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Exploring the Impacts of Working as a Firefighter on Health: A Scoping Review

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List of Acronyms

B	
BMPM	Marseille Marine Fire Brigade (Bataillon de Marins-Pompiers de Marseille)
BSPP	Paris Fire Brigade (Brigade de Sapeurs-Pompiers de Paris)
BT	Body Temperature
BTX	Benzene, Toluene, Xylene
C	
CFA	Country Fire Authority (Australia)
CRS	Chronic Rhinosinusitis
CVD	Cardiovascular Disease
E	
EMS	Emergency Medical Services
EMTs	Emergency Medical Technicians
ESP	Emergency Services Personnel
EU-OSHA	European Agency for Safety and Health at Work
F	
FEV_1/FVC	Ratio of Forced Expiratory Volume in 1 second to Forced Vital Capacity
FEV_1	Forced Expiratory Volume in 1 second
FRS	Fire and Rescue Services (UK)
FVC	Forced Vital Capacity
H	
HIC	High-Income Countries
HIV	Human Immunodeficiency Virus
HR	Heart Rate
L	
LMICs	Low- and Middle-Income Countries
M	
MA	Meta-Analysis
MDD	Major Depressive Disorder
MetSyn	Metabolic Syndrome
MRSA	Methicillin-Resistant Staphylococcus Aureus
MSDs	Musculoskeletal Disorders
N	
NGO	Non-Governmental Organization
NHLBI	National Heart, Lung, and Blood Institute
NIH	National Institutes of Health
O	
OC	Oxygen Consumption
O*NET	Occupational Information Network
OHPAHs	Occupational Exposure to Polycyclic Aromatic Hydrocarbons
OSA	Obstructive Sleep Apnea
P	
PAHs	Polycyclic Aromatic Hydrocarbons
PBDEs	Polybrominated Diphenyl Ethers

PFAS	Per- and Polyfluoroalkyl Substances
PM2.5/PM10	Particulate Matter (2.5/10 micrometers in diameter)
PPE	Personal Protective Equipment
PPTEs	Potentially Psychologically Traumatic Events
PRISMA-ScR	Preferred Reporting Items for Systematic Reviews and Meta-Analyses – Scoping Reviews
PSP	Public Safety Personnel
PTSD	Post-Traumatic Stress Disorder
R	
ROME	Répertoire Opérationnel des Métiers et des Emplois (French Repository of Jobs)
S	
SCBA	Self-Contained Breathing Apparatus
SDIS	Service Départemental d'Incendie et de Secours (French Departmental Fire and Rescue Service)
SPP	Sapeurs-pompiers Professionnels (Professional Firefighters)
SPM	Sapeurs-pompiers Militaires (Military Firefighters)
SPV	Sapeurs-pompiers Volontaires (Volunteer Firefighters)
SR	Systematic Review
SWD	Shift Work Disorder
V	
VOCs	Volatile Organic Compounds

Abstract

Title: Exploring the Impacts of Working as a Firefighter on Health: A Scoping Review

Background: Firefighters are exposed to a wide range of occupational risks comprising chemical, physical, biological, psychosocial, and safety hazards that expose them to the risk of adverse health effects. Additionally, firefighters' operational roles often go beyond fire suppression to include emergency medical services, rescue operations, and public safety responses, broadening the scope of occupational exposures beyond fire-related contexts. Study often investigated these risks, but the evidence remains scattered and often lacking subgroup-specific analysis and broader contextual insight.

Objective: The aim of this study was to systematically map and synthesize the existing knowledge on occupational health risks among firefighters, identify research gaps, and subgroup variability.

Methods: We conducted a comprehensive search of PubMed and Scopus following Arksey and O'Malley's scoping review framework along with the PRISMA-ScR reporting guidelines. The review included only systematic reviews and meta-analyses published in English between 2021 and 2025. Data were extracted according to type of exposure, health outcome, population characteristics including demographic, and subgroups variability based on factors such as age, gender and professional role (e.g, volunteer vs. career firefighters, firefighters vs. other profession).

Results: This review included a total of 37 studies. According to the findings, psychosocial, chemical, and physical exposures were the most consistently studied occupational hazards. Cancer, musculoskeletal disorder (MSDs) and sleep-related conditions appeared as common and well-documented outcomes, especially among professional firefighters subjected to exposure to carcinogens, shift work, repetitive lifting, and physical constraints. Biological, safety-related hazards and positive health outcomes were poorly explored. Subgroup analyses by demographic characteristic and job role were sparse and commonly inconsistent.

Conclusion: The review identified priority knowledge gaps in subgroup-specific risks, geographic diversity, and positive health outcomes. Future studies should focus on diverse populations, standardized definitions of exposure, and further subgroup vulnerability analysis to support evidence-based occupational health policies for firefighters.

Keywords: Occupational health, Occupational exposure, Firefighters

1. Background & Context

1.1 A Broad Perspective on Firefighters

Firefighters are emergency responders often also called first responders who play a crucial role in protecting lives, property and the environments from fire-related incidents and other emergencies. Their duties include fire suppression, rescue operations, hazardous material control and emergency medical services (1).

Due to the nature of the job responsibilities, firefighters are exposed to various occupational hazards including safety, chemical, physical, biological and psychosocial, that carry a wide range of health risks (2,3). This work aligns with the operational context of firefighters. Often, the real working condition of firefighters are much wider than fighting fires. For instance, according to DGSCGC 2023 statistics, in France, 79% of firefighter interventions consist of first aid, 6% of fires, 6% of traffic accidents, 4% of other interventions, 3% of protection of property, and 1% of technological risks. These numbers clearly demonstrate how important it is to separate the generic title "firefighter" from the concept of a single mission of battling a single fire (4).

1.2 Occupational Diversity Among Firefighters Across Countries

The terminology and the classification of firefighters as an occupation vary across different countries and occupational databases, mainly due to the differences in organizational structures, employment status and mission scope. For example, according to the Occupational Information Network (O*NET) database in the US, firefighters are classified as first responders with specialized training in emergency response and fire suppression (5). Similarly in France, the Répertoire Opérationnel des Métiers et des Emplois (ROME), the French Repository of Jobs classified firefighting as a public safety profession emphasizing emergency response and risk prevention (6). Following are organizational structures and variations of main duties and activities of firefighters across different countries.

France: In France, firefighters are referred to as "sapeurs-pompiers". They are divided into three main categories: professional firefighters (sapeurs-pompiers professionnels, SPP), volunteer firefighters (sapeurs-pompiers volontaires, SPV), military firefighters (sapeurs-pompiers militaires, SPM) (DGSCGC, 2023) (4). Volunteer firefighters usually serve alongside another primary occupation. They constitute a significant portion of the workforce, especially in rural areas. Professional firefighters are employed by local authorities (4). They make up less than one-fifth of the firefighter population and work daily alongside SPV. Military firefighters are very few in number

and depend on the Ministry of Defense (4). They are primarily stationed in two major cities: Paris (the Paris Fire Brigade; BSPP) and Marseille (the Marseille Marine Fire Brigade; BMPM) (4). In addition, private fire safety agents ("sapeurs-pompiers privés") are employed by certain institutions or companies, such as airports or industrial sites, to provide on-site fire prevention and response (7).

The United States: Firefighters are employed by local fire departments (volunteer and combination of fire departments), federal agencies, contract fire departments or private services; categorized mainly into three categories such as career firefighters, volunteer firefighters and paid-on-call responders (8). The career firefighters work mainly in the urban areas with a population more than 25,000. The volunteer firefighters serve in rural and small towns whereas paid-on-call responders serve in suburban and mixed-demand areas receiving incentives per call (8). Besides these categories, there are also combination or mixed departments of firefighters where both career and volunteer firefighters serve for a flexible coverage (8). Firefighters across all categories share the same responsibilities such as fire suppression, hazardous materials response, disaster response, emergency medical response and conducting safety programs such as fire prevention and public education (8).

The United Kingdom: Regional authorities govern the Fire and Rescue Services (FRS). The firefighters handle all kind of fire incidents and operate rescue operations (9).

Australia: Firefighters include metropolitan brigades and rural fire services; classified into career firefighters (full-time professionals) and volunteer firefighters (part-time volunteers) with specialized units like hazardous materials and urban search and rescue teams (10,11). Career firefighters are employed by state or territory services while volunteers often serve in rural areas through organizations like the Country Fire Authority (CFA). Firefighters are responsible for handling fire incidents including bushfires, natural disasters as well as community education and prevention (10,11).

Germany: Firefighting services are classified into three categories: Berufsfeuerwehr (professional), Freiwillige Feuerwehr (volunteer), and Werkfeuerwehr (industrial fire brigades) (12).

Japan: In Japan, firefighters are divided into professional and volunteer fire cop who serve in rural areas. There are also specialized units who usually handle disaster response, hazardous materials and emergency medical services (EMS) (13). Their responsibilities include fire suppression,

disaster response during earthquakes and tsunamis, advanced life support, community safety education and technical rescues. Firefighters are integral to earthquake response and disaster management (13).

Though the structures and terminology of firefighters vary by country, many occupational exposures such as chemical, physical, biological and psychosocial hazards are shared across national contexts. However, the intensity and frequency of these exposures may differ depending on mission scope and organizational structure.

1.3 Occupational Hazards

Because of the nature of the job, firefighters are subject to a variety of occupational exposures to hazards that may alter their health. These short- and long-term exposures mainly fall under five categories: chemical, physical, biological, psychosocial and safety hazards. This classification is consistent with international occupational health frameworks, particularly those defined by the European Agency for Safety and Health at Work (EU-OSHA) (14).

- **Chemical Hazards:** Firefighters are routinely exposed to chemical hazards including carcinogens, toxic fumes and particulate matter during fire suppression and rescue operations (15). These types of exposures increase the risk of cardiovascular diseases (CVDs), respiratory disease and various types of cancers including lung cancer, bladder cancer, prostatic and testicular cancers (16–18).
- **Physical Hazards:** Firefighters exposed to physical hazards at their work including extreme heat, noise and musculoskeletal injuries. The prolonged exposure to high temperature or extreme heat can cause heat stress, dehydration, and heatstroke (3). Noise exposure from sirens, equipment and structural collapses increases the risk of hearing loss and tinnitus (3). Not only that but the physical strain of heavy lifting, climbing and prolonged exertion which is very common for firefighters can also cause musculoskeletal injuries such as sprains, strains, and chronic back pain (3).
- **Biological Hazards:** Firefighters are also at risk of exposure to biological hazards including pathogens and infectious disease. During rescue operations, firefighters may be exposed to blood, bloody fluids and contaminated surfaces which can increase the risks of infectious disease like hepatitis B, hepatitis C and HIV (3).
- **Psychosocial Hazards:** Firefighters are often in situations where they witness and likely take direct action to mitigate traumatic events like severe injuries, deaths and catastrophic disasters which eventually lead to post-traumatic stress disorder (PTSD), anxiety and

depression (3). Irregular, long working hours and night shifts can disrupt sleep and lead to fatigue and emotional exhaustion (19) while poor organizational support and unclear job roles increase stress levels (20). Additionally, firefighters often need to take rapid decision in life-threatening situations which create severe time pressure on them. This time pressure can cause chronic stress and burnout (3). Furthermore, dealing with distressed people in the public sphere also contribute to emotional strain (3).

- **Safety Hazards:** Firefighters face significant injury and safety risks, including burns, structural collapses, unstable floors, and falling objects during firefighting operations as well as training. Falls from heights are also a common hazard, particularly during rescue operations or when working on elevated surfaces (3). Additionally, traffic accidents pose a substantial risk, as firefighters often travel at high speeds in adverse weather conditions to reach emergency sites (3). While acute injuries like burns or falls occur during firefighting, the highest frequency of injuries actually happens during intensive training, where firefighters engage in endurance exercises, sports, and simulated scenarios to maintain peak physical fitness for the job (21).

