



Review Article

Repercussion of working conditions on the health of wildland firefighters: a Scoping Review

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ABSTRACT

Introduction. Climate change intensifies wildfires by increasing temperatures, reducing rainfall, and bringing forward snowmelt. Their extinction involves multiple risks for firefighters due to the extreme conditions of their work. The main aim of the study was to describe the relationship between working conditions and their effects on the health of wildland firefighters.

Objectives. The main objective of this scoping review is to explore and describe the relationship between working conditions and the impact on the health of wildland firefighters.

Method. Scoping Review based on PRISMA-ScR and academic regulations, using scientific sources published between 2014 and 2024, analysed through descriptive statistics.

Results. Most studies were published between 2019 and 2022, mainly in the United States, with descriptive and cohort methodologies. The population studied consisted mainly of men with the category of wildland firefighter. The main occupational risks analysed were exposure to chemical agents and extreme temperatures. The most frequent diseases were cardiovascular, respiratory, and immunological. Among the prevention strategies, the use of protective equipment, cooling measures, shift regulation, and health surveillance stood out.

Conclusions. Repeated exposure to extreme environmental conditions affects the health of wildland firefighters, generating physical and mental issues. Improving personal protective equipment and optimising hydration, cooling, and post-exposure hygiene practices, together with health surveillance, are key to reducing the negative effects of their work.

Keywords: Occupational hazards; Occupational health; Wildfires.

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Introduction

Concept and general overview. Wildland firefighters

Working conditions are defined, according to Article 4.7 of Law 31/1995 of 8 November on the Prevention of Occupational Risks (LPRL), as “any characteristic of the job that may have a significant influence on the generation of risks to the safety and health of the worker” (1).

Firefighters are professionals responsible for extinguishing fires and providing assistance during other emergencies (2). Wildland firefighters possess specific knowledge, training, and equipment for the extinction, prevention, detection, and surveillance of wildfires (2,3).

The tasks they perform vary according to the type of crew to which they belong, enabling them to carry out their work effectively. Key types include helitack crews, ground crews, and motorised crews, each with specific roles that determine the risks they are exposed to and the consequent health impacts. Helitack crews use helicopters to carry out rapid suppression tasks in hard-to-reach areas; ground crews construct firelines and carry out controlled burns using hand tools, often on foot; motorised crews use fire engines or off-road vehicles to transport personnel and essential firefighting equipment such as hoses or water tanks (4).

Activities carried out by these crews during fire suppression include operating single-engine diesel pumps that supply water to ground crews or building firebreaks. This begins with clearing vegetation using chainsaws, followed by digging down to the mineral soil with hand tools to stop the fire’s spread. Once the fire is under control, wildland firefighters are responsible for clearing the area to remove any material that could reignite vegetation (4,5).

Moreover, when a large wildfire breaks out (over 500 hectares), firefighters are housed in a base camp near the scene, meaning they are continuously exposed to smoke as well as vehicle and machinery emissions used in suppression operations (5).

Due to the nature of the environment in which they operate, wildfires require professionals to undertake prolonged periods of strenuous activity in extreme temperatures (6).

Main risks and protective equipment

Wildfire suppression entails significant safety and health risks for wildland firefighters, as it involves an unpredictable phenomenon that demands rapid response in a complex process carried out under adverse conditions. It is essential to consider the physical environment where these fires occur, the high temperatures typical of the season, and the specific challenges associated with suppression tasks (including the handling of inherently dangerous tools) and the constant, unpredictable changes in fire behaviour and direction. The combination of these factors creates unforeseen dangers that greatly increase the likelihood of accidents (7).

The main risks include (8–13):

- Thermal risks arising from fire radiation and heat stress due to body water loss through sweating (12). High thermal intensity can cause burns, which in severe cases may lead to death (8).
- Noise and vibration risks, caused by tools and transport equipment (12). According to Royal Decree 286/2006 of 10 March on the protection of workers' health and safety from noise-related risks, the daily equivalent exposure limit for all workplace noise (including impulse noise) is 87 decibels (dB), while the peak level, defined as the maximum instantaneous sound pressure, is 140 dB (13).
- Risks from smoke exposure, resulting in the release of environmental pollutants (carbon, nitrogen oxides, carbon dioxide, etc.) harmful to respiratory health (12). PM4 and PM2.5 particles (particulate matter with diameters smaller than 4 and 2.5 micrometres, respectively) are particularly hazardous due to their ability to penetrate deep lung tissues (9,11).
- Exposure to chemical or potentially carcinogenic substances (8), particularly polycyclic aromatic hydrocarbons (PAH) and hydroxylated PAH (OHPAH). Though chemically distinct, both have carcinogenic potential, can damage DNA, and contribute to oxidative stress.
- Abrasion and friction injuries during movement or work, often caused by contact with branches, thorny plants, and other natural elements (12).
- Visibility-related risks due to smoke, steam, airborne particles, vegetation accumulation, complex terrain, and night-time operations (12).

- Impact hazards from falling rocks, trees, or branches; high-pressure hoses; or moving equipment such as helicopters and tools (12).
- Slips, trips, and falls, either at the same or different levels, owing to the forest terrain's topographical complexity and vegetation density (8,12).
- Manual handling risks, due to the frequent lifting and carrying of tools, equipment, and protective clothing (8).
- Biological risks, including insect bites or stings (8,12).
- Vehicle-related accidents, such as entrapment or being run over (8,12).
- Psychosocial risks, due to high mental and emotional demands and exposure to occupational stressors associated with the unpredictable nature of the job (10).

Wildfires and their impact

The most concerning wildfires are those that spread uncontrollably through forest fuels (14).

Climate change exacerbates wildfire intensity and duration due to higher temperatures, reduced rainfall, and earlier snowmelt (15). The year 2024 was the hottest ever recorded, with temperatures surpassing pre-industrial levels (16). In Spain, rainfall in 2023 was estimated to have decreased by 25% (17). These drought conditions prolong and intensify wildfire seasons, prompting annual state-level firefighting campaigns (18). Additionally, land use for recreational purposes, among others, has altered wildfire dynamics (15).

Magnitude

Between 2018 and 2023, Spanish wildland firefighters suffered nine occupational accidents during wildfire suppression. These included: one laceration injury, four burn-related accidents, one knee sprain, two injuries to upper and lower limbs following a fall caused by a landslide, and one fatality due to sudden collapse (19–22).

However, the actual extent of wildfires in Spain cannot be determined precisely due to the lack of official data from public sources.

Legal framework

Spanish wildland firefighters are employed by the state-owned company Transformación Agraria Sociedad Anónima and, like all workers, are entitled to effective protection in matters of occupational health and safety. According to Article 6 of Law 31/1995 of 8 November (LPRL), “The government shall regulate working conditions or specific preventive measures in particularly hazardous work” (1). This implies that the regulatory provisions of the LPRL outlined in Article 6 apply to wildfire brigade workers.

Other relevant articles include Article 16, concerning risk assessment (1), and Article 17, which states that employers must ensure the suitability of work equipment. This aligns with Royal Decree 773/1997 of 30 May, which establishes the minimum health and safety requirements for the use of personal protective equipment (PPE) (1,23).

Beyond the Spanish legal framework, several international institutions also provide guidance relevant to occupational health and safety in high-risk professions such as firefighting. In the field of occupational safety and health, the International Labour Organization (ILO) has established that a safe and healthy working environment is a fundamental principle and right at work, urging governments to implement national policies and frameworks to identify, assess, and control occupational hazards, particularly in high-risk professions such as firefighting (24). The National Institute for Occupational Safety and Health (NIOSH) in the United States recognises wildland firefighters as a population exposed to multiple hazards such as heat stress, smoke inhalation, and emerging chemical contaminants, and has established the Center for Firefighter Safety, Health, and Well-being to address these challenges through research and surveillance (25). At the European level, the European Agency for Safety and Health at Work (EU-OSHA) highlights that first responders, including firefighters, face an evolving “cocktail of hazards” aggravated by climate change, extreme heat, and air pollution, stressing the importance of ergonomic adaptation, psychosocial support, and preventive culture (26).

Given the magnitude, impact, and significance of the risks faced by wildland firefighters and their effects on health, a study is proposed to determine the scope and nature of current knowledge regarding the occupational risks encountered by wildland firefighters and their repercussions on health, encompassing both physical and psychological aspects.

Objectives

Main objective:

- To describe the relationship between working conditions and their effects on the health of wildland firefighters.

Specific objectives:

- To identify the working conditions experienced by wildland firefighters during wildfire suppression, rescues, road traffic accidents, medical emergencies, natural disasters, and hazardous materials incidents. To examine the main health problems faced by wildland firefighters in relation to the performance of their duties.
- To describe the prevention strategies and control measures applied to the risks associated with wildland firefighter activities.

Methods

Design

A Scoping Review was carried out following the corresponding PRISMA checklist (PRISMA-ScR), using a structured approach to synthesise the available information on working conditions and their impact on the health of wildland firefighters.

The literature search was conducted in July 2024.

Search strategy

The databases used were Medline (via PubMed), CINAHL, Scopus and Cuiden. Specific strategies were designed for each database using relevant descriptors related to the topic. Both free-text terms and standardised terminology from Medical Subject Headings (MeSH) and Descriptores en Ciencias de la Salud (DeCS) were used, adapting each term to the search engine in order to increase specificity (Table 1).

The search was limited to articles published between 2014 and 2024, in either Spanish or English, to ensure an up-to-date and relevant review.

The review was supplemented with a backward search to identify additional literature. This included reviewing studies related to the articles previously selected.

The research question was formulated using the PCC format (Population–Concept–Context):

- Population: wildland firefighters.
- Concept: impact of working conditions.
- Context: health problems related to wildfires.

Table 1. Search terms.

Free-text terms	Burns; Environmental hazards; Exposure; Firefighters; Forest firefighters; Heat stress disorders; Natural disasters; Occupational accidents; Occupational risks; Risk factors; Smoke inhalation injury; Wildfires; Wildland firefighter; Working conditions; Wounds.
MeSH	Accidents, occupational; Burns; Firefighters; Heat stress disorders; Natural disasters; Smoke inhalation injury; Wildfires; Working conditions; Wounds and injuries.
DeCS	Accidentes de trabajo; Bomberos; Condiciones de trabajo; Desastres naturales; Heridas y lesiones; Incendios forestales; Lesión por inhalación del humo; Quemaduras; Trastornos de estrés por calor.

The search strategy used boolean operators “OR” for terms referring to the same concept and “AND” to combine different concepts.

Article selection criteria

Articles were reviewed and analysed independently by two researchers in a two-phase selection process. In the first phase, titles and abstracts were reviewed to assess alignment with the predefined objectives. In the second phase, potentially eligible full-text articles were analysed.

Inclusion criteria:

- Articles from primary or secondary sources.
- Articles in Spanish or English.
- Articles published in the last 10 years.

- Open access articles or accessible through institutional subscriptions.
- Articles related to the study's objectives.

Exclusion criteria:

- Opinion articles, blogs or publications from non-academic/scientific websites.
- Articles whose content does not relate to the study's objectives.
- Studies on fires that are not applicable to the wildland context.

Article selection

The search strategy is shown in Table 2 (Annex I). In addition, the article selection process is described in Figure 1.

