2.

<b>Fair</b>	<b>Good Quality</b>	<b>Very Good Quality</b>
<ul style="list-style-type: none"> <li>• &gt; 30% of "Not Report"</li> <li>• &lt; 50% of "Yes"</li> </ul>	<ul style="list-style-type: none"> <li>• 50-70 % of "Yes"</li> </ul>	<ul style="list-style-type: none"> <li>• ≥ 70% of "Yes"</li> </ul>

**Figure 2.** Study quality assessment

All issues that are not applied to the article represented as "Not Applicable" are not considered for the quality rating of the article. Studies considered "good quality" or "very good quality" will be given greater weight in the contribution of this review. On the other hand, all articles that are considered "Fair" will be eliminated and not included in the review.

## 2.7 Synthesis of results

All the results will be presented in tables and graphs using descriptive statistics to relate to the incidence and prevalence of occupational illness. The results should be classified in the several categories shown in point 2.6, identifying the highlights and study goals.

## 2.8 Records Management

The reference management of the selected articles was done through the "Mendelley-Reference Management Software & Researcher Network". All selected duplicate and

excluded documents were recorded in these records, and the respective reasons for exclusion were at the different stages of the selection process.

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### Authors contributions:

Conceptualisation, T.T., I.D., J.S., M.V., J.S.B, and J.C.G.; methodology, T.T., I.D, J.S, and J.C.G.; formal analysis, T.T., I.D., J.S., M.V., J.S.B, and J.C.G; draft writing preparation, T.T., J.S. and J.C.G.; drafting and editing revision, T.T., I.D., J.S., M.V., J.S.B and J.C.G.; project administration, J.S.B., M.V. and J.C.G.; funding acquisition, J.S.B., M.P.V. and J.C.G. All authors have read and agreed with the published version of the manuscript.

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## REFERENCES

- Adetona, O., Hall, D., & Naeher, L. (2011). Lung function changes in wildland firefighters working at prescribed burns. *Inhalation Toxicology*, 23, 835–841. DOI: [10.3109/08958378.2011.617790](https://doi.org/10.3109/08958378.2011.617790)
- Barbosa, J. V., Farraia, M., Branco, P. T. B. S., Alvim-Ferraz, M. C. M., Martins, F. G., Annesi-Maesano, I., & Sousa, S. I. V. (2022). The Effect of Fire Smoke Exposure on Firefighters' Lung Function: A Meta-Analysis. *International Journal of Environmental Research and Public Health*, 19(24), 16799. <https://doi.org/10.3390/ijerph192416799>
- Carvalho, F. P., Oliveira, J. M., & Malta, M. (2014). Exposure to radionuclides in smoke from vegetation fires. *Science of the Total Environment*, 472, 421–424. <https://doi.org/10.1016/j.scitotenv.2013.11.073>
- Groot, E., Caturay, A., Khan, Y., & Copes, R. (2019). A systematic review of the health impacts of occupational exposure to wildland fires. *International Journal of Occupational Medicine and Environmental Health*, 32(2), 121–140. <https://doi.org/10.13075/ijomeh.1896.01326>
- Hejl, A. M., Adetona, O., Diaz-Sanchez, D., Carter, J. D., Commodore, A. A., Rathbun, S. L., & Naeher, L. P. (2013). Inflammatory effects of woodsmoke exposure among wildland firefighters working at prescribed burns at the Savannah River site, SC. *Journal of Occupational and Environmental Hygiene*, 10(4), 173–180. <https://doi.org/10.1080/15459624.2012.760064>
- Koopmans, E., Cornish, K., Fyfe, T. M., Bailey, K., & Pelletier, C. A. (2022). Health risks and mitigation strategies from occupational exposure to wildland fire: a scoping review. *Journal of Occupational Medicine and Toxicology*, 17(1), 2. <https://doi.org/10.1186/s12995-021-00328-w>
- Koopmans, E., Fyfe, T., Eadie, M., & Pelletier, C. (2020). Exploring prevention and mitigation strategies to reduce the health impacts of occupational exposure to wildfires for wildland firefighters and related personnel: protocol of a scoping study. *Systematic Reviews*, 9, 119. <https://doi.org/10.1186/s13643-020-01381-y>
- Miranda, A. I., Martins, V., Cascão, P., Amorim, J. H., & Valente, J. (2010). Monitoring fire-fighters' smoke exposure and related health effects during Gestosa experimental fires. 137(2), 83–94. <https://doi.org/10.2495/FIVA100081>
- Moher, D., Liberati, A., Tetzlaff, J., Altman, D. G., & Group, T. P. (2009). Preferred Reporting Items for Systematic Reviews and Meta-Analyses: The PRISMA Statement. *PLOS Medicine*, 6(7), <https://doi.org/10.1136/bmj.b2535>.

- National Heart, Lung, and B. I. (2021). Study Quality Assessment Tools. <https://www.nhlbi.nih.gov/health-topics/study-quality-assessment-tools>
- Navarro, K. (2020). Working in Smoke: Clinics in Chest Medicine, 41(4), 763–769. <https://doi.org/10.1016/j.ccm.2020.08.017>
- Page, M. J., McKenzie, J. E., Bossuyt, P. M., Boutron, I., Hoffmann, T. C., Mulrow, C. D., Shamseer, L., Tetzlaff, J. M., Akl, E. A., Brennan, S. E., Chou, R., Glanville, J., Grimshaw, J. M., Hróbjartsson, A., Lalu, M. M., Li, T., Loder, E. W., Mayo-Wilson, E., McDonald, S., ... Moher, D. (2021). The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. *Systematic Reviews*, 10(1), 89. <https://doi.org/10.1186/s13643-021-01626-4>
- Reinhardt, T. E., & Ottmar, R. D. (2004). Baseline measurements of smoke exposure among wildland firefighters. *Journal of Occupational and Environmental Hygiene*, 1(9), 593–606. <https://doi.org/10.1080/15459620490490101>
- Shamseer L, Moher D, Clarke M, Ghersi D, Liberati A, Petticrew M, Shekelle P, S. L. (2015). PRISMA-P ( Preferred Reporting Items for Systematic Review and Meta-Analysis Protocols ) 2015 checklist : recommended items to address in a systematic review protocol, DOI: [10.1186/2046-4053-4-1](https://doi.org/10.1186/2046-4053-4-1)
- Sol, J. A., Ruby, B. C., Gaskill, S. E., Dumke, C. L., & Domitrovich, J. W. (2018). Metabolic Demand of Hiking in Wildland Firefighting. *Wilderness and Environmental Medicine*, 29(3), 304–314. <https://doi.org/10.1016/j.wem.2018.03.006>
- West, M. R., West, M. R., Costello, S., Sol, J. A., & Domitrovich, J. W. (2019). Risk for heat-related illness among wildland firefighters: Job tasks and core body temperature change. *Occupational and Environmental Medicine*, 77(7), 433–438. <https://doi.org/10.1136/oemed-2019-106186>
- Youssef, H., Liousse, C., Roblou, L., Assamoi, E. M., Salonen, R. O., Maesano, C., Banerjee, S., & Annesi-Maesano, I. (2014). Non-accidental health impacts of wildfire smoke. *International Journal of Environmental Research and Public Health*, 11(11), 11772–11804. <https://doi.org/10.3390/ijerph111111772>