2. Rationale for Scoping Review

Firefighters are regularly exposed to these above-mentioned occupational hazards. Studies showed that these exposures increased the risk of adverse health outcomes including musculoskeletal injuries, cardiovascular diseases, respiratory illnesses, cancers, fertility disorders, and mental health issues (22–24). Over the years, a large body of literature has developed about these risks. For instance, systematic reviews and meta-analyses highlighted carcinogenic risks related firefighting (25), effects on cardiovascular and respiratory systems due to occupational exposures (18), and the psychosocial consequences of traumatic events and chronic stress (26). A study done on 30000 firefighters in the US found a 9% increase in all cancer diagnoses and 14% increased mortality rate among firefighters which one of the main cause is exposure to smoke from various types of fire (16). As is usually the case with systematic reviews and meta-analysis, most of these studies tend to be quite narrow and specific in their approach, focusing either on fumes, chemicals, physical strain, or mental health, which are hardly interwoven with each other. However, there are still gaps in understanding the variability of health outcomes across different subgroups of firefighters such as professional vs. volunteers, age and gender related as well as context-specific (urban-rural, regional, national) and firefighters vs. other profession variations. Further, there seems to be an emphasis on negative health outcomes, such as diseases or mortality, with less attention to positive health indicators like resilience, well-being, or coping strategies.

In this context of growing scientific evidence, some questions deserve special attention to shape future research:

- What are the most well-documented hazards and health outcomes, and what are the greatest gaps in research?
- What is the current state of knowledge on firefighters' occupational health risks, particularly across different subgroups?
- Relatedly, how do organizational structures and exposure profiles influence on firefighters' health?

To answer these questions, it is crucial to map the existing evidence, for which a scoping review is the most appropriate approach.

3. Research Objectives

Primary objective:

- To systematically map and analyze the existing knowledge on occupational hazards and health risks among firefighters.

Secondary Objectives:

- To identify major occupational exposures and health outcomes reported in the literature.
- To highlight research gaps and areas requiring further investigation.
- To analyze how health outcomes are captured in the existing literature, whether the studies focus only on negative outcomes (e.g., disease, mortality) or also include indicators of well-being (e.g., self-reported health status, resilience, coping strategies…).
- To map how much identified gaps exist concerning different subgroups of firefighters (e.g., professional vs. volunteer, gender-based differences, age-related variations and other demographic or job-related distinctions).

4. Methods

This scoping review was conducted based on the Arksey and O'Malley framework (2005), which provides a structured approach for scoping reviews, including defining the research question, identifying relevant studies, selecting studies, charting the data, and summarizing the results (27). Additionally, the PRISMA-ScR (Preferred Reporting Items for Systematic Reviews and Meta-Analyses extension for Scoping Reviews) guidelines was followed to ensure transparency and

rigor in the review process (28). A narrative synthesis was carried out to present the included study findings as directed by the study research aims and objectives.

4.1 Inclusion and Exclusion Criteria

Inclusion Criteria:

- Studies that are systematic reviews or meta-analyses
- Focus on occupational hazards of firefighters (alone or together with other occupational groups) and their health outcomes
- Available in English
- Article published between 2021 to 2025

Exclusion Criteria:

- Studies not related to firefighters or occupations that shares similar duties
- No full text available

4.2 Search strategy

An electronic literature search was conducted from 08 April 2025 to 05 May 2025 in the PubMed and Scopus database, as they provide the most comprehensive coverage of relevant studies. Search terms were adapted for each database in consultation with the review team (ME[1], CP[2] and EC[3]). The final search term included combination of "firefighter," "firefighting," "fire," or "first responder" with occupational health risks such as "occupational health", "work-related risks", "health outcomes", "illness", "disease", "health risk", "mortality", "morbidity. A combination of selected search term and Boolean linked keywords were employed in the search strategy, shown in (Table 1).

Although ScienceDirect was also initially planned for inclusion in the database search along with PubMed and Scopus, it was ultimately excluded as the platform does not allow to use complex search strings comparable to those used in PubMed and Scopus.

[1] First reviewer= Mahim Eaty (ME)
[2] Second reviewer= Charlyne Poncato (CP)
[3] Third reviewer= Emilie Counil (EC)

Table 1: Search strategy used for databases

Database	Search terms	Output
PubMed*	("firefighter*" OR "firefight*" OR "firefighting personnel" OR “firem?n” OR “Fire marshal*” OR “fire worker*” OR “fire rescuer*” OR “fire fight*” OR “fire-fight*” OR “Fire responder*” OR “First responder*”) AND ("occupational health" OR "work-related risk*" OR "health outcome*" OR "illness" OR "disease*" OR “health risk*” OR “mortality” OR “Morbidity”) AND ("systematic review" OR "meta-analysis")	129
Scopus	("firefighter*" OR "firefight*" OR "firefighting personnel" OR “firem?n” OR “Fire marshal*” OR “fire worker*” OR “fire rescuer*” OR “fire fight*” OR “fire-fight*” OR “Fire responder*” OR “First responder*”) AND ("occupational health" OR "work-related risk*" OR "health outcome*" OR "illness" OR "disease*" OR “health risk*” OR “mortality” OR “Morbidity”) AND ("systematic review" OR "meta-analysis")	188
	Total	**317**

4.3 Screening

All of the database search outputs were transferred to Zotero™ reference management software, where duplicate entries were eliminated. The filtered references were then imported into an Excel spreadsheet (.CSV format) and shared with the review team for screening. Two reviewers (ME and CP) independently carried out this screening process for inclusion and exclusion of literature based on the relevance to the research question. Initially, study titles and abstracts were screened by two reviewers based on the predefined inclusion and exclusion criteria. If there was a disagreement, the decision was made through discussions between the reviewers. A third reviewer (EC) provided input when a consensus could not be achieved. For each excluded study, a justification was recorded in the form of a comment. Full texts of the selected studies were then assessed for eligibility by one reviewer and categorized as include, excluded, and to be discussed. The excluded marked studies were further assessed for eligibility by the second reviewer. For studies marked “to be discussed”, the second and third reviewer provided input following the same

procedure as in the abstract screening stage. A final decision was then made after full texts review. Studies that did not meet the inclusion criteria were excluded and documented with notes.

Additionally, the data were limited to publications in English, and only literature published between 2021 and May 2025 timeframe was included in the analysis.

4.4 Data Extraction and Charting

A standardized data extraction form (Excel spreadsheet) [Appendix 1] was developed to systematically capture the key information from the included systematic reviews and meta-analyses. All citations were imported into the Excel spreadsheet (.CSV format) with basic bibliographic information including author(s) name, year of publication, journal name and study tittle. Additional variables recorded for each study included the country or region of focus, study aim, study design, population characteristics (e.g., age, gender distribution, targeted population, geographic coverage, work setting), range of sample size, and type of occupational exposure(s) and health outcomes assessed.

We also extracted key results and subgroup variations including differences by firefighter type (e.g., professional vs. volunteer, structural vs. wildland), gender-based differences, age-related trends (e.g., younger vs. older firefighters) or other demographic factors.

Prior to full extraction, the form was piloted on two studies (one systematic review, one meta-analysis) and reviewed by the review team to ensure completeness, consistency, relevance, and clarity of the extracted items. One reviewer (ME) then extracted data from the remaining studies with regular consultation with review team when uncertainties arose. The second reviewer (CP) cross-checked a random subset to ensure accuracy. Discrepancies were resolved through discussion or third-reviewer consultation. Extracted data were compiled into a structured .CSV file, categorizing studies into predefined themes of health outcomes.

Data extraction and coding were carried out on May 2025.

4.5 Quality Appraisal

Although formal quality assessment is not mandatory in scoping reviews, a quality assessment was conducted in this review to provide a more informed interpretation of the existing evidence. The NIH Quality Assessment Tool for Systematic Reviews and Meta-Analyses developed by the National Heart, Lung, and Blood Institute (NHLBI) in 2013 was used for assessing the quality (29). This tool was selected because this scoping review exclusively included systematic reviews and

meta-analyses focused on occupational health among firefighters. This tool evaluates 8 critical aspects of systematic review and meta-analysis including clarity of research questions, comprehensiveness of search strategies, study selection methods, risk of bias assessment, and synthesis of results.

The first reviewer (ME) conducted the initial quality assessment and marked each question on the NIH checklist as “Yes”, “No”, “Not Reported” (NR), “Not Applicable” (NA) or “Cannot Determine” (CD). The second reviewer (CP) cross-checked a random subset to determine inter-rater reliability and ensure accuracy. Discrepancies and “CD” marked categories were resolved through discussion or third-reviewer consultation. All the quality scores were then standardized as percentages based on the number of criteria applicable to each study. Articles were categorized into the following quality levels:

- **Very good quality**: >70% of applicable items rated as “Yes”
- **Good quality**: 50–70% of applicable items rated as “Yes”
- **Fair quality**: <50% of applicable items rated as “Yes”

4.6 Synthesis of Result

A narrative synthesis was conducted to report the findings of the included studies. Firstly, the extracted information was combined and summarize based on the characteristics and thematic areas. The synthesis aimed to identify patterns of occupational health risks and outcomes among firefighters, with particular attention to different subgroups (e.g., professional vs. volunteer, gender, age), timeframes, and international contexts.

Following the Arksey and O’Malley (2005) framework, data were charted across key domains including reported exposures, and associated health outcomes. Each included study was first categorized by the nature of the occupational hazard such as chemical, physical, biological, psychosocial, or safety-related [Appendix 2]. Within these categories, health outcomes were grouped into thematic areas such as:

- Cancer and Carcinogenic Risks
- Cardiovascular and Respiratory Health
- Musculoskeletal Disorders and Physical Strain
- Infectious Diseases and Biological Health Risks
- Mental Health and Psychosocial Stressors
- Positive Health Indicators and Resilience

- Others (Insomnia, sleep apnea, shift work disorder (SWD))

Additionally, to synthesize the strength of findings across studies, results were classified as:

- **Conclusive**: multiple high-quality studies report consistent findings with statistically significant associations.
- **Mixed**: studies report conflicting or heterogeneous results across populations, methods, or outcomes.
- **Inconclusive**: findings are limited by small sample sizes, or insufficient statistical power.

A detailed description of each study's aim and key findings is provided in Appendix 3.