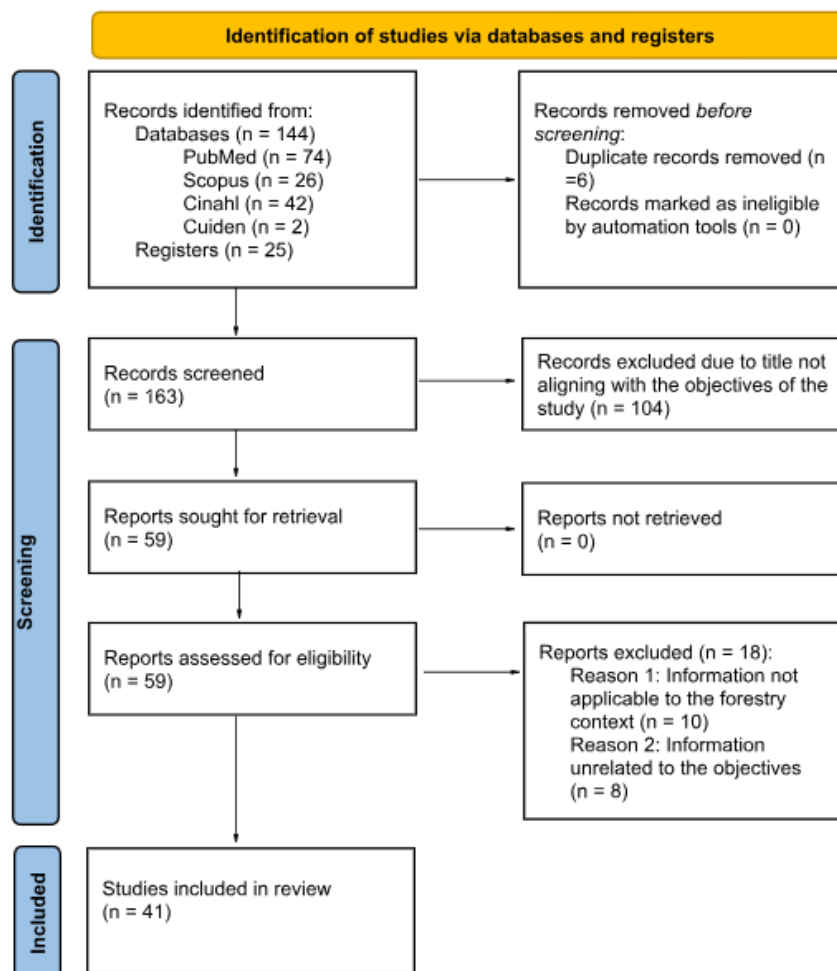


Figure 1. Article selection process (27).

Data collection and analysis

Variables

A set of variables and supplementary information were collected in a Microsoft Excel spreadsheet:

- Year: The calendar year the article was published. Ordinal qualitative variable. Categories: All consecutive years from 2014 to 2024

- Country: The country where the study was conducted. Nominal, qualitative, polytomous variable. Categories: countries where the articles were published.

- Study design: The design of the articles included in the review. Nominal, qualitative, polytomous variable. Categories: randomised clinical trials, descriptive studies, cohort studies, quasi-experimental studies, systematic reviews, literature reviews, meta-analyses.

- Biological sex: Refers to chromosomal sex. Nominal, qualitative, dichotomous variable. Categories: male, female.

- Sample size: Number of participants in each study. Quantitative discrete variable.

- Study population: Type of firefighters included. Nominal, qualitative, polytomous variable. Categories: firefighters, wildland firefighters, volunteer firefighters.

- Working conditions: Activities or exposures posing health risks. Nominal, qualitative, polytomous variable. Categories: high temperatures, chemical agents, medical emergencies, hazardous materials, fire hazards, firefighting, rescues, vehicle accidents, overnight camp stays, physical and psychological stressors, noise exposure.

- Health problems: Refers to health conditions. Nominal, qualitative, polytomous variable. Categories: respiratory diseases, cardiovascular diseases, exhaustion and heatstroke, mental disorders, musculoskeletal disorders, immune diseases, cancer, urological conditions, burns, death.

- Prevention and control: Strategies to prevent disease and control risks. Nominal, qualitative, polytomous variable. Categories: PPE use, damage minimisation strategies, hydration and nutrition monitoring, controlled shifts/activities, hygiene measures, prescribed burns, health surveillance.

Data analysis

The data were extracted into an Excel database, including the established variables, objectives, results, and conclusions. Descriptive statistical procedures were used for

quantitative analysis through SPSS Statistics v.24.0, calculating absolute and relative frequencies. The main results are presented as figures and tables.

Ethical considerations

Data were obtained from articles published in the databases mentioned. Therefore, according to Law 14/2007 of 3 July (28), ethics committee approval was not required.

Results

General descriptive results

Regarding publication year, most articles were published between 2022 (n=7) and 2019 (n=6), followed by 2020, 2021, and 2024 (n=5), then 2017 (n=3), with lower output in the remaining years (Figure 2).

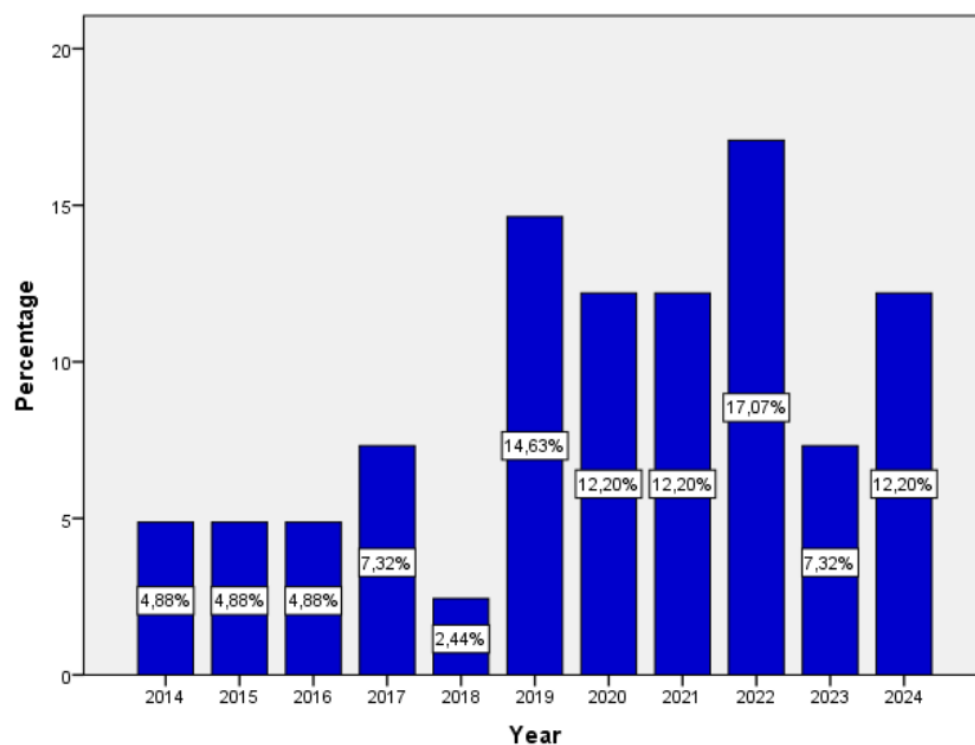


Figure 2. Percentage of articles published per year (2014–2024).

As for the country of publication, the majority were from the USA (60.97%, n=25), followed by Australia (12.19%, n=5), Canada (7.31%, n=3), Spain and Portugal (4.87%, n=2 each), and one article each from China, Russia, Switzerland and Belgium.

In terms of study design (Figure 3), most were descriptive studies (n=13) and cohort studies (n=8), followed by literature reviews (n=7), quasi-experimental studies (n=6), randomised clinical trials (n=3), systematic reviews (n=3) and one meta-analysis (n=1).

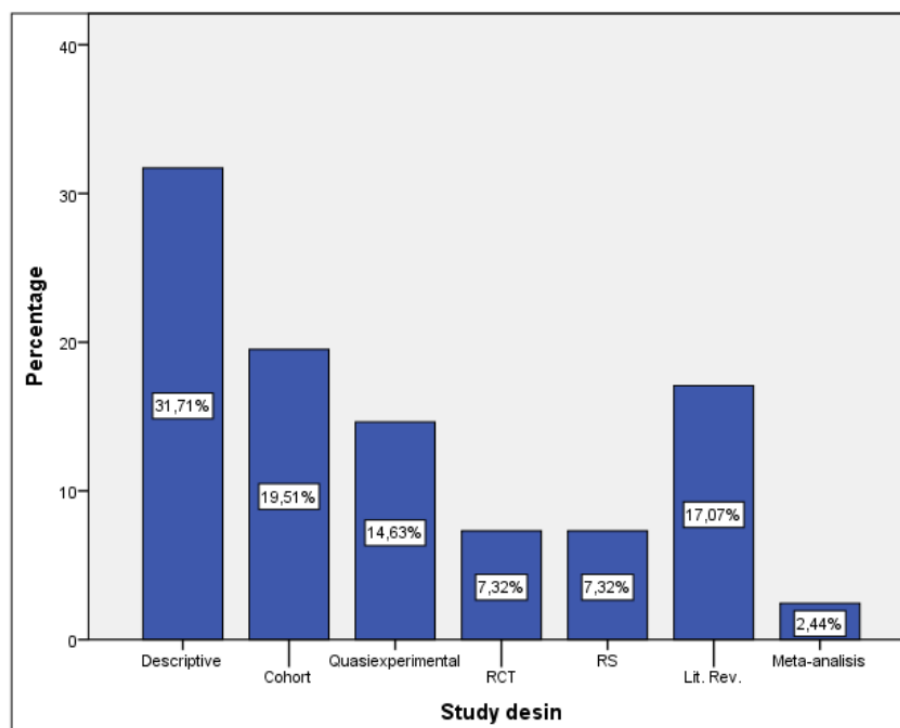


Figure 3. Study designs

RCT: Randomised Clinical Trial; SR: Systematic Review; Lit. Rev.: Literature Review.

Analysis of participants' biological sex showed that 90.27% (n=4,493) were male and 9.72% (n=484) female, out of a total of 4,977 participants. Some articles did not specify sex.

A total of 6,093 participants were included, of whom 61.15% (n=3,726) were wildland firefighters, 38.81% (n=2,365) firefighters, and only 0.03% (n=2) volunteer firefighters.

Table 3 (Annex II) summarises key characteristics such as first author, year, title, country of publication, study design, biological sex, and sample size.

Results related to the objectives

To understand the impact of working conditions on wildland firefighters' health and the prevention and protection strategies, a compilation of objectives, main results and conclusions was prepared (Table 4, Annex III).

The conclusions of the analysed studies were grouped into three main areas:

- Risky working conditions for wildland firefighters.
- Health problems experienced by firefighters due to their profession.
- Prevention and promotion strategies in wildland firefighting.

The analysis of working conditions in fire suppression and exposure to harmful situations revealed that no studies referred specifically to medical emergencies or general exposure to hazardous materials. Only one study was found on each of the following: rescues, vehicle accidents, overnight camp stays, physical and psychological determinants, noise exposure, and exposure to biological agents.

As shown in Figure 4, chemical exposure was the most frequently studied risk (n=29), followed by high temperatures (n=11), issues related to firefighting (n=10), and intrinsic fire hazards (n=5).

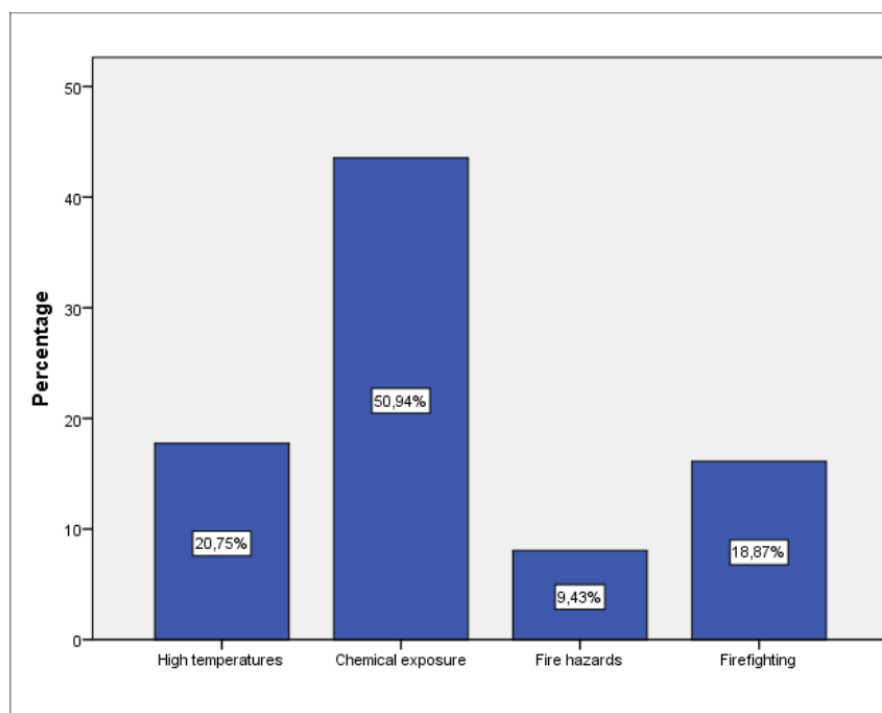


Figure 4. Working conditions and risk exposure.

Regarding health problems due to working conditions, one article addressed urinary disorders, one burns, and two focused on death. Figure 5 shows the most frequently studied conditions: cardiovascular diseases (n=14), respiratory diseases (n=13), immune disorders (n=9), cancers (n=8), exhaustion and

heatstroke (n=7), mental disorders (n=5), and musculoskeletal conditions (n=4).

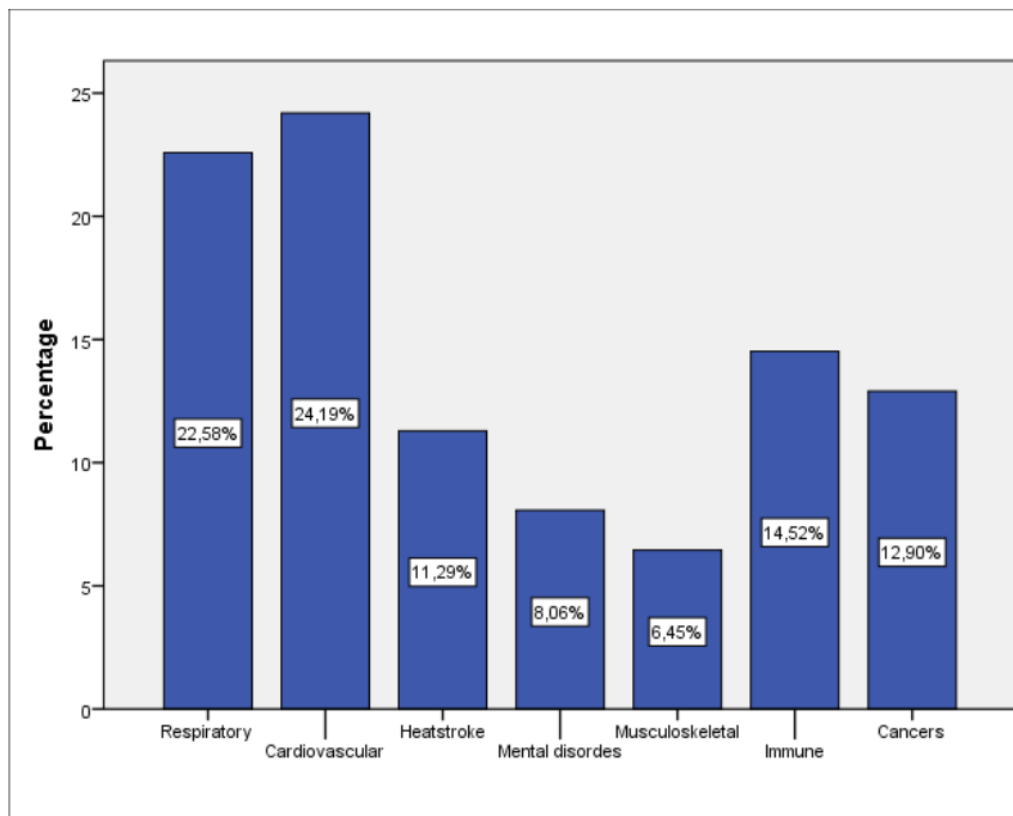


Figure 5. Health problems

Out of all the articles analysed, 16 focused on prevention strategies or control measures to mitigate work-related risks. As shown in Figure 6, these included: PPE use (n=15); damage minimisation strategies (n=14), such as training in realistic conditions, cooling strategies after fires, and rest periods; attention to hydration and nutrition (n=6); controlled shifts and activities (n=7); hygiene measures (n=4); prescribed burns (n=2); and health surveillance systems (n=3).

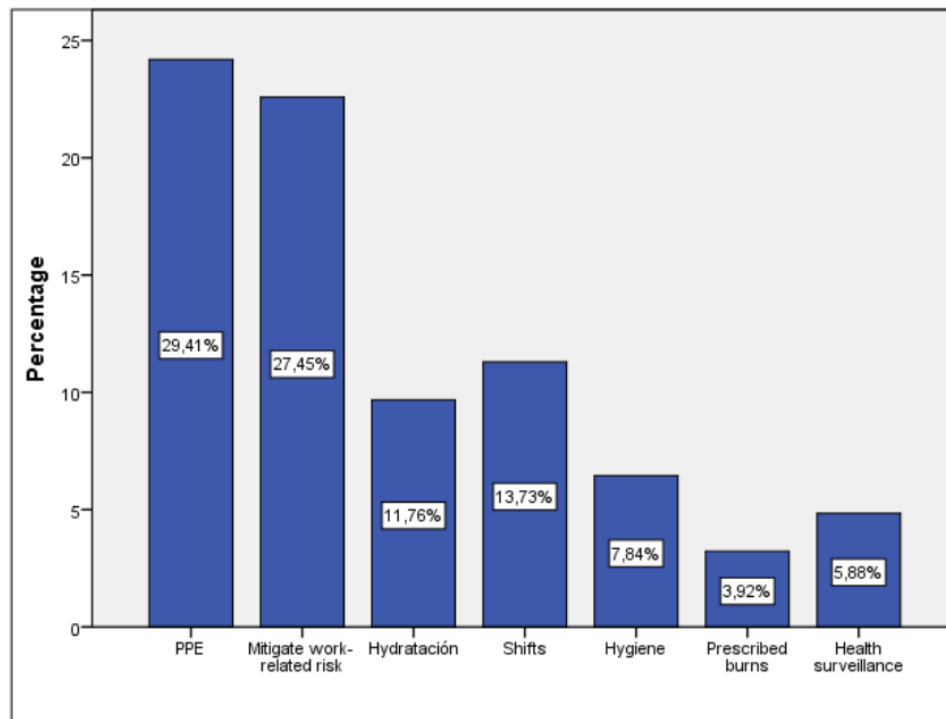


Figure 6. Prevention and control measures.

Discussion

The increase in publications from 2019 to 2024 may be attributed to more intense and prolonged wildfires due to climate change, as well as growing interest in the occupational hazards these fires pose to human health. The lockdown during the COVID-19 pandemic reduced carbon emissions due to decreased transportation and industrial activity, providing a unique opportunity to study the impact of environmental factors on air quality and human health.

With regard to the geographical distribution of studies, the United States was where most research was conducted. This may be due, in addition to its vast territory, to the availability of a robust infrastructure in terms of health research and funding. Other countries such as Australia and Canada were also prominent in this field of research, likely due to their vulnerability to such fires.

In terms of study design, descriptive articles predominated. This is probably due to the difficulty of implementing more comprehensive studies in this context. Although the presence of randomised controlled trials would be advisable to establish direct causality, in

the case of wildfires, limitations due to the unpredictable nature of these scenarios must be considered. Nevertheless, descriptive studies provide valuable information that helps to understand the risks these workers are exposed to.

Finally, the data regarding participant characteristics showed a marked male predominance, reflecting the masculinisation of the profession. Likewise, most participants were wildland firefighters as opposed to structural or volunteer firefighters. This finding may be related to the greater availability and accessibility of wildland firefighters, who often work in large institutions, facilitating access for research purposes.

Hazardous working conditions

Heat exposure increased both core and skin temperature, as well as perceived thermal sensation (29,30), although it did not affect heart rate or perceived exertion, likely due to the firefighters' capacity for self-regulation and the use of physical measures such as hydration (31). Other studies identified an increase in fatigue, which negatively affected performance (32).

Wildland firefighters were exposed to pollutants such as PAHs and volatile organic compounds, including acrolein, benzene, and formaldehyde (11,33). It was found that small amounts of these toxic substances could be absorbed through the skin, especially under hot and humid conditions, highlighting the need for additional measures to reduce chronic exposure (34).

Regarding physical risks, it was concluded that heat and humidity negatively affected balance, increasing the risk of falls, slips or trips (32). The most common injuries included sprains, strains and accidents involving tools or machinery (35). Furthermore, 93% of fatal incidents during firefighting operations were related to aerial accidents, mainly caused by structural failures (24%), loss of pilot control (24%), collisions with terrain or objects (20%), and hazardous weather conditions (15%) (36). High mortality rates were also reported due to aviation incidents, vehicle accidents, and entrapments, with motorised crew firefighters experiencing the highest injury rates (35).

Wildfire smoke was considered a significant risk due to the high concentrations of fine particles (PM_{2.5} and PM₄) recorded during activities such as direct suppression, sweeping, and holding (37-39). Evidence showed that wildfires emitted higher levels of PM_{2.5} compared to prescribed burns, suggesting that the latter may mitigate health effects (40). Although environmental concentrations of PM_{2.5} remained within expected levels, 5% of firefighters exceeded the permissible limits for CO (carbon monoxide), and 22% were exposed to hazardous levels of crystalline silica and quartz (41-43).

Main health problems

Exposure to wildfire smoke impacted respiratory health by causing a short-term decrease in lung function (44), manifested as a reduction in FEV₁ (forced expiratory volume in one second) immediately after exposure (45). However, no evidence showed that the decline in lung function persisted over time, as no follow-up testing was conducted post-exposure (44).