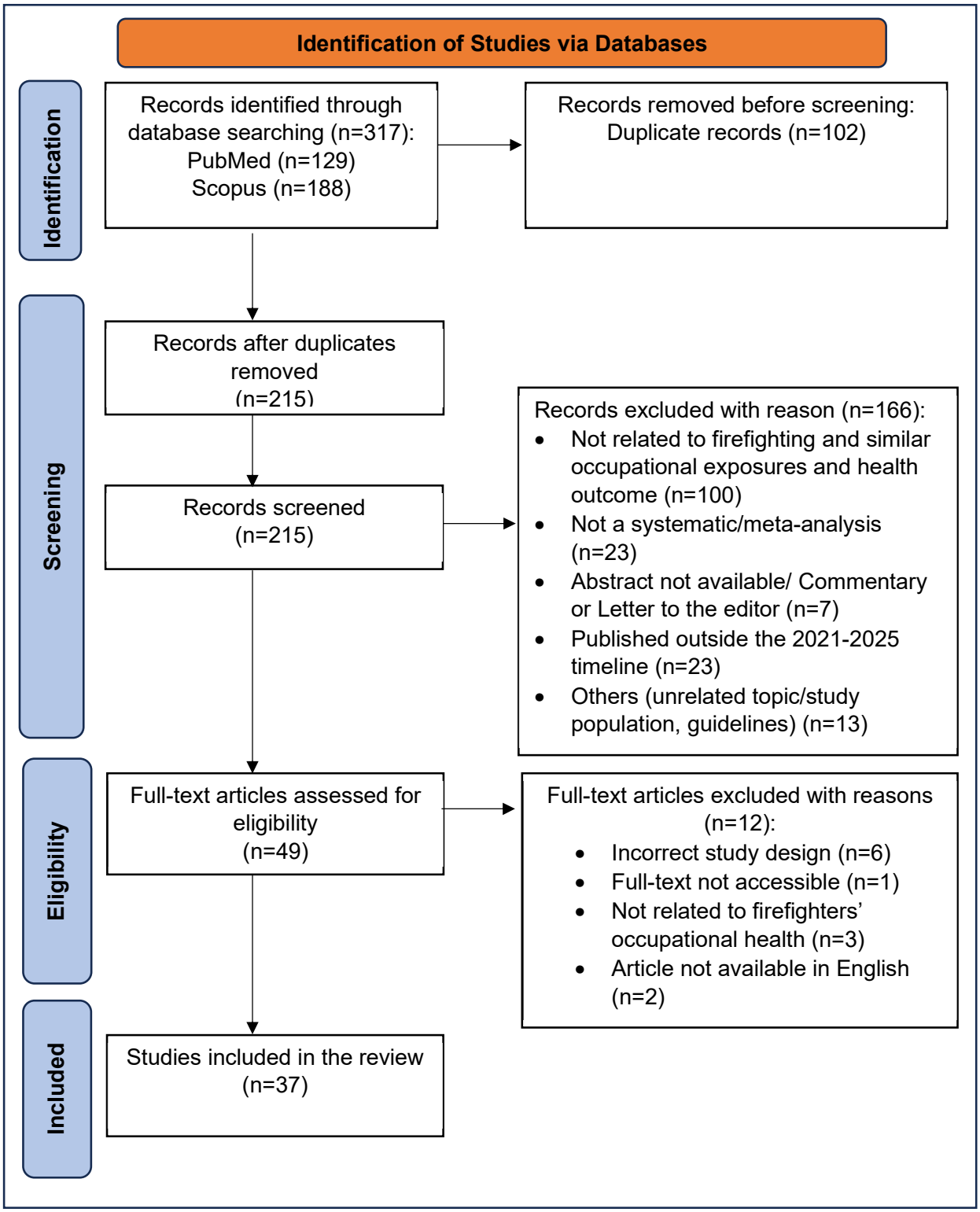
5. Results

5.1 Study selection

A total of 317 records were retrieved from initial database searches (PubMed=129 and Scopus=188). After removing 102 duplicate entries, 215 unique records were screened by title and abstract. A total of 166 records were excluded based on the predefined criteria. The following are the exclusion reasons: not related to firefighting or comparable occupational exposures and health outcomes (n=100), not being a systematic review or meta-analysis (n=23), absence of an abstract or commentary or letter to the editor (n=7), publication outside the 2021–2025 inclusion timeframe (n=23) and others (unrelated topic/study population, guidelines) (n=13).

The remaining 49 studies were then retrieved for full-texts assessment for eligibility. Following the full-text assessment, 12 studies were eliminated based on the inclusion & exclusion criteria, leaving a final sample of 37 studies. The reason for exclusion were: wrong study design (n=6), full-text not accessible (n=1), not related to firefighters' (or similar occupations) occupational health (n=3) and article not available in English (n=2) [Figure 1].

Figure 1: PRISMA Flow diagram of study selection



5.2 NIH Quality Checklist

We assessed the quality of the 37 included studies. Based on the predefined scoring thresholds, 32 studies were identified as “very good” in quality and 4 studies were classified as“good”. Only one study fell into the “fair” category with less than 50% of the applicable items rated positively. Regarding specific NIH quality tool criteria, all included studies demonstrated well-structured and focused research questions, and they clearly defined and reported their eligibility criteria for inclusion and exclusion. 36 studies used a comprehensive search strategy, and approximately 28 studies reported independent, dual screening of study records. Additionally, most studies also listed included studies and systematically assessed their quality [Figure 2].

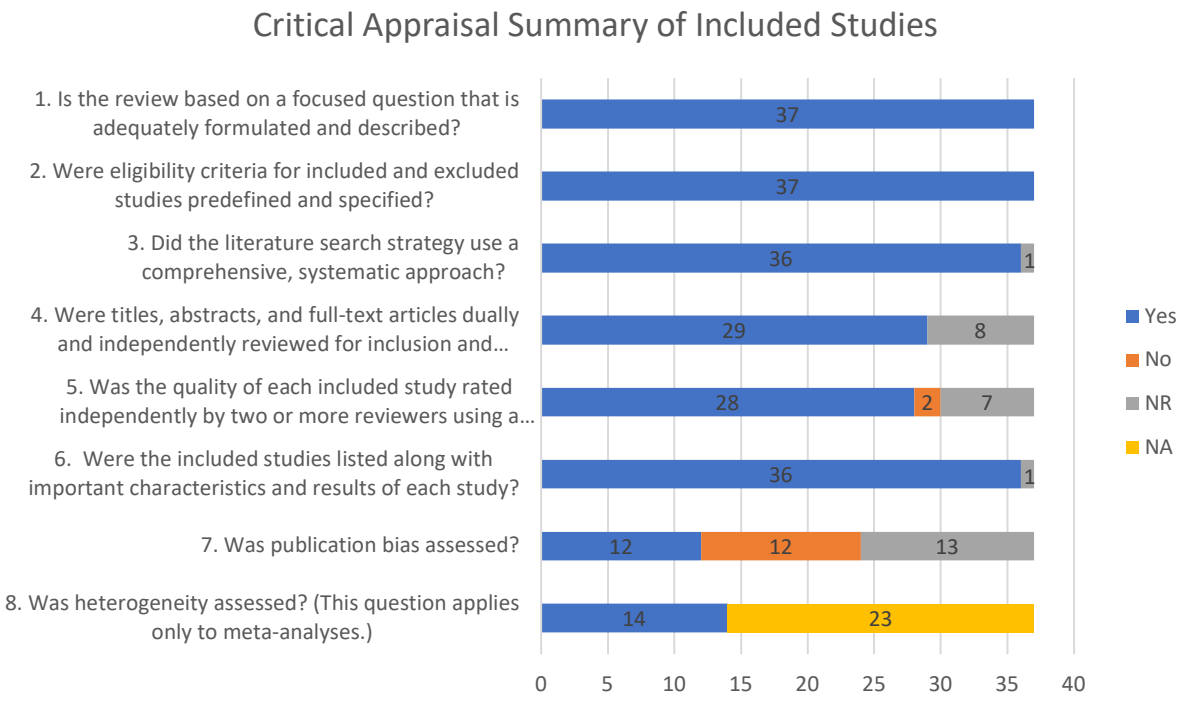


Figure 2: Critical appraisal summary using the NIH Quality Assessment Tool for systematic reviews and meta-analyses.

5.3 General Characteristics of Included Studies

The included studies were published between 2021 to May 2025, with the highest number of studies published in 2021 (n=11), followed by 2023 (n=10), and 2022 (n=9). The remaining studies were published in 2024 (n=4) and 2025 (n=3).

In terms of study design, systematic reviews were the most common, accounting for 51.4% (n=19) of the included studies, while mixed of systematic and meta-analysis comprised 32.4% (n=12) and meta-analyses comprised 16.2% (n=6). Each systematic review and meta-analysis included 8 to 66 primary studies in its analysis ranging 12 to 45,698 participants per study. Regarding study populations, most studies focused explicitly on firefighters (62.2%, n=23), while firefighters along with other professions and firefighter with other first responders were 18.9% (n=7) each.

Gender representation across the included studies was largely skewed toward male participants. A majority of studies (62.2%, n=23) involved samples with more than 70% male participants and 5.4% exclusively focused on male firefighter. Only a small number of studies conducted both male and female-specific analyses (16.2%, n=6), and 16.2% (n=6) were unspecified. The age range was also not specified in 18 out of 37 studies (≈ 48.6%) and when reported, the mean ages ranged from 30 to 40 years most of the times.

The vast majority of the studies (34 out of 37) had an international geographic scope, incorporating data from multiple countries across various continents. Only 3 studies had a domestic focus, among which 2 studies exclusively had focused on the United States and another on Poland.

The studies assessed a diverse type of exposure, and many assessed multiple types of exposure. The mental and psychosocial hazards were the most frequently examined exposures (54.05%, n=20), followed by chemical (37.8%, n=14), physical hazards (27.03%, n=10), biological hazards (5.4%, n=2) and safety-related hazards (5.4%, n=2). The mental and psychosocial hazards were studied often in combination with physical hazards.

Most studies (n=26) concentrated on negative health outcomes. Consistently with the above-mentioned hazards, the most commonly investigated areas were mental health (43.2%, n=16), including stress, PTSD, and burnout, followed by cancer risks (29.7%, n=11), and musculoskeletal disorders (16.2%, n=6). Only 7 studies explicitly investigated positive health indicators such as resilience, posttraumatic growth, and coping strategies (Table 2).

Detailed characteristics of the included studies are available in Appendix 4.

Table 2: General characteristics of included studies

Characteristic	Category	n (%)	Remarks
Publication Year	2021	11 (29.7%)	
	2022	9 (24.3%)	
	2023	10 (27.0%)	
	2024	4(10.8%)	
	2025	3 (8.1%)	
Study Design	Systematic Reviews (SR)	19 (51.4%)	
	Meta-Analyses (MA)	6 (16.2%)	
	Mixed of Systematic Review and Meta-analysis (Both SR+ MA)	12 (32.4%)	
Study sample size	Range of Primary Studies Included	8 to 66 studies	12 to 45,698 participants in each study
Study Population	Firefighters only	23 (62.2%)	
	Firefighters and other professions	7 (18.9%)	
	Firefighters with other first responders	7 (18.9%)	
Gender Representation	Predominantly Male (>70% male)	23 (62.2%)	
	Both Genders Included	2 (5.4%)	
	Male-Only	6 (16.2%)	
	Unspecified	6 (16.2%)	
Age of Participants	Not Specified	18 (48.6%)	
	Reported (mostly mean 30–40 years)	19 (51.4%)	Broad range: 13 to 101 years
Geographic Scope	International	34 (91.9%)	Data from multiple countries
	Domestic	3 (8.1%)	Exclusively two in USA, and other in Poland
Geographic Focus of some highlighted country	United States	33 (89.2%)	
	Canada	27 (73.0%)	
	Australia	19 (51.4%)	
Exposure Types	Mental and psychosocial Hazards	20 (54.05%)	
	Chemical Hazards	14 (37.8%)	
	Physical Hazards	10 (27.03%)	
	Biological Hazards	2 (5.4%)	
	Safety-related Hazards	2 (5.4%)	
Health Outcomes	Mental Health and Psychosocial Stressors	16 (43.2%)	
	Cancer and Carcinogenic Risks	11 (29.7%)	
	Musculoskeletal Disorders	6 (16.2%)	
	Cardiovascular & Respiratory Health	5 (13.5%)	
	Positive Health Indicators (e.g., resilience, coping)	7 (18.9%)	

5.4 Major Occupational Exposures and Associated Health Outcomes

5.4.1 Mental and Psychosocial Exposures

We identified 20 studies that frequently assessed mental and psychosocial occupational exposures of firefighters. Out of these 20 studies, 14 studies exclusively investigated mental and psychosocial occupational exposures (19,26,30–41), while 5 studies addressed mental health and psychosocial exposures in combination with physical exposures (e.g., physical strain, sleep deprivation, or physically demanding tasks) (42–46) and 1 study included both with chemical and physical exposures (20). This combination reflects the complex interplay between mental and physical demands inherent to firefighting and related emergency service occupations. It is found that often the studies which overlapped with other occupational exposures lacked in depth analysis of mental and psychosocial exposures related health outcomes. Additionally, in half of the studies (n=10), study population focus on firefighters along with other professional group. To be specific, 10 studies focused exclusively on firefighters, aligning directly with the objective of this review (20,26,30,37,38,41–45). The remaining 10 studies included broader or mixed populations involving other public safety personnel (PSP) or trauma-exposed occupational groups (19,31–36,39,40,46). These broader cohorts were composed of:

- Public Safety Personnel (PSP) groups, which included police officers, firefighters, paramedics, and rescue/recovery workers (31).
- First responders including firefighters, emergency medical technicians (EMTs), paramedics, and prehospital care providers (33).
- Trauma-exposed workers including healthcare professionals, armed forces personnel, train drivers, war journalists, and disaster survivors (32).
- Civilian emergency services personnel (ESP) including firefighters, paramedics, and police officers in active service roles (35).
- First responders including police, EMS personnel, firefighters and paramedics (19).
- Emergency responders (NGO workers, psychosocial professionals, and both volunteer and professional firefighters) (37).
- One study also focused on women in male-dominated occupations, such as law enforcement, firefighting, truck driving, and construction, contributing insights into gender-specific vulnerabilities and occupational stressors (36).
- Another study broadly included trauma-exposed adults, incorporating firefighter experiences alongside soldiers and patients with chronic illness (39).