Regarding cardiovascular problems, it was observed that exposure to an average PM₄ concentration of 510 µg/m³ for 49 days per year led to increased blood carboxyhaemoglobin, arterial stiffness (37), hypertension, strokes, arrhythmias or acute myocardial infarction (33), increasing the risk of cardiovascular events by 1–2% for short-term exposure and up to 5–10% for prolonged exposure (46).

Ninety per cent of firefighters considered heat stress and heat stroke to be significant risks during firefighting (47). Moreover, one in three identified personal protective equipment (PPE) as a factor that exacerbated heat fatigue (48). Although exposure to high temperatures affected performance and balance (32), there was no increase in the number of heat-related injuries (31), probably due to acclimatisation exercises before deployment to the fire line, as well as cooling and rehydration breaks (47).

Post-traumatic stress disorder (PTSD) was identified as the most prevalent mental health condition, affecting up to 84% of wildland firefighters following exposure to a major fire (35), although prevalence decreased to 10–28% after seven years (44,49). Additionally, wildland firefighters showed higher suicide rates than structural firefighters, possibly due to isolation during fire suppression tasks, spending long periods away from civilisation and their families and friends (35).

Musculoskeletal injuries, such as sprains, foot and knee pain, or falls, were more frequent in lower-complexity fires (32), possibly due to reduced alertness or failure to follow cooling, rehydration, and acclimatisation protocols. Lower back pain due to the weight of tools and equipment was also reported (32), suggesting the need to use lighter materials or vehicles for transporting gear.

As for immunological conditions, a relationship was observed between smoke exposure and changes in immune cell levels, including increased blood basophils and decreased lymphocytes, neutrophils, eosinophils, and monocytes. Additionally, a redistribution of neutrophils, lymphocytes, and monocytes in the lungs was found, increasing their concentration in the sputum of firefighters and leaving the rest of the body more vulnerable to opportunistic infections. However, these effects appeared to reverse after a clearance period without exposure (50).

Firefighters were exposed to high concentrations of toxic and/or carcinogenic compounds, resulting in a 1.12 times greater risk of developing any type of cancer than the general population (51), with a 3% prevalence for basal cell skin cancer and 2% for squamous cell carcinoma (52), likely related to sun exposure during non-firefighting tasks, as they typically do not wear clothing that fully covers the skin. An association with bladder cancer and mesothelioma was also found (34), possibly linked to the reuse of contaminated PPE, allowing toxins to be absorbed through the skin and mucous membranes.

Preventive and control measures

The use of PPE was an essential measure to reduce exposure to pollutants and other hazards inherent to firefighting activities. However, limitations in design and functionality, particularly regarding respiratory protection, persisted. Studies stressed the need for equipment to protect not only against particles but also gases (42,53). This was especially relevant in areas with high incidence of diseases such as coccidioidomycosis (54). Furthermore, to optimise effectiveness and minimise heat stress, advances in materials and technologies were necessary, including the incorporation of cooling systems and weight reduction in PPE (32,48,55).

Proper hydration was crucial to prevent heat stress and maintain productivity (31,48). Although the literature varied on the most effective methods, among the combined

approaches—water and sports drinks, ad libitum intake with an initial water bolus (35), and self-regulated hydration (29)—the latter, being the most physiological, appeared to be the most promising. In addition, nutritional replenishment, including electrolytes, was highlighted as essential for sustaining performance and preventing heat-related illnesses (47).

Proper recovery after exercise was fundamental to preventing heat exhaustion and safeguarding long-term health (29, 31, 42, 43, 47, 55, 56). Strategies such as using cooling vests or deploying trailers with air filtration systems proved useful (32,42), although their implementation remained limited. Moreover, exercising in hot conditions may help improve acclimatisation (47), underscoring the importance of tailored training programmes for wildland firefighters.

Task rotation, limiting working hours, and frequent breaks were effective practices to reduce physical and mental strain, as well as the harmful effects of exposure to smoke or noise (29,42,43,57).

Likewise, strict personal hygiene and proper maintenance of PPE were essential to minimise dermal and respiratory exposure to toxic compounds (34,50,53). Measures such as post-work showers and nasal rinses proved effective (35,53), although their implementation could vary depending on the environment and available resources.

Prescribed burns were also an effective tool to reduce pollution levels and prevent uncontrolled wildfires (40,51).

In addition to these strategies, periodic health monitoring, such as PAH urinary metabolite analysis (53) or cardiovascular examinations (33), enabled early detection of adverse conditions. This was particularly important for addressing the cumulative risks associated with prolonged and repeated exposure to pollutants.

Finally, the implementation of crew resource management systems improved operational safety, particularly in aviation-related activities (36).

These preventive measures are consistent with the institutional approaches promoted by major occupational health organisations. The findings of this Scoping Review are aligned with the institutional perspectives advanced by the ILO, the NIOSH and the EU-OSHA, all of which advocate a comprehensive and preventive approach to occupational risk management. The ILO Guidelines on Occupational Safety and Health Management Systems

emphasise anticipation and prevention of hazards, participatory management, and continuous improvement of safety practices (58). NIOSH underscores the importance of continuous health monitoring, development of task-specific protective equipment, and tailored interventions for both structural and wildland firefighters (25). EU-OSHA stresses that climate change and environmental stressors amplify occupational risks and therefore require integrated prevention plans and ergonomic redesign (26).

The results of this article reinforce these institutional principles by demonstrating the cumulative physical and psychological impacts of prolonged exposure to heat, smoke, and physical strain. Incorporating the frameworks promoted by these organisations could enhance national and organisational policies, optimise firefighter health surveillance systems, and ensure that preventive measures are grounded in internationally recognised standards for occupational safety and health.

Strengths and limitations

The main strength of this review lies in the large number of articles analysed and the diversity of study designs, which provides a comprehensive overview of the health of wildland firefighters.

However, a significant limitation is the lack of updated data on occupational accidents and occupational diseases reported by wildland firefighters in Spain. Although efforts were made to gather information, only partial data from certain years provided by the Directorate-General for Civil Protection and Emergencies were obtained, supplemented with information from various portals, which may have affected accuracy and reliability.

Finally, another limitation of this review was the limited data collected on female participants. Although the number of women working in wildfire suppression has increased over the past 10 years, none of the included studies specified whether biological differences were taken into account in toxicological assessments, limiting understanding of potential sex-based health effects.

Future lines of research

In view of the anticipated increase in the intensity and duration of wildfires, there is a clear need to develop new lines of research that facilitate the implementation of a detailed

registry system to monitor exposure to occupational risk factors. This would support the development of interventions aimed at improving the health of these professionals and aid in designing prevention strategies in clinical practice.

Furthermore, it would be of interest to develop future studies to determine whether occupation-related health problems affect men and women differently, enabling a more equitable approach to prevention and treatment.

The working conditions of wildland firefighters and their health impacts serve as a small-scale example of the consequences that factors such as global temperature rise may have on physically demanding outdoor occupations, as well as the effects of smoke from large fires on public health, marking a line of research that extends from the specific to the collective.

Conclusions

The work of wildland firefighters presents significant risks to their health and safety due to the extreme environmental conditions and physical demands of their duties, including constant exposure to smoke, fine particles, and chemical compounds that affect both respiratory and cardiovascular health. Additionally, high temperatures and humidity, alongside the risk of accidents—such as aerial incidents—heighten workers' vulnerability.

Repeated exposure to extreme environmental conditions has consequences for the health of these firefighters. Physically, respiratory and cardiovascular effects, heat stress and musculoskeletal injuries stand out, as well as an increased risk of cancer and immune system alterations. Mentally, the elevated suicide rate in this group and the psychological impact of confronting high-risk situations are of particular concern.

Although self-management strategies, such as hydration and physical effort control, are essential for mitigating some of these risks, cumulative exposure remains a long-term health concern. Therefore, it is crucial to implement rigorous safety measures, improve PPE, optimize hydration, cooling and post-exposure hygiene practices, and develop health surveillance programmes. Innovation in these areas is key to reducing hazards and protecting the well-being of wildland firefighters in the performance of their duties.

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Conflicts of interest

Authors declare no conflicts of interest.

References

1. Ley 31/1995, de 8 de noviembre, de Prevención de Riesgos Laborales. Boletín Oficial del Estado, número 269, (10 de noviembre de 1995). Available at: <https://www.boe.es/buscar/act.php?id=BOE-A-1995-24292>
2. Real Academia Española y Asociación de Academias de la lengua Española. Diccionario panhispánico de dudas: bombero, bombera. 2ª ed. Madrid, RAE; 2005. Available at: <https://www.rae.es/dpd/bombero>
3. Ministerio para la Transición Ecológica y el Reto Demográfico. Las Brigadas de Refuerzo en Incendios Forestales (BRIF) del Ministerio. Ministerio para la Transición Ecológica y el Reto Demográfico. Available at: <https://www.miteco.gob.es/es/biodiversidad/temas/incendios-forestales/extincion/brif.html>
4. Navarro K, Butler C, Fent K, Toennis C, Sammons D, Ramirez-Cardenas A, et al. The Wildland Firefighter Exposure and Health Effect (WFFEHE) Study: Rationale, Design, and Methods of a Repeated-Measures Study. *Ann Work Expo Health*. 2 de julio de 2022;66(6):714-27. DOI: 10.1093/annweh/wxab117.
5. Navarro K. Working in Smoke: Wildfire Impacts on the Health of Firefighters and Outdoor Workers and Mitigation Strategies. *Clin Chest Med*. 2020;41(4):763-9. DOI: 10.1016/j.ccm.2020.08.017.
6. Instituto Nacional de Seguridad y Salud en el Trabajo. Nota Técnica de Prevención 867: Ropa de protección para bomberos forestales. INSST. 2024. Available at: <https://www.insst.es/documents/94886/326775/867w.pdf/4fcaf1e5-cc6d-451-b292-5d9bb0549c7a?version=1.0&t=1617977711908>
7. Junta de Andalucía. Plan INFOCA. Prevención de Riesgos Laborales. Junta de Andalucía. Available at: <https://www.juntadeandalucia.es/medioambiente/portal/areas-tematicas/medio-forestal/incendios-forestales>

Majjaoui-Sekkaki O, Arribas-López A, González-Pisano AC, Mayo-Herrero M, Naranjo-Pastor P. Repercussion of working conditions on the health of wildland firefighters: a Scoping Review. *Eur J Occ Health Nurs*. 2025; 4 (3): 11-63. DOI:10.70324/ejohn.v4i3.75

8. UGT. Guía de prevención de riesgos laborales para bomberos y bomberas forestales. UGT. 2024. Available at: <https://www.ugt.es/ugt-presenta-una-guia-de-prevencion-de-riesgos-laborales-para-bomberos-y-bomberas-forestales>
9. Samborska V, Ritchie H. Wildfires. Our World Data. 2024. Available at: <https://ourworldindata.org/wildfires>
10. Pelletier C, Ross C, Bailey K, Fyfe T, Cornish K, Koopmans E. Health research priorities for wildland firefighters: a modified Delphi study with stakeholder interviews. *BMJ Open*. 2022;12(2):e051227. DOI: 10.1136/bmjopen-2021-051227.
11. Navarro K, Kleinman M, Mackay C, Reinhardt T, Balmes J, Broyles G, et al. Wildland firefighter smoke exposure and risk of lung cancer and cardiovascular disease mortality. *Environ Res*. 2019;173:462-8. DOI: 10.1016/j.envres.2019.03.060.
12. Comité de lucha contra incendios forestales. Catálogo de Equipos de Protección Individual. Revisión 2011. Ministerio para la Transición Demográfica y el Reto Ecológico. 2012. Available at: <https://www.miteco.gob.es/es/biodiversidad/temas/incendios-forestales/epis.html>.
13. Real Decreto 286/2006, de 10 de marzo, sobre la protección de la salud y la seguridad de los trabajadores contra los riesgos relacionados con la exposición al ruido. Boletín Oficial del Estado, número 60, (11 de marzo de 2006). Available at: <https://www.boe.es/buscar/act.php?id=BOE-A-2006-4414>
14. Grupo de trabajo de estadística comité de lucha contra incendios forestales. Parte de incendio forestal (9ª actualización). Ministerio de Agricultura y Pesca, Alimentación y Medio Ambiente. Available at: https://www.miteco.gob.es/es/biodiversidad/temas/incendios-forestales/coordinacion-institucional/grupos_trabajo_clif.html
15. Koopmans E, Fyfe T, Eadie M, Pelletier C. 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. *Syst Rev*. 2020;9(1):119. DOI: 10.1186/s13643-020-01381-y.
16. Organización Meteorológica Mundial. La Organización Meteorológica Mundial confirma que en 2023 la temperatura mundial batió todos los récords. Organización Meteorológica Mundial. 2024. Organización Meteorológica Mundial. Available at: <https://wmo.int/es/news/media-centre/la-organizacion-meteorologica-mundial-confirma-que-en-2023-la-temperatura-mundial-batio-todos-los>
17. Subdirección General de Planificación Hidrológica. Informe mensual de seguimiento de la situación de sequía y escasez: Diciembre de 2023. Ministerio para la Transición Ecológica y el Reto Demográfico. 2023. Available at: <https://www.miteco.gob.es/es/agua/temas/observatorio-nacional-de-la-sequia/informes-mapas-seguimiento/infomapas2023.html>

18. Dirección General de Protección Civil y Emergencias. El Gobierno adelanta la campaña estatal contra incendios forestales por segundo año consecutivo. Ministerio del Interior. 2024. Available at: <https://www.proteccioncivil.es/-/el-gobierno-adelanta-la-campa%C3%B1a-estatal-contra-incendios-forestales-por-segundo-a%C3%B1o-consecutivo>
19. Dirección General de Protección Civil y Emergencias. Informe de incendios forestales 2022. Ministerio del Interior. 2022. Available at: https://www.proteccioncivil.es/documents/20121/0/INFORME%20IIF%202022-FINAL_DICIEMBRE.pdf/a9cf0986-be76-d244-283a-4d3295309fae
20. Dirección General de Protección Civil y Emergencias. Informe de incendios forestales 2023. Ministerio del Interior. 2023. Available at: <https://www.proteccioncivil.es/documents/20121/0/INFORME+IIF+2023-FINAL+%281%29.pdf/803a01c7-98b6-fc44-4b7f-988b2dfbbb08?t=1719832142402>
21. Dirección General de Protección Civil y Emergencias. Informe de la campaña de incendios forestales 2020 a efectos de protección civil. Ministerio del Interior. 2020. Available at: <https://www.proteccioncivil.es/documents/20121/93518/Campana-Incendios-Forestales-2020.pdf/8d11eed8-b09e-8c4d-3303-85c0715ff0c7?t=1613989388231>
22. Dirección General de Protección Civil y Emergencias. Resumen del desarrollo de la campaña de incendios forestales 2018 perspectiva de protección civil. Ministerio del Interior: Subdirección General de prevención, planificación y emergencias. 2018. Available at: <https://www.proteccioncivil.es/documents/20121/73228/CAMPANA-DE-INCENDIOS-FORESTALES-2018.pdf/360d0042-d22e-b0a1-d6f1-741c04b151cc?t=1613633791229>
23. Real Decreto 773/1997, de 30 de mayo, sobre disposiciones mínimas de seguridad y salud relativas a la utilización por los trabajadores de equipos de protección individual. Boletín Oficial del Estado, número 140 (12 de junio de 1997). Available at: <https://www.boe.es/buscar/act.php?id=BOE-A-1997-12735>
24. International Labour Organization (ILO). ILO designates occupational safety and health as a Fundamental Right at Work. Safety+Health Magazine. 2022. Disponible en: <https://www.safetyandhealthmagazine.com/articles/22730-ilo-designates-occupational-safety-and-health-as-a-fundamental-right-at-work>
25. Centers for Disease Control and Prevention (CDC). Center for firefighter safety, health, and well-being. National Institute for Occupational Safety and Health (NIOSH); 2025 [consultado el 20 de octubre de 2025]. Disponible en: <https://www.cdc.gov/niosh/centers/firefighter-safety-and-health.html>
26. European Environment Agency (EEA). Effects on occupational health and safety. Europa EU, s/f [consultado el 20 de octubre de 2025]. Disponible en: <https://climate-adapt.eea.europa.eu/en/observatory/evidence/health-effects/occupational-health-safety>

27. PRISMA statement. PRISMA statement. Available at: <https://www.prisma-statement.org/scoping>
28. Ley 14/2007, de 3 de julio, de Investigación biomédica. Boletín Oficial del Estado, número 159, (4 de julio de 2007). Available at: <https://www.boe.es/eli/es/l/2007/07/03/14>
29. Larsen B, Snow R, Aisbett B. Effect of heat on firefighters' work performance and physiology. *J Therm Biol.* 2015;53:1-8. DOI: 10.1016/j.jtherbio.2015.07.008.
30. Vincent G, Aisbett B, Larsen B, Ridgers N, Snow R, Ferguson S. The Impact of Heat Exposure and Sleep Restriction on Firefighters' Work Performance and Physiology during Simulated Wildfire Suppression. *Int J Environ Res Public Health.* 2017;14(2):180. DOI: 10.3390/ijerph14020180.
31. Sol J, West M, Domitrovich J, Ruby B. Evaluation of Environmental Conditions on Self-Selected Work and Heat Stress in Wildland Firefighting. *Wilderness Environ Med.* 2021;32(2):149-59. DOI: 10.1016/j.wem.2021.02.004.
32. Games K, Winkelmann Z, McGinnis K, McAdam J, Pascoe D, Sefton J. Functional Performance of Firefighters After Exposure to Environmental Conditions and Exercise. *J Athl Train.* 2020;55(1):71-9. DOI: 10.4085/1062-6050-75-18.
33. Williams V, Perreault L, Yazbeck C, Micovic N, Oakes J, Bellini C. Impact of Wildfires on Cardiovascular Health. *Circ Res.* 2024;134(9):1061-82. DOI: 10.1161/CIRCRESAHA.124.323614.
34. Everaert S, Schoeters G, Claes K, Raquez J, Buffel B, Vanhaecke T, et al. Balancing Acute and Chronic Occupational Risks: The Use of Nitrile Butadiene Rubber Undergloves by Firefighters to Reduce Exposure to Toxic Contaminants. *Toxics.* 2023;11(6):534. DOI: 10.3390/toxics11060534.
35. Koopmans E, Cornish K, Fyfe T, Bailey K, Pelletier C. Health risks and mitigation strategies from occupational exposure to wildland fire: a scoping review. *J Occup Med Toxicol.* 2022;17(1):2. DOI: 10.1186/s12995-021-00328-w.
36. Butler C, O'Connor M, Lincoln J. Aviation-Related Wildland Firefighter Fatalities — United States, 2000–2013. *MMWR Morb Mortal Wkly Rep.* 2015;64(29):793-6. DOI: 10.15585/mmwr.mm6429a4.
37. Chen H, Samet JM, Bromberg P, Tong H. Cardiovascular health impacts of wildfire smoke exposure. *Part Fibre Toxicol.* 2021;18(1):2. DOI: 10.1186/s12989-020-00394-8.
38. Navarro K, West M, O'Dell K, Sen P, Chen I, Fischer E, et al. Exposure to Particulate Matter and Estimation of Volatile Organic Compounds across Wildland Firefighter Job Tasks. *Environ Sci Technol.* 2021;55(17):11795-804. DOI: 10.1021/acs.est.1c00847.
- Majjaoui-Sekkaki O, Arribas-López A, González-Pisano AC, Mayo-Herrero M, Naranjo-Pastor P. Repercussion of working conditions on the health of wildland firefighters: a Scoping Review. *Eur J Occ Health Nurs.* 2025; 4 (3): 11-63. DOI:10.70324/ejohn.v4i3.75

39. Navarro K, Fent K, Mayer A, Brueck S, Toennis C, Law B, et al. Characterization of inhalation exposures at a wildfire incident during the Wildland Firefighter Exposure and Health Effects (WFFEHE) Study. *Ann Work Expo Health*. 2023;67(8):1011-7. DOI: 10.1093/annweh/wxad046.
 40. Kiely L, Neyestani S, Binte-Shahid S, York R, Porter W, Barsanti K. California Case Study of Wildfires and Prescribed Burns: PM 2.5 Emissions, Concentrations, and Implications for Human Health. *Environ Sci Technol*. 2024;58(12):5210-9. DOI: 10.1021/acs.est.3c06421.
 41. Ferguson M, Semmens E, Weiler E, Domitrovich J, French M, Migliaccio C, et al. Lung function measures following simulated wildland firefighter exposures. *J Occup Environ Hyg*. 2017;14(9):738-47. DOI: 10.1080/15459624.2017.1326700.
 42. Reinhardt T, Broyles G. Factors affecting smoke and crystalline silica exposure among wildland firefighters. *J Occup Environ Hyg*. 2019;16(2):151-64. DOI: 10.1080/15459624.2018.1540873.
 43. Henn S, Butler C, Li J, Sussell A, Hale C, Broyles G, et al. Carbon monoxide exposures among U.S. wildland firefighters by work, fire, and environmental characteristics and conditions. *J Occup Environ Hyg*. 2019;16(12):793-803. DOI: 10.1080/15459624.2019.1670833.
 44. Groot E, Caturay A, Khan Y, Copes R. A systematic review of the health impacts of occupational exposure to wildland fires. *Int J Occup Med Environ Health*. 2019;32(2):121-40. DOI: 10.13075/ijomeh.1896.01326.
 45. Gaughan D, Piacitelli C, Chen B, Law B, Virji M, Edwards N, et al. Exposures and cross-shift lung function declines in wildland firefighters. *J Occup Environ Hyg*. 2014;11(9):591-603. DOI: 10.1080/15459624.2014.895372.
 46. Hadley M, Henderson S, Brauer M, Vedanthan R. Protecting Cardiovascular Health From Wildfire Smoke. *Circulation*. 2022;146(10):788-801. DOI: 10.1161/CIRCULATIONAHA.121.058058.
 47. Carballo-Leyenda B, Villa-Vicente J, Delogu G, Rodríguez-Marroyo J, Molina-Terrén D. Perceptions of Heat Stress, Heat Strain and Mitigation Practices in Wildfire Suppression across Southern Europe and Latin America. *Int J Environ Res Public Health*. 2022;19(19):12288. DOI: 10.3390/ijerph191912288.
 48. Fullagar H, Schwarz E, Richardson A, Notley S, Lu D, Duffield R. Australian firefighters perceptions of heat stress, fatigue and recovery practices during fire-fighting tasks in extreme environments. *Appl Ergon*. 2021;95:103449. DOI: 10.1016/j.apergo.2021.103449.
 49. Doley R, Bell R, Watt B. An Investigation Into the Relationship Between Long-term Posttraumatic Stress Disorder Symptoms and Coping in Australian Volunteer Firefighters. *J Nerv Ment Dis*. 2016;204(7):530-6. DOI: 10.1097/NMD.0000000000000525.
- Majjaoui-Sekkaki O, Arribas-López A, González-Pisano AC, Mayo-Herrero M, Naranjo-Pastor P. Repercussion of working conditions on the health of wildland firefighters: a Scoping Review. *Eur J Occ Health Nurs*. 2025; 4 (3): 11-63. DOI:10.70324/ejohn.v4i3.75