Among these studies, the most commonly reported exposures were trauma from critical incidents, psychosocial stressors (e.g., organizational pressure, role conflict), sleep disturbances, and coping-related factors (e.g., social support, resilience, emotion regulation) (19,26,30–41). Studies reported that these exposures were associated with a range of adverse mental health outcomes including PTSD, burnout, depression, anxiety, suicidal ideation, and hazardous alcohol use (19,26,30–41). A smaller group of studies also explored positive psychological outcomes, such as resilience and post-traumatic growth (31,33,35).

Trauma-related exposures, particularly repeated or acute exposure to potentially psychologically traumatic events (PPTEs) such as witnessing injury or death, or being involved in emergency rescues were among the most cited psychological hazards. Five studies (MA=1, Both SR+MA=1, SR=3) explicitly focused on trauma and PTSD (33–34,38–40). These studies reported elevated PTSD prevalence among firefighters. The strength of evidence on trauma and PTSD was moderate to strong, with two studies providing conclusive findings (33,39), one reporting inconclusive (34) and others presenting consistent associations (38,40).

Occupational stress from psychosocial sources including psychosocial stressors (e.g., organizational pressure, role conflict) high workload, low control, organizational dysfunction, and harassment was another recurrent theme. We found 4 studies (MA=1, SR=3) that examined these exposures in relation to burnout, depression, suicidal ideation, and alcohol use. This body of evidence was rated strong, with two studies offering conclusive findings (26,32), and two studies reporting mixed but supportive results (36,47).

5 studies (SR=3, Both SR+MA=1, and MA=1) reported that sleep disturbances, shift work, fatigue were strongly associated with a range of adverse including burnout, cognitive decline, mental distress, sleep disorders (19,37,42,45,46). Among these, two reviews offer conclusive evidence (19,45), while three present mixed but notable findings (37,42,46). One of reviews notably reported the prevalence of sleep disorders among the studied populations such as insomnia in 28% of individuals, SWD in 31%, and OSA in 30% (19).

Three studies (SR=2; Both SR+MA=1) were identified which focused on psychological coping mechanisms and resilience as both exposure factors and potential moderators of mental health outcomes (31,33,35). These studies explored how adaptive coping (e.g., seeking support, problem-solving) and maladaptive coping (e.g., avoidance, denial) impacted outcomes like PTSD, depression, and emotional exhaustion (31,33,35). The evidence here was mixed, with trends suggesting benefit from adaptive coping, but limited by small effect sizes and heterogeneity.

Another study included firefighters along with women in other male-dominated occupations (law enforcement, firefighting, truck driving, and construction) and explored organizational culture, gender composition, workplace relationships, and psychosocial hazards such as sexual harassment. This study provided mixed evidence (conclusive for some psychosocial factors but limited by study design and self-report bias) (45) [see detailed mapping in Appendix 5].

5.4.2 Chemical Exposures

Across the literature we found that 14 studies (16,20,48–59) studied chemical exposures of firefighters and other related professions and its related health outcomes where 4 studies were overlapped with other exposure types (20,25,54,56). The most frequently assessed chemical exposures were fire smoke, combustion byproducts including volatile organic compounds (VOCs) such as benzene and formaldehyde, polycyclic aromatic hydrocarbons (PAHs), particulate matter (PM2.5/PM10), diesel exhaust, and substances like asbestos and flame retardants (e.g., PFAS, PBDEs) (20,44–46). The included study findings indicated that chemical exposures have significant associations with increased cancer risks among firefighters.

Cancer was the most commonly studied outcome where mesothelioma, bladder, testicular, melanoma, and prostate cancers were frequently assessed.11 studies (SR=5; Both SR+MA=4; MA=2) investigated these cancer outcomes where 3 study reported conclusive evidence about associations with chemical exposures (PAHs, Benzene, Diesel Exhaust and other carcinogenic substances) and increased cancer risks including mesothelioma, bladder cancer prostate, testicular, and melanoma cancers (25,53,55) and 8 study reported mixed findings (16,20,49–51,56,59).

Two systematic reviews and one meta-analysis compared respiratory outcomes of PM2.5 and other combustion product exposures, two of which had mixed evidence (57,58) and one was inconclusive (58). These studies however consistently noted declines in lung function (e.g., FEV_1, FVC) (57,58) and increased inflammatory biomarkers following exposure (59).

Some studies explicitly focused on acute exposure to fire smoke components such as benzene, carbon monoxide, and acrolein and its related adverse health outcomes. Notably, we identified two studies that provided conclusive evidence of enhanced chronic rhinosinusitis (CRS) (54) and cancer incidence (28), and 2 other studies reported mixed findings related to elevated OHPAHs (occupational exposure to polycyclic aromatic hydrocarbons) post-fire (53) and respiratory and cardiovascular symptoms (59).

We identified 4 studies thatfocused on specific chemical classes such as per- and polyfluoroalkyl substances (PFAS) and asbestos **(**MA=2, Both SR+MA=1; SR=1) which provided moderate evidence (one conclusive and three mixed) of association between these exposures to cancer including prostate and testicular cancers (48,50,52,56).

Additionally, we also identified two systematic reviews that explicitly examined the effects of mixed chemical agents such as benzene, toluene, xylene (BTX), soot, and heavy metals on firefighter health. Both studies reported mixed evidence, with one identifying an increased risk of lung cancer but inconsistent exposure-response patterns (16) [see detailed mapping in Appendix 6].

5.4.3 Physical Exposures

We identified 10 studies that explored physical occupational exposures among firefighters (20,42–46,48,56,60,61). The most common cited occupational exposures of firefighters were emergency response, heavy physical tasks, physical strain, disrupted sleep, fatigue, poor sleep quality and environmental stressors (e.g., heat, noise). These exposures were found to have link with a wide spectrum of negative health outcomes including musculoskeletal disorders (MSDs), cardiovascular health, metabolic syndrome, sleep disturbances, and cognitive impairments (20,42–46,48,56,60,61). MSD problems emerged as one of the most consistently reported consequences of physical stressors. 3 studies focused on MSDs explicitly (MA=2; Both SR+MA=1). These studies reported increased MSD prevalence among firefighters (20,44,60). Tahernejad et al. (2024), analyzing data up to2022 across 12 countries, and Khoshakhlagh et al. (2024), covering studies up to 2022 from 15 countries, reported that the prevalence of MSDs among firefighters was 46.4% and 41%, respectively. According to their findings, the most affected body areas are lower back (31–34%), knees, shoulders, and neck. These outcomes are attributed to repetitive movements, awkward postures, heavy lifting, and biomechanical strain (44,60). These studies provided strong evidence, with 2 studies offering conclusive findings (44,60) while remaining study provided mixed findings (17).

CVDs and cardiometabolic conditions including metabolic syndrome (MetSyn) were assessed in 1 study, which showed moderate to strong evidence. The physical demands, shift work and emergency responses increase these risks. The study documented a 22.3% prevalence of MetSyn (43).

Additionally, a number of studies reported about sleep disturbances, fatigue, poor sleep quality, which contributed to both physical and mental health decline. We identified 2 studies (SR=1; Both

SR+MA=1) that examined the association between shift work and sleep disruption (44,46). Both studies provided conclusive evidence of significant sleep disturbances among firefighters. Notably, 30.5% reported sleep disorders, and over half (51.4%) experienced poor sleep quality (44). Another study confirmed the long-term cognitive and cardiovascular impacts of poor sleep, though its short-term physical performance effects remained inconclusive (46). The physical fitness, workload, and resilience were examined in 1 systematic review which provided mixed evidence. The study confirmed that higher physical fitness reduced injury risk, while the role of psychological resilience and organizational factors remained less certain (42).

Lastly, use of PPE was addressed in one study, which provided conclusive evidence that PPE (e.g., heavy boots, SCBA) significantly increased physiological stress indicators including heart rate (HR), oxygen consumption (OC), and body temperature (BT), with boot weight increasing oxygen consumption by 3%–10% per kilogram (61). DeBono et al. (2023) talked about physical exposures along with chemical exposures but did not explore any direct association between physical exposure and its related health outcome (48) [see detailed mapping in Appendix 7].

5.4.4 Biological Exposures

We found two studies that explored biological exposures, one of which also included chemical exposures under broader environmental factors. However, neither study explicitly focused on firefighters as the sole study population; instead, they combined firefighters with emergency medical services (EMS) clinicians (62) or other blue-collar professionals (54).

The key exposures discussed among these two studies were infectious agents (e.g., SARS-CoV-2, MRSA, Hepatitis C), smoke, pesticides, dust, gases and fumes, and workplace allergens. One of these reviews focused on EMS clinicians and firefighters who are exposed to infectious agents. This study reported that that EMS personnel were more at risk comparing to firefighters, with conclusive evidence provided for increased hospitalization and death related to exposure to infectious agents among EMS workers (62).

The other review examined occupational exposure to chemical and environmental agents among firefighters and similar professions (54). It also mentioned allergens as a biological exposure within broader environmental factors but did not explore their health impacts separately (54).

5.4.5 Safety-Related Exposures

We found two systematic reviews that explored safety-related exposures among firefighters (36,61). Among these two studies, only one study focused exclusively on firefighters and examined

the physiological safety related exposures such as impacts of personal protective equipment (PPE) use including protective clothing, boots, self-contained breathing apparatus (SCBA), and helmets. It provided conclusive evidence (61). The second study examined musculoskeletal injuries during physical training in law enforcement and firefighter recruits. This study reported that no firefighter-specific data were found therefore no findings were reported, leading to inconclusive findings (36).

5.4.6 Geographic Coverage

The included 37 studies of this scoping review showed a wide range of international geographic coverage. However, a significant bias toward HIC was observed. North America was the most represented region, with the United States (33 studies) and Canada (27 studies) dominating the research landscape. Europe also featured prominently in the included studies particularly France, the United Kingdom, Germany, and the Netherlands. Oceania also had a strong contribution with Australia featured in 19 studies. Notable Asian participation was observed by China, South Korea and Japan along minimal representation of other Asian countries (16,19,30–32,42,48–51,53,60,62)

South American and African countries were found to be most underrepresented (16,20,26,48,49,52,62). Few studies from country like Brazil and South Africa were noted and there was little representation from countries like Ethiopia, Nigeria and Ecuador (19,30–33,60,63). The Middle Eastern countries, primarily Saudi Arabia and Iran were found to be moderately represented (31,41,44,45,54,61).

Overall, even though the research covered a wide range of geographical areas, only a few of them used data from LMICs, making them glaringly underrepresented. This imbalance highlights a critical gap in global research inclusivity.

5.5 Subgroup Analysis

Across the included articles, we identified 12 studies that reported subgroup differences in occupational health outcomes in firefighters, reporting differences by firefighter type (career vs. volunteer), occupations, gender, age, work-related attributes, and conditions of work (20,30,32,40,41,44,46,50,53,54,58,62). We also identified additional 9 studies that briefly talked about minimal variation in their study (19,31,37,42,43,45,55,56,61). However, subgroup analysis was often inconsistently addressed or just briefly acknowledged with limited use of statistical testing. Only 5 of these reviews conducted inferential methods such as meta-regression to

evaluate whether subgroup characteristics significantly influenced prevalence estimates or effect sizes (19,30–32,55).

Differences by type of firefighter status were reported in 8 studies (20,30,37,41,46,53,55,58). However, only 3 studies provided comparative findings directly between career vs. volunteer firefighters (20,37,41). Two studies reported differences between wild-land vs urban located workers (46,58). Differences by job role: EMS personnel vs. administrative personnel (30), instructor vs. trainee (55) were reported in two studies, while one study compared structural (career) vs wild-land firefighters (53). Additionally, two studies reported sparse reference to volunteer firefighters, for the most part citing shortages of data or lack from official databases (37,41). Among these studies, only two studies used inferential analysis (30,55) other provided descriptive comparison.