50. Paiva A, Barros B, Oliveira M, Alves S, Esteves F, Fernandes A, et al. Biomonitoring of polycyclic aromatic hydrocarbons exposure and short-time health effects in wildland firefighters during real-life fire events. *Sci Total Environ.* 2024;926:171801. DOI: 10.1016/j.scitotenv.2024.171801.
51. Hwang J, Chong N, Zhang M, Agnew R, Xu C, Li Z, et al. Face-to-face with scorching wildfire: potential toxicant exposure and the health risks of smoke for wildland firefighters at the wildland-urban interface. *Lancet Reg Health Am.* 2023;21:100482. DOI: 10.1016/j.lana.2023.100482.
52. Semmens E, Domitrovich J, Conway K, Noonan C. A cross-sectional survey of occupational history as a wildland firefighter and health. *Am J Ind Med.* 2016;59(4):330-5. DOI: 10.1002/ajim.22566.
53. Hwang J, Xu C, Grunsted P, Agnew R, Malone T, Clifton S, et al. Urinary Metabolites of Polycyclic Aromatic Hydrocarbons in Firefighters: A Systematic Review and Meta-Analysis. *Int J Environ Res Public Health.* 2022;19(14):8475. DOI: 10.3390/ijerph19148475.
54. Donnelly M, Maffei D, Sondermeyer-Cooksey G, Ferguson T, Jain S, Vugia D, et al. Notes From the Field: Coccidioidomycosis Outbreak Among Wildland Firefighters — California, 2021. *MMWR Morb Mortal Wkly Rep.* 2022;71(34):1095-6. DOI: 10.15585/mmwr.mm7134a4.
55. Fullagar H, Notley S, Fransen J, Richardson A, Stadnyk A, Lu D, et al. Cooling strategies for firefighters: Effects on physiological, physical, and visuo-motor outcomes following fire-fighting tasks in the heat. *J Therm Biol.* 2022;106:103236. DOI: 10.1016/j.jtherbio.2022.103236.
56. Sol J, Ruby B, Gaskill S, Dumke C, Domitrovich J. Metabolic Demand of Hiking in Wildland Firefighting. *Wilderness Environ Med.* 2018;29(3):304-14. DOI: 10.1016/j.wem.2018.03.006.
57. International Labour Organization (ILO). ILO guidelines for health and safety management systems. ELCOSH; 2001 [consultado el 20 de octubre de 2025].
58. Broyles G, Kardous C, Shaw P, Krieg E. Noise exposures and perceptions of hearing conservation programs among wildland firefighters. *J Occup Environ Hyg.* 2019;16(12):775-84. DOI: 10.1080/15459624.2019.1668001.
59. Gordon H, Lariviere M. Physical and psychological determinants of injury in Ontario forest firefighters. *Occup Med.* 2014;64(8):583-8. DOI: 10.1093/occmed/kqu133.
60. Adetona A, Adetona O, Gogal R, Diaz-Sanchez D, Rathbun S, Naeher L. Impact of Work Task-Related Acute Occupational Smoke Exposures on Select Proinflammatory Immune Parameters in Wildland Firefighters. *J Occup Environ Med.* 2017;59(7):679-90. DOI: 10.1097/JOM.0000000000001053.

61. Xu X, Shang Y, Tian L, Weng W, Tu J. Fate of the inhaled smoke particles from fire scenes in the nasal airway of a realistic firefighter: A simulation study. *J Occup Environ Hyg.* 2019;16(4):273-85. DOI: 10.1080/15459624.2019.1572900.
62. Crespo-Ruiz B, Esteban-García P, Fernández-Vega C, Crespo-Ruiz C, Rivas-Galan S. A Descriptive Analysis of Body Composition Among Forest Firefighters in Spain. *J Occup Environ Med.* 2020;62(5):e174-9. DOI: 10.1097/JOM.0000000000001842.
63. Meshkov N, Bukhtiyarov I, Valtseva E. Occupational risk factors and physical condition of firefighters. *Russ J Occup Health Ind Ecol.* 2020;60(10):658-73. DOI: 10.31089/1026-9428-2020-60-10-658-673.
64. West M, Costello S, Sol J, Domitrovich J. Risk for heat-related illness among wildland firefighters: job tasks and core body temperature change. *Occup Environ Med.* 2020;77(7):433-8. DOI: 10.1136/oemed-2019-106186.
65. Cherry N, Beach J, Galarneau J. Are Inflammatory Markers an Indicator of Exposure or Effect in Firefighters Fighting a Devastating Wildfire? Follow-up of a Cohort in Alberta, Canada. *Ann Work Expo Health.* 2021;65(6):635-48. DOI: 10.1093/annweh/wxaa142.
66. Teixeira J, Bessa M, Delerue-Matos C, Sarmento B, Santos-Silva A, Rodrigues F, et al. Firefighters' personal exposure to gaseous PAHs during controlled forest fires: A case study with estimation of respiratory health risks and in vitro toxicity. *Sci Total Environ.* 2024;908:168364. DOI: 10.1016/j.scitotenv.2023.168364.
67. Weheba A, Vertigan A, Abdelsayad A, Tarlo S. Respiratory Diseases Associated With Wildfire Exposure in Outdoor Workers. *J Allergy Clin Immunol Pract.* 2024;S221321982400326X. DOI: 10.1016/j.jaip.2024.03.033.

ANNEXES

Annex I.

Table 2. Search strategy

Database	Retrieved
MEDLINE (via Pubmed) Date of search: july 2024	
((("firefighters"[MeSH Terms] OR "firefighters"[Title/Abstract] OR ("wildfires"[Title/Abstract] OR "wildfires"[MeSH Terms])) AND ("natural disasters"[MeSH Terms] OR "natural disasters"[Title/Abstract] OR "environmental hazards"[Title/Abstract] OR ("working conditions"[Title/Abstract] OR "working conditions"[MeSH Terms]) OR "occupational risks"[Title/Abstract]) AND ("accidents, occupational"[MeSH Terms] OR ("accidents occupational"[Title/Abstract] OR "occupational accidents"[Title/Abstract]) OR ("smoke inhalation injury"[Title/Abstract] OR "smoke inhalation injury"[MeSH Terms]) OR ("Burns"[MeSH Terms] OR "Burns"[Title/Abstract]) OR ("heat stress disorders"[Title/Abstract] OR "heat stress disorders"[MeSH Terms]) OR ("wounds and injuries"[MeSH Terms] OR "Wounds"[Title/Abstract]))) AND (y_10[Filter]))	70
((("firefighters"[MeSH Terms] OR "firefighters"[Title/Abstract] OR ("wildfires"[Title/Abstract] OR "wildfires"[MeSH Terms])) AND ("natural disasters"[MeSH Terms] OR "natural disasters"[Title/Abstract] OR "environmental hazards"[Title/Abstract] OR ("working conditions"[Title/Abstract] OR "working conditions"[MeSH Terms]) OR "occupational risks"[Title/Abstract]) AND ("accidents, occupational"[MeSH Terms] OR ("accidents occupational"[Title/Abstract] OR "occupational accidents"[Title/Abstract]) OR ("smoke inhalation injury"[Title/Abstract] OR "smoke inhalation injury"[MeSH Terms]) OR ("Burns"[MeSH Terms] OR "Burns"[Title/Abstract]) OR ("heat	4

stress disorders"[Title/Abstract] OR "heat stress disorders"[MeSH Terms]) OR ("wounds and injuries"[MeSH Terms] OR "Wounds"[Title/Abstract])) AND "Spain"[Title/Abstract]) AND (y_10[Filter])	
SCOPUS Date of search: July 2024	
(TITLE-ABS-KEY (forest AND firefighter) AND TITLE-ABS-KEY (risk AND factors)) AND PUBYEAR > 2013 AND PUBYEAR < 2025	26
CINAHL Date of search: July 2024	
TX forest firefighters OR TX wildland firefighter AND exposure AND risk factors	29
TX forest firefighters OR TX wildland firefighter AND exposure AND risk factors AND Spain	13
CUIDEN Date of search: July 2024	
("Wildfires")OR(("wildland")AND("firefighters"))	2

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Annex II.

Table 3. Main characteristics of the studies.

Author(s)	Title	Country	Design	Sex	Sample size
Gordon et al. (2014)(54)	Physical and psychological determinants of injury in Ontario forest firefighters	Canada	QS	Not stated	252 wildland firefighters
Gaughan et al. (2014)(41)	Exposures and Cross-shift Lung Function Declines in Wildland Firefighters.	USA	Cohorts	17 M	17 wildland firefighters
Butler et al. (2015)(32)	Aviation-Related Wildland Firefighter Fatalities-United States, 2000-2013	USA	DS	76 M 2 F	78 wildland firefighters
Larsen et al. (2015)(25)	Effect of heat on firefighters' work performance and physiology	Australia	Cohorts	33 M 6 F	39 firefighters
Doley et al. (2016)(45)	An Investigation Into the Relationship Between Long-term Posttraumatic Stress Disorder Symptoms and Coping in Australian Volunteer Firefighters	Australia	Cohorts	271 M 6 F	277 firefighters

Author(s)	Title	Country	Design	Sex	Sample size
Semmens et al. (2016)(52)	A cross-sectional survey of occupational history as a wildland firefighter and health	USA	DS	414 M 85 F	499 wildland firefighters
Adetona et al. (2017)(60)	Impact of Work Task-Related Acute Occupational Smoke Exposures on Select Proinflammatory Immune Parameters in Wildland Firefighters	USA	QS	9 M 3 F	10 firefighters 2 voluntarios
Ferguson et al. (2017)(41)	Lung function measures following simulated wildland firefighter exposures	USA	RCT	10 M	10 firefighters
Vincent et al. (2017)(30)	The Impact of Heat Exposure and Sleep Restriction on Firefighters' Work Performance and Physiology during Simulated Wildfire Suppression	Australia	Cohorts	27 M 3 F	30 firefighters
Sol et al. (2018)(56)	Metabolic Demand of Hiking in Wildland Firefighting	USA	QS	116 M 15 F	131 wildland firefighters
Broyles et al. (2019)(58)	Noise exposures and perceptions of hearing conservation programs among wildland firefighters	USA	Cohorts	245 M 19 F	264 wildland firefighters
Groot et al. (2019)(44)	A systematic review of the health impacts of occupational exposure to wildland fires.	Canada	SR	Not stated	Not stated