Comparative differences in occupational health outcomes between firefighters and other professions were identified in 4 studies (32,40,54,62). One of these studies provided a comparative analysis between EMS clinicians and firefighters (62), another compared firefighter vs. blue-collar professions (54) and a third study reported differences between firefighters and police (40). Another study reported a comparative finding across armed forces, first responder and health care worker (32). Though, this study separately discussed occupational health outcomes of firefighters, it did not explore nor present direct comparisons between firefighters and the other occupational groups. However, one of these studies applied inferential analysis (32).

Gender-based differences were identified in 5 studies (19,30,31,45,61) thoroughly which only two conducted inferential analyses (19,31); other provided descriptive. One study provided extensive stratified data across 8 of 12 non-cancer disease categories, indicating that female firefighters had significantly higher mortality rates from circulatory diseases, respiratory illnesses, and suicide compared to their male counterparts; provided descriptive comparison (30). In the same study, outcomes in other categories such as mental health, sleep disorders, and genitourinary conditions included both genders but were not consistently stratified or emphasized. A meta-regression analysis in another study considered the influence of sex on effect sizes, though it did not report detailed sex-specific findings (31). Two studies examined sleep-related health outcomes and found that males had a higher prevalence of sleep disorders overall, whereas females demonstrated higher risks of insomnia and excessive daytime sleepiness in certain contexts (19). One additional study investigated physiological response differences and reported that women had lower increases in OC per unit of boot weight compared to men (61). Collectively,

these findings indicate some emerging gender-specific insights, though the reporting remains inconsistent and often lacks comprehensive stratification.

Age-related trends were mentioned in 6 studies (19,40,42–44,56), though none conducted inferential subgroup analysis. One of these studies reported that older firefighters were experiencing higher injury and health risks (42), one reported increased MSDs (44), one reported higher prostate cancer risk (40) and another reported OSA prevalence increased with age (19). The rest of the two studies reported age-related health condition prevalence (43) and prostate cancer risk (56), though these findings lacked statistical significance and standardization.

Other job-related factors such as years of service (n=11) (16,30,33,36–38,41,44,45,48,49,59), rank (n=3) (30,36,41), and fire-call/emergency duties (n=2) (30,53) were reported thoroughly across the included studies. However, only one employed inferential analysis. Four of these identified service duration as a contributor to long-term cancer risk and toxic exposure accumulation, particularly in relation to structural and wildland firefighting participation (16,25,49,59). Three studies linked extended service to psychosocial risks including distress, alcohol use, and probable major depressive disorder (MDD) (37,38,41). Additionally, three studies addressed occupational rank as an exposure modifier, with findings showing that higher rank was associated with increased burnout, role ambiguity, and managerial stress (30,36,41). However, none offered standardized metrics for job exposure indices.

Working condition variables such as shift work, organizational factors, PPE use, and geographic variability in context were reported thoroughly in 18 studies, none of which used inferential method (19,25,35,37,41–44,46,49–52,55,56,58). Shift and night work were highlighted in 13 studies as contributors to sleep disorders, fatigue, metabolic strain, and psychological burnout (19,25,35,37,41–44,46,51,52,56). Geographic and regional differences were described in five studies, with notable disparities in exposure levels, regulatory practices, and respiratory outcomes across continents (49,50,55,58). Differential effects to PPE use and availability were outlined in four studies (16,44,49,50). Organizational factors like culture, fairness and suboptimal sleeping arrangements were addressed in three studies (26,36,46). However, organizational structures as a determinant of exposure profiles and outcomes still remain underexplored [see detailed mapping in Appendix 8].

6. Discussion

This scoping review is the most comprehensive effort to date to bring together systematic evidence on occupational health risks faced by firefighters. While many individual studies have examined risks in relation to distinct hazards such as smoke inhalation, PTSD, or musculoskeletal disorders, this review is unique in its synthesis of prior systematic reviews and meta-analyses across a broad range of exposure categories and health outcomes. By doing so, it addresses important questions on what types of health risks get more attention, areas of research gaps including about whether health outcomes differ by subgroup. This review also focuses on how the health of firefighters has been assessed within diverse contexts and populations, with special considerations for organizational configurations, subgroup risks and overlooked health domains.

A recent umbrella review by Descatha et al. (2025) synthesized 47 systematized reviews on firefighters' occupational exposures and related health outcomes, covering a broad range of topics including cancer, musculoskeletal disorders, mental health, and various chemical and psychosocial hazards. That review offered a broad overview of the work exposome in firefighting, and outcomes, primarily focusing on general patterns and well-established risks, while identifying key areas of concern and gaps in knowledge (64). However, it was limited to a specific geographic scope (North America & Australia) and did not explore detailed subgroup analysis or assess whether variations in firefighter type (e.g., professional vs. volunteer), gender, or geographic context affect health outcomes (64). This scoping review extents that work by adding a particular attention to subgroup disparities, global geographic representation and methodological gaps. It offers deeper insights into underexplored areas such as positive health indicators, contextual variations, and occupational inequities that will help to identify key priorities for future research and policy development in firefighter occupational health.

6.1 Landscape of Firefighter Health Risks

This review found that mental & psychosocial hazards were the most commonly explored occupational risks among firefighters, followed by chemical, physical and other exposures. Mental health outcomes, including PTSD, burnout, and depression were likewise strongly associated with traumatic events and organizational stressors (26,31,33,36,37,39). Among chemical exposures, strong evidence links firefighters' exposure to carcinogens such as PAHs, benzene, and flame retardants with increased risks of cancers, particularly mesothelioma, prostate, and testicular cancers (20,48–52,56,59). For physical exposures, MSDs and sleep-related conditions found as

common and well-documented outcomes, especially among structural firefighters subjected to shift work, repetitive lifting, and physical strain (19,20,44,51).

However, the review also found limited emphasis on biological risks, including infectious diseases and bloodborne pathogen, although these risks clearly relevant to emergency response work (62). Furthermore, the beneficial health dimensions of firefighters' well-being such as resilience, coping mechanisms, and post-traumatic growth remain underrepresented in the literature, with only a handful of reviews exploring these areas (31,33,35,37,41).

6.2 Methodological and Contextual Gaps in Exposure Assessment

Building on the exposure-related findings above, another central issue is the fragmentation in how exposures are measured and contextualized. Across chemical, physical, and biological domains, many studies did not account for real-time exposure metrics, such as smoke composition, PPE effectiveness, or physiological load during active fire suppression (16,49,53,55,59,61). Particularly in the chemical domain, few studies used biomonitoring data or evaluated dermal absorption routes and internal dose-response relationships (52,53,55,56). As a result, much of the evidence remains abstracted from the operational realities of firefighting.

Additionally, inconsistent definitions of exposures (e.g., "chemical exposure" or "burnout"), heterogeneous outcome measures (e.g., multiple PTSD scales), and disparities in inclusion criteria across the studies make it difficult to synthesize results (16,49,53,59,60,62).

Variability in exposure according to mission, task, or geography is underexplored. Emerging risks like PPE-induced heat stress, sleep disruption, or cumulative exposure to stress and trauma require more integrated assessment tools. Moreover, very few studies examined organizational structures, such as leadership support, training quality, or communication systems, as factors influencing health outcomes. The mental exhaustion from organizational stress is also often discussed in isolation, despite their co-occurrence in real settings. Without integrated measures that reflect the interaction between work environment, physical demand, and individual vulnerability, occupational health strategies risk being misaligned with real-world needs.

6.3 Subgroup Representation and Occupational Inequities

In addition to exposure gaps, a major concern that emerged from this review is the lack of consistent subgroup analysis. Although occupational risks are not uniform across firefighters and similar workers populations, subgroup analyses remain limited or absent in most reviews. Only 12

studies attempted comparisons based on gender, age, job role, or career stage, and even fewer performed in-depth stratified analysis (20,30,32,40,41,44,46,50,53,54,58,62). Female firefighters, for example, appear to have higher rates of circulatory and respiratory illness and suicide (30), yet few studies explored these risks in depth or examined protective interventions. Findings suggest that women may face disproportionate risks in cardiovascular health, mental illness, and PPE-related strain (19,30,61). However, gender-based analysis was often limited due to male-dominated samples or the absence of sex-disaggregated data. Similarly, volunteer and wildland firefighters, who may face more variable conditions and reduced institutional support were also underrepresented in the evidence base (43,48,49).

Job-related factors such as rank, years of service, or specific roles (e.g., instructor vs. trainee) are inconsistently considered (30,49,55,59). These findings reflect broader occupational health disparities, where gender, role, and resource access shape both exposure and outcome. The review therefore raises questions about the adequacy of current surveillance and reporting systems in capturing the full spectrum of risks across the firefighting and similar role workforce. Improving subgroup analysis therefore is essential to support equitable policy development and targeted intervention.

6.4 Geographic Diversity Limits Generalizability

Closely tied to subgroup underrepresentation, the review revealed a systemic issue: the global firefighter and similar workers community is not equitably represented in research, and this limits the field's ability to inform diverse occupational contexts. The current literature is heavily concentrated on HIC, particularly the United States, Canada, and Australia. A limited studies used data from LMICs. This uneven geography of research reflects broader structural issues in academic funding and research infrastructure. Addressing this imbalance will require long-term investment, inclusive research design, and international collaboration to ensure that the global firefighter workforce is adequately represented.

6.5 Predominant Focus on Negative Outcomes Overlooks Resilience and Well-Being

The literature overwhelmingly emphasizes negative health outcomes including PTSD, burnout, cancer, and musculoskeletal disorders. Only seven studies explicitly addressed positive health indicators, such as resilience, post-traumatic growth, or effective coping strategies (31,33,35,37,41). Even when mentioned, positive outcomes were typically treated as secondary themes and inconsistently measured.

This gap reflects a deficit-based framing of firefighter health that overlooks protective factors, support systems, and organizational practices that could mitigate risks. Moreover, the lack of longitudinal and interventional designs hampers our understanding of how occupational resilience develops and how it can be fostered across career stages (25,33,37,41).

Future research should adopt a more balanced framework that includes not only risks but also protective factors that enhance firefighter health, physiological and psychological recovery of firefighters.

7. Limitation

This review has some limitations that should be acknowledged. First, the study was restricted to English language articles published between 2021 to 2025 which, which may have excluded key systematic reviews or meta-analyses before 2021 or published in other languages. This time and language limitation may have caused the exclusion of landmark or regionally significant studies.

Second, one included review focused broadly on “first responders” without specifying whether firefighters were part of the study population. Additionally, a few other studies categorized firefighters under broader occupational groupings such as “public safety personnel (PSP),” “emergency responders,” or “EMS professionals,” alongside police officers, paramedics, military personnel and other professionals. Most of these cases, firefighter-specific work and exposure-related health outcomes and job-specific comparative variations were not reported explicitly instead general or common occupational risks within these groups were focused in reporting. This lack of specificity made it particularly challenging to extract firefighter-relevant information, especially regarding subgroup variations based on role, gender, or service context.

8. Conclusion and Future Directions

This scoping review aimed to systematically map the extent, nature, and gaps in scientific evidence on firefighters’ occupational health based on existing systematic reviews and meta-analyses, with a particular attention to subgroup variability and the inclusion of both negative and positive health indicators. The key findings perfectly align with the review objectives. The MSDs, cancer, and psychological distress emerged were found as the most consistently documented risks. In contrast, sleep-related conditions, infectious disease risks, and positive psychosocial outcomes remain underexplored.

The demographic and occupational subgroups such as female, volunteer, and wildland firefighters remain significantly underrepresented, limiting the equity and applicability of current evidence. Furthermore, a few studies look at health risks in the context of organizational factors like leadership, shift patterns, PPE use in different working situations, which are important for understanding risks that can be changed.

These findings underscore the need for a more integrative and equitable research agenda. Future studies should focus on:

- Inclusive study by gender, age, role, and geographic diversity
- Standardized definitions of outcomes and measures of exposure for synthesis and policy use
- Long-term and intervention studies of organizational and psychosocial health determinants
- Positive outcomes, such as resilience and coping, to balance the current focus on disease

These findings have important implications for powerful stakeholders, including occupational health researchers, fire service management, policy-makers, and labor health advocatess. For policy-makers and fire department administrators, the results are a plea for stronger surveillance, targeted interventions, and flexible occupational health standards that account for the diversity of real working conditions and the range of situations encountered by firefighters. For researchers, the review offers a roadmap of occupational issues not yet sufficiently investigated and methodological advances. Transnational coordination and investment in context-specific exposure assessment will be essential to attaining global applicability and generalizability. Future research should also incorporate insights from the social and labor sciences to deepen understanding of the lived work experiences of firefighters.

In conclusion, despite considerable advancement towards the definition of occupational health risks among firefighters, the field has to evolve towards a more systems-based, equitable, and comprehensive perspective of firefighter health to enable evidence-based practice and policy worldwide.

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Appendices

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Appendix 1: Data Extraction Form

General Information about the Paper						Contexts and Aims of the Paper			Occupational Exposures and Health Outcomes Considered		
Sl No	Title	Author	Year of Publication	Journal	Article Type	Research Aims	Type of Targeted Population	Geographic coverage (Regional or International)	Types of Occupational Exposures Assessed	Types of Health Outcomes (Negative or Positive or Both)	Health Outcome

Population and Sample Characteristics							
Number of Included Studies	Countries where Single Study Included in the Paper	Period Covered (start year)	Period Covered (End year)	Sample Size of included studies (Range)	Age/ Age Range	Gender Distribution	Other Demographic or Job-related factors

Key Results		Subgroup Variations in Results if Discussed in any					Research or data gaps identified by authors of the paper		
Effect size	Evidence Strengths (conclusive, inconclusive or mixed)	Differences by firefighter type (Professional vs. volunteers, structural vs. wildland, …)	Gender-based Difference	Age-related Trends	Other Job-Related Factors (rank, years of service)	Other Working Conditions Factors (shift work, night work, types of working situation/settings, urban/rural…)	Data Gap (as labeled in the author)	Research Gap	Other

Appendix 2: Categorization of the Types of Occupational Exposures Assessed

Author	Occupational Exposures Assessed	Types of Occupational Exposure				
		Chemical	Physical	Biological	Psychosocial	Safety-related
Kang et al. (2025) (16)	Fire smoke, particulate matter (PM2.5), carcinogenic chemicals from fire smoke (e.g., asbestos, benzene, cadmium, silica), and specific fire scenarios (structure, vehicle, wildland fires) and use of personal protective equipment (PPE) especially for respiratory protect	√				
DeBono et al. (2023) (48)	General firefighting exposures, including exposure to combustion products (PAHs, particulates), asbestos, chemicals in firefighting foams (PFAS), flame retardants, diesel exhaust, ultraviolet radiation, night shift work, and biological uptake through dermal absorption, inhalation, ingestion	√	√			
Igboanugo et al. (2021) (63)	Psychosocial stressors				√	
Casjens et al. (2021) (49)	Carcinogen	√				
Kim et al. (2022) (30)	Job stress, shift work, emergency response duties.				√	

Cuenca-Lozano et al. (2023) (20)	Physical, chemical, mechanical, and psychosocial risk factors, Organizational and perception-related factors	√	√		√	
Heydari et al. (2022) (42)	Resilience-related indicators: physical fitness, injury risk, sleep disturbances, BMI, chronic diseases (e.g., cardiovascular, respiratory, metabolic disorders), musculoskeletal issues, high-risk behaviors (smoking, alcohol), occupational stress, psychological resilience, workload, and job-related competencies		√		√	√
Jahnke et al. (2024) (50)	Carcinogen: (but category not specified)	√				
Laroche et al. (2021) (51)	Chemicals from combustion, soot, polycyclic aromatic hydrocarbons (PAHs), volatile organic compounds (VOCs), asbestos, diesel exhaust, and other carcinogens	√				
Tahernejad et al. (2024) (60)	Ergonomic risk factors and physical exertion		√			
Lee et al. (2023) (52)	Carcinogenic substances such as polycyclic aromatic hydrocarbons (PAHs), benzene, combustion products, organo-chlorine and -phosphorus compounds, phenols, phthalates and heavy metals and metalloids	√				
Di Nota et al. (2021) (31)	Exposure to potentially traumatic events (PPTE), critical incidents				√	
Russell et al. (2023) (62)	Exposure to infectious agents (Bloodborne pathogens (e.g., Hepatitis C), Airborne/droplet infections (e.g., SARS-CoV-2), Skin/mucosal exposure, Needlestick injuries, MRSA (Methicillin-resistant Staphylococcus aureus) colonization)			√		
Beckett et al. (2023) (43)	Shift work, emergency response, physical stress and physically demanding tasks		√		√	
Hwang et al. (2022) (53)	Polycyclic aromatic hydrocarbons (PAHs)	√				
Alkholaiwi et al. (2022) (54)	Smoke, pesticides, dust, gases and fumes, workplace allergens, blue-collar work (e.g., firefighting, farming)	√		√		
Irizar et al. (2021) (32)	Repeated exposure to trauma in occupational settings (e.g., combat, accidents, medical emergencies)				√	

Díaz-Tamayo et al. (2022) (33)	Traumatic events (accidents involving children, multiple victims, injuries or deaths involving colleagues, dealing with violent individuals, witnessing suicides, or experiencing threats at incidents)				√	
Coenen et al. (2021) (34)	Combat trauma, occupational trauma				√	
Huang et al. (2022) (19)	Shift work, irregular work schedules, circadian rhythm disruption		√		√	
Hwang et al. (2021) (55)	Polycyclic aromatic hydrocarbons (PAHs)	√				
Khoshakhlagh et al. (2024) (44)	Job stress, mental and physical demands, highly biomechanically demanding activities, insufficient job control, job position, work time, weight lifting, restricted mobility with PPE and psychosocial stressors		√		√	
Ledda et al. (2023) (56)	Firefighting, physical activity, night shift work, chemical exposure (e.g., benzene, toluene, xylene, alkylphenolic compounds), solar ultraviolet radiation, farming (pesticides)	√	√			
Kyron et al. (2021) (35)	Potentially psychologically traumatic events (PPTEs), operational stressors, critical incidents, off-duty stressors (e.g., personal trauma, non-work events				√	
Khoshakhlagh et al. (2023) (45)	Shift work, mental health stressors, musculoskeletal disorders, body mass index (BMI), work hours and emergency call frequency, and traumatic events.		√		√	
Wah et al. (2025) (57)	Wildfire smoke (PM2.5, PM10, CO, PAHs, benzene, SO2, NOx), prescribed burns, and vegetation fire experiments.	√				
Ramezanifar et al. (2023) (61)	Use of PPE (e.g., protective clothing, boots, SCBA, helmets)		√			
Riddle et al. (2023) (36)	Organizational culture; gender composition; workplace relationships; job physicality; harassment remedies				√	√
Garmon-Jones et al. (2023) (37)	Sleep disturbances, Occupational stress, Length of service, Coping style, social support, Emotional intelligence, Empathy				√	

Barbosa et al. (2022) (58)	Fire smoke (wildland and urban fires), particulate matter, gases (carbon monoxide, nitrogen dioxide, polycyclic aromatic hydrocarbons, formaldehyde, benzene and acrolein), and other combustion byproducts	√				
Murphy et al. (2022) (47)	Physical training during recruit programs					√
Teixeira et al. (2024) (59)	Chemical agents: Polycyclic aromatic hydrocarbons (PAHs), volatile organic compounds (VOCs), carbon monoxide (CO), fine particulate matter (PM2.5), formaldehyde, benzene	√				
Wagner et al. (2021) (38)	large-scale disasters (natural and manmade) including terrorist attacks, wildfires, earthquakes, plane crashes, explosions				√	
Cyniak-Cieciura et al. (2021) (39)	Combat trauma, occupational trauma (firefighters, police)- disasters (floods, fires), motor vehicle accidents, chronic illnesses				√	
Frost et al. (2021) (46)	Sleep deprivation/restriction, sleep quality, shift schedule (eg- 24 h shift), poor sleep hygiene, environmental stressors (heat, noise)		√		√	
Wesemann et al. (2022) (40)	Terrorist attacks (e.g., 9/11 WTC, Berlin Christmas market attack, Paris attacks), traumatic events, proximity to the event, exposure to human remains, injury during response				√	
García-Iglesias et al. (2025) (41)	Work-related stress, traumatic events, role ambiguity, work-family conflict, rotating shifts, organizational demands				√	
	Total Count (%)	14(37.84 %)	11(29.73 %)	2 (5.41%)	20 (54.05%)	3 (8.11%)

Appendix 3: Study Aims and Key Findings

Author (Year)	Aims	Exposure Types	Health Outcomes	Key Findings	Strength of Evidence
Kang et al. (2025) (16)	To provide a comprehensive narrative review of the published literature on factors associated with lung cancer risk among firefighters.	Chemical	Lung cancer incidence	Mixed SMRs across studies.	Mixed
DeBono et al. (2023) (48)	The objective of the analysis was to meta-analyze the association between ever-employment and duration of employment as a firefighter and cancer incidence and mortality.	Chemical, Physical	Elevated risks for multiple cancers; inverse association for lung cancer.	Mesothelioma (RR=1.58), bladder (1.16), prostate (1.21), testicular (1.37)	Conclusive
Igboanugo et al. (2021) (63)	To investigate the academic literature to answer the following key research question: what health outcomes are associated with the work-related psychosocial stressors typically experienced by those within the fire service?	Psychosocial	Depression, burnout, alcohol use disorders, non-depressive mental health problems	Qualitative synthesis (6 health themes).	Conclusive
Casjens et al. (2021) (49)	To evaluate the cancer risks among firefighters in the time course and from different geographical areas.	Chemical	Cancer incidence (mesothelioma, bladder, prostate, testicular, colon, skin cancers etc.)	Overall cancer incidence: mSI=1.00 (95% CI: 0.93–1.07). Mesothelioma (mSIR=1.46), bladder (mSIR=1.14).	Mixed
Kim et al. (2022) (30)	To identify the risk of non-cancer diseases in firefighters and to determine whether the risk differs according to job characteristics.	Psychosocial	12 disease categories incl. PTSD, MI, lumbar herniation	PTSD (HR=1.40), lumbar disc herniation (HR=1.43), acute MI (HR=1.21).	Mixed
Cuenca-Lozano et al. (2023) (20)	To analyze the risks and consequences faced by firefighters and thus provide elements to improve safety management systems in institutions.	Chemical, Physical, Psychosocial	Skin cancer, injuries, PTSD, resilience	Qualitative	Mixed

Heydari et al. (2022) (42)	To identify indicators influencing the level of fire-fighters' resilience and to develop a comprehensive framework, including domains and indicators, for assessing and building resilience in firefighters.	Physical, Psychosocial	Injuries, chronic illness, mental health problem	Qualitative	Mixed
Jahnke et al. (2024) (50)	To determine if geographic differences and different practices in strategies/tactics, exposure types, and use of personal protective equipment (PPE) may lead to differences in incidence and mortality between U.S. and non-U.S. firefighters.	Chemical	Cancer incidence and mortality	Prostate (SIRE=1.208), melanoma (SIRE=1.609).	Mixed
Laroche et al. (2021) (51)	To assess the conclusion consistency across the available systematic reviews on the cancer risk in firefighters.	Chemical	Cancer incidence/mortality	Qualitative	Mixed
Tahernejad et al. (2024) (60)	To investigate the prevalence of MSDs among firefighters.	Physical	MSDs	MSDs (46.39%); lower back (34.32%), knee (19.97%).	Conclusive
Lee et al. (2023) (52)	To understand the overall relationship between firefighting and cancer and provides an updated review of worldwide cancer risk among firefighters.	Chemical	Elevated cancer risks	Melanoma (SIRE=1.14), prostate (SIRE=1.09), testicular (SMRE=1.64).	Mixed
Di Nota et al. (2021) (31)	To identify published research on longitudinal coping outcomes among PSP and evaluate changes in coping over time with a meta-analysis.	Psychosocial	Adaptive/maladaptive coping	Small effect sizes (adaptive: d=0.18; avoidant: d=−0.12).	Inconclusive
Russell et al. (2023) (62)	To synthesize literature on the prevalence, incidence, and severity of occupationally-acquired infections in EMS clinicians and firefighters.	Biological	COVID-19, MRSA, Hep C	OR for COVID hosp.=4.23 (comparing EMS vs. firefighters).	Mixed
Beckett et al. (2023) (43)	to provide a reliable estimate of the pooled prevalence of MetSyn and its components, as well as the factors associated with MetSyn among firefighters.	Physical, Psychosocial	MetSyn and components	MetSyn (22.3%), hypertension (39.1%), obesity (35.6%).	Conclusive