Author(s)	Title	Country	Design	Sex	Sample size
Navarro et al. (2019)(11)	Wildland firefighter smoke exposure and risk of lung cancer and cardiovascular disease mortality	USA	DS	Not stated	80 wildland firefighters
Xu et al. (2019)(61)	Fate of the inhaled smoke particles from fire scenes in the nasal airway of a realistic firefighter: A simulation study	China	QS	1 M	1 bombero
Reinhardt et al. (2019)(42)	Factors affecting smoke and crystalline silica exposure among wildland firefighters.	USA	DS	Not stated	Not stated
Henn et al. (2019)(43)	Carbon monoxide exposures among U.S. wildland firefighters by work, fire, and environmental characteristics and conditions.	USA	DS	Not stated	585 wildland firefighters
Crespo-Ruiz et al. (2020)(62)	A Descriptive Analysis of Body Composition among Forest Firefighters in Spain	Spain	DS	605 M 96 F	701 wildland firefighters
Games et al. (2020)(32)	Functional Performance of Firefighters After Exposure to Environmental Conditions and Exercise	USA	RCT	13 M	13 firefighters

Author(s)	Title	Country	Design	Sex	Sample size
Meshkov et al. (2020)(63)	Occupational risk factors and physical condition of firefighters	Russia	Lit. review	Not stated	Not stated
Navarro et al. (2020)(5)	Working in Smoke: Wildfire Impacts on the Health of Firefighters and Outdoor Workers and Mitigation Strategies	USA	Lit. review	Not stated	Not stated
West et al. (2020)(64)	Risk for heat-related illness among wildland firefighters: job tasks and core body temperature change.	USA	QS	271 M 27 F	301 wildland firefighters
Cherry et al. (2021)(65)	Are Inflammatory Markers an Indicator of Exposure or Effect in Firefighters Fighting a Devastating Wildfire? Follow-up of a Cohort in Alberta, Canada	Canada	Cohorts	148 M 12 F	160 wildland firefighters
Fullagar et al. (2021)(48)	Australian firefighters perceptions of heat stress, fatigue and recovery practices during fire-fighting tasks in extreme environments	Australia	DS	417 M 51 F 5 "others"	473 firefighters
Chen et al. (2021)(37)	Cardiovascular health impacts of wildfire smoke exposure	USA	Lit. review	Not stated	Not stated

Author(s)	Title	Country	Design	Sex	Sample size
Navarro et al. (2021)(38)	Exposure to Particulate Matter and Estimation of Volatile Organic Compounds across Wildland Firefighter Job Tasks	USA	QS	71 M 10 F	81 wildland firefighters
Sol et al. (2021)(31)	Evaluation of Environmental Conditions on Self-Selected Work and Heat Stress in Wildland Firefighting	USA	DS	193 M 28 F	221 wildland firefighters
Carballo-Leyenda et al. (2022)(47)	Perceptions of Heat Stress, Heat Strain and Mitigation Practices in Wildfire Suppression across Southern Europe and Latin America	Switzerland	DS	1328 M 131 F	1459 firefighters
Donnelly et al. (2022)(54)	Notes From the Field: Coccidioidomycosis Outbreak Among Wildland Firefighters - California, 2021	USA	DS	Not stated	7 wildland firefighters
Fullagar et al. (2022)(55)	Cooling strategies for firefighters: Effects on physiological, physical, and visuo-motor outcomes following fire-fighting tasks in the heat	Australia	RCT	11 M 3 F	14 firefighters
Hadley et al. (2022)(46)	Protecting Cardiovascular Health From Wildfire Smoke	USA	Lit. review	Not stated	Not stated

Author(s)	Title	Country	Design	Sex	Sample size
Hwang et al. (2022)(53)	Urinary Metabolites of Polycyclic Aromatic Hydrocarbons in Firefighters: A Systematic Review and Meta-Analysis	USA	Meta-analysis	Not stated	Not stated
Koopmans et al. (2022)(35)	Health risks and mitigation strategies from occupational exposure to wildland fire: a scoping review	USA	SR	Not stated	Not stated
Navarro et al. (2022)(4)	The Wildland Firefighter Exposure and Health Effect (WFFEHE) Study: Rationale, Design, and Methods of a Repeated-Measures Study	USA	Cohorts	Not stated	154 wildland firefighters
Everaert et al. (2023)(34)	Balancing Acute and Chronic Occupational Risks: The Use of Nitrile Butadiene Rubber Undergloves by Firefighters to Reduce Exposure to Toxic Contaminants	Belgium	SR	Not stated	Not stated
Hwang et al. (2023)(51)	Face-to-face with scorching wildfire: potential toxicant exposure and the health risks of smoke for wildland firefighters at the wildland-urban interface	USA	Lit. review	Not stated	Not stated
Navarro (2023)(39)	Characterization of inhalation exposures at a wildfire incident during the Wildland Firefighter Exposure and Health Effects (WFFEHE) Study	USA	DS	Not stated	19 wildland firefighters

Author(s)	Title	Country	Design	Sex	Sample size
Kiely et al. (2024)(40)	California Case Study of Wildfires and Prescribed Burns: PM _{2.5} Emissions, Concentrations, and Implications for Human Health	USA	DS	Not stated	Not stated
Paiva et al. (2024)(50)	Biomonitoring of polycyclic aromatic hydrocarbons exposure and short-time health effects in wildland firefighters during real-life fire events	Portugal	DS	176 M	176 wildland firefighters
Teixeira et al. (2024)(66)	Firefighters' personal exposure to gaseous PAHs during controlled forest fires: A case study with estimation of respiratory health risks and in vitro toxicity	Portugal	QS	42 M 6 F	48 firefighters
Weheba et al. (2024)(67)	Respiratory Diseases Associated With Wildfire Exposure in Outdoor Workers	Spain	Lit. review	Not stated	Not stated
Williams et al. (2024)(33)	Impact of Wildfires on Cardiovascular Health	USA	Lit. review	Not stated	Not stated

RCT: Randomised controlled trial, DS: Descriptive study, QS: Quasi-experimental study, Lit. review: Literature review, SR: Systematic review. M: Male, F: Female.

Annex III.

Table 4. Aim, main findings and conclusions.

Author(s)	Aim	Results	Conclusions
Gaughan et al. (2014)(45)	To study exposure to smoke particles and assess changes in lung function.	A positive association was found between exposure to smoke particles—particularly fine particles—and a decrease in FEV ₁ in firefighters.	FEV ₁ measurements were taken immediately after smoke exposure; therefore, they should be repeated after a smoke-free period to determine the extent of the FEV ₁ reduction.
Gordon et al. (2014)(59)	To identify the physical and psychological factors influencing the likelihood of injuries among wildland firefighters.	High stress was the strongest predictor of serious injuries.	Physical and personality factors were relevant to minor injuries. Occupational stress was a key factor in serious injuries.

Author(s)	Aim	Results	Conclusions
Butler et al. (2015)(36)	To update data on aviation-related deaths among wildland firefighters.	67% of the deaths occurred during fire suppression, 16% during training exercises, 4% during prescribed burns, and the remaining 14% during other activities.	It is essential to follow safety guidelines to assess risks, limit exposure, and improve teamwork.
Larsen et al. (2015)(29)	To compare performance, physiology, behaviour, and perceptual responses.	During heat exposure, participants experienced higher core temperatures, increased fluid intake, and elevated heart rates.	Performance improved in temperate and warm conditions due to task rotation and frequent rest breaks.
Doley et al. (2016)(49)	To investigate the long-term impact of the Ash Wednesday bushfire on volunteer firefighters.	28% of respondents showed symptoms of psychiatric impairment after the disaster. Emotion-focused coping was associated with poorer mental health outcomes.	Eighty-four months after the disaster, a group of firefighters continued to present symptoms of PTSD.

Author(s)	Aim	Results	Conclusions
Semmens et al. (2016)(52)	To investigate the cumulative effects of years of work as a wildland firefighter.	Cancer prevalence was below 1% (except for basal cell skin cancer at 3% and squamous cell skin cancer at 2%), with 13% reporting hypertension, 13% hypercholesterolaemia, 3% arrhythmia, 14% hearing loss, 7% depression, and 9% asthma.	A long career as a wildland firefighter was associated with self-reported cardiovascular risk factors and musculoskeletal problems.
Adetona et al. (2017)(60)	To assess the effect of work on specific proinflammatory biomarkers in wildland firefighters.	Firefighters involved in prescribed burns showed a greater IL-8 response, and higher levels of C-reactive protein and serum amyloid A.	Those responsible for igniting the burns showed greater inter-shift changes in three proinflammatory mediators.
Ferguson et al. (2017)(41)	To simulate wildland firefighters' occupational exposure to wood smoke and assess respiratory impact.	Exposure to wood smoke did not produce significant changes in lung function.	PM2.5 concentrations and other environmental parameters remained within expected and controlled levels.

Author(s)	Aim	Results	Conclusions
Vincent et al. (2017)(30)	To compare physical performance and work-related physiological indices after sleep restriction.	The combination of heat and sleep deprivation had a cumulative effect on work performance, although it did not affect status, motivation, or perceived strain.	There were no differences in physiological responses, hydration status, motivation, or perceived exertion. Locomotion was negatively affected by heat.
Sol et al. (2018)(56)	To document the characteristics of hiking during wildfire suppression and wildland firefighter training.	There was a high metabolic demand during the shift, especially during ingress hikes and training sessions, due to equipment weight and terrain slope.	Terrain slope, walking speed, equipment load, and environmental variability determine the physiological demands on wildland firefighters.
Broyles et al. (2019)(58)	To understand and characterise noise exposure under the extreme working conditions of wildland firefighters.	54% of firefighters were exposed to levels exceeding 80 dB, 32% exceeded 85 dB, and 16% exceeded 90 dB. 65% used hearing protection (43.3% earplugs, 8% earmuffs, 0.7% both, and 13% other	In all roles studied, wildland firefighters exceeded noise exposure limits, increasing the risk of hearing loss. The majority used

Author(s)	Aim	Results	Conclusions
		devices), while 23% did not use any, and 13% did not respond.	hearing protection and were aware of the hazard.
Groot et al. (2019)(44)	To summarise the evidence of health impacts related to occupational exposure to wildfires.	Fire suppression was associated with decreased lung function, increased respiratory symptoms, development of hypertension, PTSD, and musculoskeletal injuries.	Exposure to wildfires may lead to respiratory issues, PTSD, and an increased risk of hypertension.
Navarro et al. (2019)(11)	To estimate the risk of lung cancer and cardiovascular mortality due to PM ₁₀ exposure.	The relative risk for lung cancer and cardiovascular disease was greater than 1 across all exposure settings.	There was a high risk of developing lung cancer and cardiovascular disease.
Xu et al. (2019)(61)	To investigate the inhalation, transport, and deposition of smoke particles during wildfire missions.	Short-term exposure to high concentrations of ultrafine particles could induce adverse cardiovascular changes.	Real-time particle concentration during debris removal was crucial for assessing actual exposure risks.