Hwang et al. (2022) (53)	to estimate the elevated levels of urinary OHPAH among firefighters, evaluate potential risk attributions, assess the scope of preventive efforts, and determine their utility as a diagnostic	Chemical	Elevated urinary OHPAH levels	Elevated OHPAH (e.g., OHFLU ↑1.71×, $p < 0.0001$).	Conclusive
Alkholaiwi et al. (2022) (54)	To find the association between environmental and occupational exposures and chronic rhinosinusitis (CRS) development.	Chemical, Biological	CRS	OR=1.44 (smoking); dust and pesticide exposure.	Conclusive
Irizar et al. (2021) (32)	Determine international prevalence of hazardous and harmful alcohol use across trauma-exposed occupations. Compare prevalence across different occupations. Assess impact of measurement tools and geography. Explore associations with demographics and mental health.	Psychosocial	Alcohol use, comorbidities	Hazardous alcohol use (21.6%), harmful use (10.65%).	Conclusive
Díaz-Tamayo et al. (2022) (33)	To characterize the coping strategies used by first responders to emergencies in the face of exposure to traumatic events.	Psychosocial	PTSD, burnout, posttraumatic growth	Qualitative	Conclusive
Coenen et al. (2021) (34)	Identify work-related exposures associated with PTSD Quantify the extent to which such exposures contribute to PTSD	Psychosocial	PTSD	Combat exposure (OR=1.89), confrontation with death (OR = 1.63).	Inconclusive
Huang et al. (2022) (19)	To investigate and estimate the prevalence of sleep disorders and associated comorbidities among first responders for medical emergencies.	Psychosocial	SWD, OSA, insomnia, etc.	Strong links to PTSD (OR=1.78), depression (OR=9.74).Shift work disorder (31%), OSA (30%), insomnia (28%).	Conclusive

Hwang et al. (2021) (55)	To identify the association between PAH exposure levels and contributing risk factors to derive best estimates of the effects of exposure on structural firefighters' working environment in fire.	Chemical	Cancer incidence	Neck absorption highest (1.43×, $p < 0.001$); inhalation ↑20–40× with longer fire duration.	Conclusive
Khoshakhlagh et al. (2024) (44)	To explore the global prevalence of musculoskeletal disorders (MSDs) among firefighters using a systematic review and meta-analysis	Physical, Psychosocial	MSDs	MSDs (41%); lower back (31%), neck (9%).	Conclusive
Ledda et al. (2023) (56)	To evaluate the influence of occupational exposures on prostate cancer (PCa) risk	Chemical, Physical	Prostate cancer	Firefighting: OR=1.36–1.45; night shifts: OR=1.10–4.64.	Mixed
Kyron et al. (2021) (35)	To synthesize prospective studies identifying risk and protective factors for mental health and wellbeing among civilian emergency service personnel (ESP)	Psychosocial	PTSD, depression, burnout	Qualitative	Mixed
Khoshakhlagh et al. (2023) (45)	To determine the global prevalence of, and the factors associated with, sleep disorders and poor sleep quality among firefighters.	Physical, Psychosocial	Sleep disorder, poor sleep quality, PTSD, depression	Sleep disorders (30.49%), poor sleep quality (51.43%).	Conclusive
Wah et al. (2025) (57)	To conduct a systematic review and synthesis of the respiratory effects of fighting wildfires focusing on respiratory function, respiratory symptoms, airway inflammation and, where available, respiratory diseases.	Chemical	Reduced FEV1/FVC, asthma	14/19 studies show lung function decline.	Mixed
Ramezanifar et al. (2023) (61)	To investigate the effects of PPE on firefighters' HR, oxygen OC and BT.	Physical	Increased HR, OC, and BT	Boot weight ↑ OC by 3%–10% per kg.	Conclusive
Riddle et al. (2023) (36)	To review the known antecedents that put female workers at risk of sexual harassment in select male-dominated occupations and to identify gaps in the literature and opportunities for future occupational health nursing research	Psychosocial	Psychosocial hazards	Qualitative	Mixed

Garmon-Jones et al. (2023) (37)	To explore other factors contributing towards general mental health within the fire service and inform future research/interventions	Psychosocial	Burnout, depression, PTSD	Qualitative	Mixed
Barbosa et al. (2022) (58)	To evaluate the potential associations between firefighters' occupational exposure and their lung function deterioration.	Chemical	FEV1, COPD, asthma	FEV_1 (99.23%), FVC (103.08%).	Inconclusive
Murphy et al. (2022) (47)	To determine the injury epidemiology of law enforcement and firefighter recruits.	Safety-related	Medical injuries	Injury rates: 1.67–4.24/1000 days	Inconclusive
Teixeira et al. (2024) (59)	To characterize occupational chemical exposure at the firefront of wildland fires by identifying chemical agents, their concentrations, toxicological effects, and their consequences on the physiological effects and health status of firefighters	Chemical	Respiratory/cardiovascular diseases, cancer	PAHs, CO, PM2.5 exceeded OSHA limits; strong disease links.	Mixed
Wagner et al. (2021) (38)	To evaluate whether the prevalence of PTSD, major depressive disorder (MDD), and anxiety disorders (ADs) is elevated in firefighters exposed to large-scale disaster, and to synthesize predictive factors for these disorders.	Psychosocial	PTSD, depression, anxiety	PTSD (M=12.3%), MDD (M=18.7%).	Mixed
Cyniak-Cieciura et al. (2021) (39)	To verify temperament traits according to the Regulative Theory of Temperament as risk/protective factors of PTSD symptoms development. To examine moderators (e.g., gender, trauma type, study design) influencing PTSD-temperament relationships	Psychosocial	PTSD symptoms	Emotional reactivity (r=0.34).	Conclusive
Frost et al. (2021) (46)	To systematically review the effects of sleep on firefighter occupational performance and health	Physical, Psychosocial	Cognitive decline, cardiovascular disease	Qualitative	Mixed
Wesemann et al. (2022) (40)	To examine mental health outcomes of emergency service personnel exposed to terrorist attacks over time and identify risk and resilience factors.	Psychosocial	PTSD, MDD, anxiety	PTSD (1.3–16.5%), depression (1.3–25.8%).	Mixed

García-Iglesias et al. (2025) (41)	To identify the risk factors that contribute to burnout within firefighting teams and brigades. To uncover the protective factors that can serve as defense mechanisms against the development of this stress-induced condition. To explore how burnout manifests in team members after they have been exposed to various stressful events.	Psychosocial	Burnout, PTSD, resilience	Qualitative	Mixed

Appendix 4: General Characteristics of Included Studies

Author (Publication year)	Article Type	Study Population	Study Period Covered (Years included in Review)	Number of Included Studies (n)/sample Population Range	Geographic Coverage	Countries	Standardized Age / Age Range	Gender Distribution
Kang et al. (2025) (16)	SR	Firefighters	1972–2022	n=8 / 2289 to 32,301	International	United States (San Francisco, Chicago, Philadelphia), Europe, Canada, New Zealand, China	Not specified	Predominantly male
DeBono et al. (2023) (48)	MA	Firefighters	Till 2020	n=16 / Not mentioned	International	USA, Norway, Canada, Spain, France, Sweden, Denmark, Nordic, Australia, New Zealand, South Korea	Mean age: >55 years.	Predominantly male

Igboanugo et al. (2021) (63)	SR	Firefighters	Not reported	n=29 / 186 to 45,698	International	South Korea, US, Japan, Poland, Canada, United Kingdom, Portugal, Brazil	Not specified.	Both
Casjens et al. (2021) (49)	Both SR+MA	Firefighters	Till 2018	n=25 / 4 to 34796	International	USA, Canada, France, Sweden, Denmark, South Korea, Australia, New Zealand, Northern Europe	Not specified.	Male only
Kim et al. (2022) (30)	SR	Firefighters	Till 2021	n=66 / 86 to 45,698	International	Korea, USA, Denmark, France, Japan, Brazil, Switzerland, Finland, UK, China, India, Greece, Taiwan, Qatar, Germany	Age range: 20–60 years.	Predominantly male
Cuenca-Lozano et al. (2023) (20)	SR	Firefighters	2013–2022	n=15 / Not mentioned	International	Not reported	Not specified.	Predominantly male
Heydari et al. (2022) (42)	SR	Firefighters	Till 2018	n=31 / Not Mentioned	International	USA, Canada, Netherlands, Korea, Malaysia, Iran, Poland, UK, Italy, Belgium, Ghana, China,	Not specified.	Unspecified
Jahnke et al. (2024) (50)	Both SR+MA	Firefighters & other occupation	2009–2020	n=24 / 3 to 30057	International	U.S., Canada, France, Sweden, Denmark, Korea, Australia, New Zealand, Nordic region	Not specified.	Predominantly male

Laroche et al. (2021) (51)	SR	Firefighters	1959–2018	n=11/Not Mentioned	International	Canada, USA, UK, Australia, Iran, and European	Not specified.	Predominantly male
Tahernejad et al. (2024) (60)	Both SR+MA	Firefighters	2022	n=26 / 106 to 21466	International	Canada, South Korea, Cyprus, Finland, Iran, USA, Spain, Greece, Brazil, UK, Netherlands, and India	Not specified.	Predominantly male
Lee et al. (2023) (52)	MA	Firefighters	1978–2022	n=38 / Not Mentioned	International	US and non-US coutries	Mean age: 30–39.4 years (one study: 57 years).	Both
Di Nota et al. (2021) (31)	Both SR+MA	Firefighters & other first responders	2000–2019	n=10 / 11 to 744	International	Italy, Saudi Arabia, USA, Australia, e, New Zealand, India, Canada	Not specified.	Unspecified
Russell et al. (2023) (62)	SR	Firefighters & other first responders	2006–2022	n=25 / 52 to 22,647	Domestic	US	Mean age: 35–45 years.	Predominantly male
Beckett et al. (2023) (43)	Both SR+MA	Firefighters	1999–2023	n=25 / 47 to 6947	International	USA, Germany, Canada, South Korea, Iran, Turkey	Mean age: 40.8 ± 8.2 years.	Predominantly male
Hwang et al. (2022) (53)	Both SR+MA	Firefighters	1997–2021	n=27 / 6 to 242	International	U.S., Canada, Portugal, Finland, Sweden, Germany, Australia, Denmark, Norway, Netherlands	Not reported uniformly.	Predominantly male

Alkholaiwi et al. (2022) (54)	SR	Firefighters & other occupation	1989–2021	n=15 / 19 to 5848	International	China, Korea, Canada, Saudi Arabia, Denmark	Age range: 14–101 years (mean ~40).	Both
Irizar et al. (2021) (32)	MA	Firefighters & other occupation	2000–2020	n=55 / 36 to 8561	International	United States, United Kingdom, Canada, Australia, Norway, Germany, South Africa, Lebanon, Malawi, Nigeria, France, Switzerland	Mean age: 28–60 years.	Predominantly male
Díaz-Tamayo et al. (2022) (33)	SR	Firefighters & other first responders	Fist registry - 2022	n=31 / 38 to 658	International	USA, Canada, Australia, South Africa, Poland, China, Saudi Arabia, Korea, Greece, Spain, Portugal, Switzerland, France, Germany, Hungary	Age range: 20–62 years.	Predominantly male
Coenen et al. (2021) (34)	Both SR+MA	Firefighters & other occupation	2005–2019	n=33 / 19 to 2,549,949	International	USA, UK, Denmark, Japan, Israel, Netherlands, Germany, Portugal, Italy, Norway, Korea	Age range: 18–65 years.	Predominantly male