Author(s)	Aim	Results	Conclusions
Reinhardt et al. (2019)(42)	To quantify the inhaled amounts of smoke- and soil-derived substances (carbon monoxide, silica, and quartz crystals).	Only 5% of firefighters had an average CO exposure above the permissible limit. 22% exceeded permitted levels of silica and quartz crystals, particularly during tasks that stirred up soil dust.	No respirators were found to provide adequate protection against quartz particles.
Henn et al. (2019)(43)	Analyze the changing conditions that influence the levels of CO to which firefighters are exposed.	Time-weighted average CO exposure levels were low (2.4 ppm), but sawyers exceeded the limit, with an average of 6.8 ppm and peaks reaching up to 25 ppm. Exposure limits were exceeded in only 2–4% of shifts.	The use of chainsaws and prescribed burning of grasslands or wood increased CO levels. Factors such as humidity, wind, and inexperience may also have contributed to increased exposure.

Author(s)	Aim	Results	Conclusions
Crespo-Ruiz et al. (2020)(62)	Define the body composition profile of wildland firefighters as a basis for reducing cardiovascular and musculoskeletal problems.	The BMI of female firefighters was within the normal weight range, while in males it indicated overweight. Both groups had a body fat percentage above recommended levels, although men showed greater bone and lean mass. Both men and women exceeded the WHO's recommended levels of physical activity.	Wildland firefighters demonstrated above-average physical fitness compared to the general population, although their body composition revealed a high risk of cardiometabolic diseases.
Games et al. (2020)(32)	Examine the effect of environmental conditions, as well as exercise, on balance, rectal temperature, and perceived fatigue outcomes.	Performance index was negatively affected by exercise and heat. Both exercise and environmental heat contributed to an increase in rectal temperature. The rate of perceived fatigue rose when exercise was performed in hot conditions.	Exercise, heat, and a humid environment all affected balance, leading to an increase in falls, slips, and trips.

Author(s)	Aim	Results	Conclusions
Meshkov et al. (2020)(63)	Review and analyze national and international publications on the professional activity of firefighters and evaluate the influence of risk factors on their health.	Respiratory and musculoskeletal diseases were the most common among firefighters, with relative risks of 2.8 and 2.1 respectively, and were the main causes of morbidity. Firefighters exposed to occupational hazards and high psychological stress showed higher disability rates.	There was no consensus regarding the prevalence of malignant myeloma in firefighters compared to the general population. However, there was a higher incidence of disability due to sensory diseases and conditions affecting the circulatory and digestive systems than in the general population.
Navarro et al. (2020)(5)	Examine the health impacts through the measurement of smoke exposure.	Lung function declined (risk of lung cancer mortality 8-43%) and mortality from cardiovascular diseases increased (risk of mortality 16-30%).	Health risks increased due to the rise in wildfire spread in the urban-forest interface.

Author(s)	Aim	Results	Conclusions
West et al. (2020)(64)	Estimate the association between work tasks and changes in core body temperature.	Physically active jobs were associated with changes in core body temperature, exceeding 38.5°C during walks. The physiological load index increased from sedentary activities to high-category activities, but it did not reflect a high physiological load overall.	High-intensity physical activities and their duration were considered modifiable factors that increased the risk of heat-related diseases.
Cherry et al. (2021)(65)	Investigate how exposure to smoke particles affects levels of inflammatory markers.	Exposure to PM2.5 was the best predictor of respiratory issues.	The findings highlighted the importance of evaluating respiratory health by considering all exposures to extreme conditions.
Fullagar et al. (2021)(48)	Gather perceptions of heat stress, fatigue, and recovery practices.	Structural firefighting was reported as the hottest activity (62%), and heat fatigue was worsened by PPE (38%). Recovery techniques included resting in the shade and drinking cold water (55%).	Uniforms, protective clothing, and external heat sources were identified as the main contributors to heat stress.

Author(s)	Aim	Results	Conclusions
Chen et al. (2021)(37)	Examine the published literature on the association between cardiovascular effects and exposure to wildfire smoke.	An increase in arterial stiffness was associated with the presence of levoglucosan in urine. Wildland firefighters working 49 days per year were exposed to an average PM4 concentration of 510 µg/m³.	Wildfire smoke contributed to high levels of air pollutants, which were a risk factor for adverse cardiovascular effects.
Navarro et al. (2021)(38)	Measure PM4 exposure and compare concentrations between primary work tasks and crews.	The permissible exposure limit for formaldehyde was exceeded. Those performing direct suppression tasks had higher peak PM4 concentrations and showed statistically significant exposure to VOCs.	High cumulative exposures led to effects such as reduced lung function, increased inflammation, and the development of cardiovascular diseases.
Sol et al. (2021)(31)	Evaluate heat stress during wildfire management activities considering environmental conditions.	Wildland firefighters showed large variations in urine density. They worked with core temperatures above resting values and in diverse environments.	No heat-related injuries occurred. Rest was the main strategy used to mitigate heat accumulation.

Author(s)	Aim	Results	Conclusions
Carballo-Leyenda et al. (2022)(47)	Gather perceptions of heat stress and heat mitigation strategies.	Ninety percent considered heat stress a significant risk to their health and safety, identifying solar radiation, working near flames, and personal protective equipment as the main sources.	Heat acclimatization was regarded as an effective strategy to cope with heat stress.
Donnelly et al. (2022)(54)	Identify and analyze an outbreak of coccidioidomycosis among wildland firefighters.	Of seven firefighters, three cases were confirmed as coccidioidomycosis. All affected individuals had worked in dusty conditions without respiratory protection.	The increasing frequency of coccidioidomycosis highlighted the need for improved PPE and training.
Fullagar et al. (2022)(55)	Quantify the effects of two cooling strategies.	No differences were observed in physical or visuomotor conditions, although core temperature and heart rate decreased. Memory and perception were unaffected, but selective attention and reaction time were impacted.	The cooling strategies benefited health and safety by reducing core temperature, lowering heart rate, and improving cardiac function.

Author(s)	Aim	Results	Conclusions
Hadley et al. (2022)(46)	Link wildfire smoke exposure to cardiovascular effects.	Exposure to PM2.5 increased the risk of short- and long-term cardiovascular conditions, including out-of-hospital cardiac arrests, and was associated with mental health disorders. Associations were also found between air pollution exposure and strokes.	PM2.5 was the leading modifiable environmental risk factor for cardiovascular disease and accounted for 13.3% of cardiovascular deaths worldwide.
Hwang et al. (2022)(53)	Estimate urinary OHPAH levels in firefighters, identify risk factors, and evaluate the effectiveness of preventive efforts as diagnostic tools.	A significant increase in urinary OHPAH levels was observed in firefighters after wildfires, with dermal and respiratory exposure being the main routes. Metabolites from dermal exposure had a longer half-life.	Decontamination techniques included rinsing the nasal passages, along with annual medical evaluations to detect occupational exposures and prevent cancers and cardiovascular diseases.

Author(s)	Aim	Results	Conclusions
Koopmans et al. (2022)(35)	Identify the impact of occupational exposure to wildfires, and examine the characteristics and effectiveness of prevention and mitigation strategies.	Changes in respiratory health were identified, along with increased arterial stiffness and a high prevalence of hypertension and arrhythmias. PTSD was common, and injuries tended to be more severe toward the end of the season. The leading causes of death were cardiac arrest and accidents, while noise exposure posed hearing risks.	The lack of evidence on long-term effects made preventive decision-making more difficult.
Navarro et al. (2022)(4)	Investigate occupational exposures and health effects of wildland firefighters in the United States.	The complexity and challenges of gathering measurements to examine the effects of occupational exposures on the health of wildland firefighters were reported.	The three-year study had to be abruptly concluded after the second year due to the onset of the COVID-19 pandemic.

Author(s)	Aim	Results	Conclusions
Everaert et al. (2023)(34)	Report on the use of nitrile gloves as a preventive measure, illustrate the difficult balance between chronic and acute occupational risks, and highlight the need for more studies on this practice and burn incidence.	Chemical absorption through the skin increased due to high temperatures and humidity, raising the incidence of cancer (especially mesothelioma and bladder cancer). The use of butadiene nitrile gloves was suggested, along with opting for washable gloves or decontamination techniques.	Some pollutants managed to penetrate the PPE, accumulating on the skin if frequent decontamination was not carried out. Butadiene nitrile inner gloves provided effective protection, although they increased the risk of deep burns.
Hwang et al. (2023)(51)	Study the economic cost and health impact, respiratory protection, pollutant mix, and proactive management of wildfires.	Acute exposure to PM2.5 increased mortality by 0.26% per year. A high incidence of cancer and mortality rates was observed. A relationship was found between years of experience as wildland firefighters and an increased risk of hypertension and arrhythmias.	Prescribed burning controlled the frequency and risk of wildfires, preventing exposure to the toxic mix from fires in the urban-forest interface.

Author(s)	Aim	Results	Conclusions
Navarro (2023)(39)	Evaluate air pollutant exposures and their effects on health.	Significant exposure to air pollutants was found, with high concentrations of benzene and other compounds resulting from the use of chainsaws and combustion-engine tools.	No respirator was found to provide protection against both particles and gases from wildfire smoke.
Kiely et al. (2024)(40)	Evaluate the impact of burning conditions and seasons on air quality and health, and highlight the importance of the timing of the burn.	Without emissions, PM _{2.5} concentrations did not exceed 45 µg/m ³ ; but during wildfires, they exceeded 150 µg/m ³ . The benefits of prescribed burns were emphasized to minimize exposure to fine particles and improve health safety.	Prescribed burns emitted less PM _{2.5} , CO, and CO ₂ than wildfires, suggesting that this practice may reduce health risks from exposure to air pollutants.

Author(s)	Aim	Results	Conclusions
Paiva et al. (2024)(50)	Evaluate the impact of firefighting on urinary OHPAH levels and short-term effects on wildland firefighters during real wildfires..	Exposure to wildfire smoke increased OHPAH levels in the urine of firefighters, causing eye and respiratory irritation (27%) and headaches (13%), which persisted in 11% of cases. An increase in white blood cells was observed, indicating an acute inflammatory response.	The increase in OHPAH levels affected non-smokers more. Years of service were negatively correlated with urinary PAH levels.
Teixeira et al. (2024)(66)	Analyze firefighter exposure to PAHs during wildfires.	PAH levels in the breathable air of firefighters during controlled wildfire events were significantly higher than in control groups. The lung cancer risk limits set by the WHO were exceeded.	The need to improve respiratory and dermal protection measures and surveillance was emphasized.

Author(s)	Aim	Results	Conclusions
Weheba et al. (2024)(67)	Explore the interaction between wildfires and respiratory diseases, including mechanisms, health consequences, and potential preventive measures for outdoor workers.	Restrictive respiratory changes were observed in relation to prolonged smoke exposure without respiratory protection. No significant increase in the diagnosis of chronic obstructive pulmonary disease was observed, but there was an increase in the occurrence of asthma and asthma attacks in those who already had the disease.	The effects of wildfires on the respiratory tracts of firefighters highlighted the need for individual strategies to reduce the risk of short- and long-term respiratory issues.
Williams et al. (2024)(33)	Evaluate cardiovascular outcomes of an average shift in wildland firefighters, depending on the number and duration of work shifts.	Smoke inhalation was associated with hypertension, cardiovascular diseases, oxidative stress, and inflammation, which were intensified by physical and thermal exertion, increasing long-term cardiovascular risk.	Inhalation of wildfire smoke was associated with cardiovascular morbidity and mortality in the days following exposure.