Huang et al. (2022) (19)	MA	Firefighters & other first responders	2002–2022	n=28 / 21 to 51,149	International	USA, Canada, Italy, South Korea, Australia, Poland, China, Ecuador, Brazil, France, Ethiopia, India	Mean age: 26.6–52.8 years.	Predominantly male
Hwang et al. (2021) (55)	Both SR+MA	Firefighters	1997–2020	n=20 / 4 to 53	International (High Income countries)	USA, Canada, Sweden, Denmark, UK, Netherlands, Finland, France, Australia	Not specified.	Predominantly male
Khoshakhlagh et al. (2024) (44)	Both SR+MA	Firefighters	Till 2022	n=31 / 39 to 31,743	International	USA, Canada, South Korea, Iran, Brazil, Greece, Netherlands, Finland, Cyprus, Poland, France, UK, Australia, New Zealand, China	Age range: 19–59 years.	Predominantly male
Ledda et al. (2023) (56)	SR	Firefighters & other occupation	Not reported	n=11 / Cases ranged from 114 to 1933; Controls ranged from 400 to 63,912	International	US, Canada, Spain, France, Australia	Not specified.	Male only
Kyron et al. (2021) (35)	SR	Firefighters & other first responders	1960–2020	n=66 / 25 to 16488	International	US, Australia, Netherlands, Canada	Not specified.	Unspecified

Khoshakhlagh et al. (2023) (45)	Both SR+MA	Firefighters	2000–2022	n=47 / 23 to 51,149	International	USA, South Korea, Brazil, Iran, Australia, Canada, Finland, France, Poland, Greece, Thailand, Turkey	Age range: 18–82 years (mean: 33–44).	Both
Wah et al. (2025) (57)	SR	Firefighters & other first responders	Till 2024	n=26 / 17 to 1,234	International	US, Canada, Portugal, Thailand, Greece, Israel, France, and Italy	Age range: 25–60 years.	Predominantly male
Ramezanifar et al. (2023) (61)	SR	Firefighters	2010–2021	n=18 / 7 to 50	International	USA, Australia, South Korea, Iran, Spain, UK, Canada	Not specified.	Predominantly male
Riddle et al. (2023) (36)	SR	Firefighters & other occupation	1980–2020	n=25 / 21 to 2531	Domestic	US	Not specified.	Predominantly male
Garmon-Jones et al. (2023) (37)	SR	Firefighters	Not reported	n=10 / 27 to 6307	International	UK, USA, Brazil, Canada, Australia	Age range: 21–51 years (mean: 32.8–49.7).	Predominantly male
Barbosa et al. (2022) (58)	MA	Firefighters	1990–2021	n=24 / 17 to 2043	International	USA, Portugal, Greece, Netherlands, Denmark, Switzerland, Croatia, Australia, Taipei (Asia), Sardinia, Corsica	Age groups: 20–30 (30%), 31–40 (35%), >40 (35%).	Unspecified
Murphy et al. (2022) (47)	SR	Firefighters & other occupation	Inception-2021	n=8 / 169 to 1423	International	Israel, USA, Australia, China, New Zealand.	Mean age: 18.7–27.3 years (2 studies).	Both

Teixeira et al. (2024) (59)	SR	Firefighters	1993–2023	n=41 / Not Specified	International	USA, Australia, Portugal	Not specified.	Unspecified
Wagner et al. (2021) (38)	SR	Firefighters	1980–2017	n=22 / 36 to 9715	International	USA, Australia, Netherlands, Malaysia, Kuwait, Taiwan, Japan, Norway	Not specified.	Predominantly male
Cyniak-Cieciura et al. (2021) (39)	MA	Firefighters & other occupation	1999–2019	n=19 / 17 to 550	Domestic	Poland	Age range: 13–85 years.	Both
Frost et al. (2021) (46)	SR	Firefighters	1996–2021	n=15 / 10 to 705	International	Australia, US, Canada, Japan, Korea	Not specified.	Predominantly male
Wesemann et al. (2022) (40)	SR	Firefighters & other first responders	Till 2021	n=33 / 28 to 28232	International	US, Germany, France, Spain, Iraq	Mean age: 35–42 years.	Predominantly male
García-Iglesias et al. (2025) (41)	SR	Firefighters	2014–2024	n=34 / 40 to 18936	International	China, United States, France, Poland, Portugal, Korea, Greece, Romania, Iran, Russia, Brazil, Turkey, Kazakhstan	Not specified.	Unspecified

Appendix 5: Evidence Mapping of Mental & Psychological Exposures and Key Findings

Most Documented Mental & Psychosocial Exposure	Related Health Outcomes	Number of Studies & Type	Strength of Evidence	Key Findings
Repeated exposure to trauma, PPTEs, indirect trauma	PTSD, anxiety, depression	MA (n=1); (n=1); SR (n=3)	Moderate: Conclusive, n=2 (33,39); Mixed, n=2 (38,40); Inconclusive, n=1 (34).	PTSD prevalence ranged from 0.9%–32.5% (38); OR for combat trauma 1.89 (34); trauma exposure linked to PTSD, anxiety, depression (40); nonadaptive coping linked with negative mental health (33).
Psychosocial stressors, job strain, organizational pressure	Burnout, depression, suicidal ideation, alcohol use	MA (n=1); SR (n=3)	Strong: Conclusive, n=2 (32,63); Mixed, n=2) (36,41).	Job stress linked to burnout, depression, alcohol use disorders (63); Hazardous Alcohol Use (Overall), 21.6% (32) increased risk of burnout (41).
Sleep disturbances, shift work, fatigue	Burnout, cognitive decline, mental distress, sleep disorders	SR (n=3); Both SR+MA (n=1); MA (n=1)	Strong: Conclusive, n=2 (19,45); Mixed, n=3) (37,42,46).	Burnout and poor mental health linked to poor sleep and occupational stress (37); cognitive decline with chronic poor sleep, poor sleep negatively impact cognitive performance and health (46). Sleep disorders: Insomnia 28%, SWD 31%, OSA 30 % (19).
Coping strategies (adaptive vs avoidant), social support	PTSD symptoms, depression, resilience	Both SR+MA (n=1); SR (n=2)	Moderate (Conclusive, n=1 (33); Mixed, n=1(35); Inconclusive, n=1(31).	Adaptive coping slightly improved outcomes (d = 0.18); avoidant coping linked to worse outcomes (d = -0.12) (31); resilience protective against stress (35); nonadaptive coping linked with negative mental health outcomes (PTSD and burnout) (33).
Organizational culture; gender composition; workplace relationships; job physicality; harassment remedies	psychosocial hazards specifically, sexual harassment	SR= 1	Conclusive, n=1 (36).	Psychosocial hazards-specifically, sexual harassment.

Appendix 6: Evidence Mapping of Chemical Exposures and Key Findings

Most Documented Chemical Exposure	Related Health Outcomes	Number of Studies & Type	Strength of Evidence	Key Findings
PAHs, Benzene, Diesel Exhaust and other carcinogenic substances	Cancer (mesothelioma, bladder, testicular, melanoma, prostate), elevation in urinary OHPAH and other carcinogenic risk	MA (n=2); Both SR+MA (n=4); SR (n=5)	Strong: Conclusive, n=3 (48,53,55); Mixed, n=8 (16,20,50–52,56,59,65).	Elevated risks: mesothelioma (SIR=1.46), bladder (mSMR=1.72 (65), prostate (SIRE=1.21 (50), testicular (RR =1.37 (48), melanoma (SIRE=1.61 (50).
VOCs, Formaldehyde, PM2.5/PM10	Respiratory (lung function decline, inflammation)	SR (n=2); MA (n=1)	Moderate: Mixed, n=2 (57,59); Inconclusive, n=1 (58).	Reduced lung function (FEV1/FVC), respiratory symptoms like asthma (57,58); consistent inflammation biomarkers (59)
Fire smoke components (benzene, CO, acrolein)	Respiratory, cardiovascular, cancer	Both SR+MA (n=2); SR (n=2)	Moderate: Conclusive, n=3 (53–55); Mixed, n=1 (59).	Elevated OHPAHs post-fire (OHFLU 1.71× (53); Chronic rhinosinusitis (CRS) (54), increased cancer risk (55,59); and respiratory outcomes (59).
PFAS, asbestos	Cancer (prostate, testicular, colon, mesothelioma, thyroid, melanoma)	MA (n=2), Both SR+MA (n=1); SR (n=1)	Moderate: Conclusive, n=1 (48); Mixed, n=3 (50,52,56).	Increased cancer risk such as prostate (48,50,52,56) testicular, colon, mesothelioma, melanoma, bladder, skin, kidney (48,50,52).
Mixed chemical agents (BTX, soot, metals)	General cancer, indirect psychological strain	SR (n=2)	Limited: Mixed, n=2 (16,20).	Increased lung cancer risk (16), exposure-response inconsistent; also linked to organizational and perception-related stressors (20).

Appendix 7: Evidence Mapping of Physical Exposures and Key Findings

Most Documented Physical Exposure	Related Health Outcomes	Number of Studies & Type	Strength of Evidence	Key Findings
Ergonomic risks, physical exertion	Musculoskeletal Disorders (MSDs): back, neck, shoulder, knee	MA (n=2); Both SR+MA (n=1);	Strong: Conclusive, n= 2 (44,60); Mixed, n=1 (20).	Increased MSD (20,44,60), MSD prevalence ~46.4%, body-specific pain: back 34.3%, neck 18.4% (60); pooled MSD=41%, body-specific pain: back 31%, neck 9% (44).
MSDs and disrupted sleep, fatigue, poor sleep quality	Sleep disorders, Cognitive decline, cardiovascular, injuries, burnout	Both SR+MA (n=1) SR (n=1)	Strong: Conclusive, n=1(45); Mixed, n=1 (46).	sleep disorder 30.5 %, poor sleep quality 51.4% (45), Sleep quality affects long-term health/cognition; unclear on short-term performance (46).
Physical stress and physically demanding tasks, emergency duties	Metabolic syndrome, obesity, hypertension	Both SR+MA (n=1)	Moderate–Strong: Conclusive, n=1(43).	Higher prevalence MetSyn 22.3%, obesity 35.6%, hypertension 39.1% (43).
Fitness, BMI, workload, resilience factors	Injury, resilience, physical performance	SA (n=1)	Mixed (Conclusive on physical fitness/injury; mixed on psychological).	Fitness protects against injury; resilience a key positive predictor (42).
PPE Use	Increased physiological stress including HR, OC, and body temperature BT	SR, (n=1)	Moderate: Conclusive, n=1 (61).	Boot weight increased OC by 3%–10% per kg (61).

Appendix 8: Summary of Subgroup Analyses in Reviewed Studies

Author	Subgroup Analysis	Subgroup Domains Examined	Firefighter Type Differences	Gender-Based Differences	Age-Related Trends	Other Job-Related Factors	Working Conditions
Kim et al. (30)	Yes	Firefighter Type, Gender	EMS personnel had higher PTSD risk than administrative personnel (OR 3.68; CI 1.47–9.23).	Higher female mortality (8 of 12 non-cancer disease categories) including circulatory (SMR 2.49 vs 0.69), respiratory (SMR 4.35), suicide (SMR 2.52 vs 0.55).	Not examined	Rank, years of service	Emergency response duties.
Cuenca-Lozano et al (20)	Yes	Volunteer vs Career Firefighter, Gender, Age	Volunteers had lower risk perception.	Higher rates of problematic alcohol use in females.	Older age linked to higher injury risk.	Equipment weight increases fatigue & fall risk.	Not examined
Heydari et al. (42)	Slightly Yes	Age	Not examined	Women potentially at higher injury risk.	Older age → higher injury/health risks.	Not examined	Sleep disorders, shift work, stress.
Jahnke et al. (50)	Yes	Region	Not examined	Not examined	Not examined	Regional variations between US and non-US firefighters (e.g., PPE use, tactics).	Not examined

Di Nota et al. (31)	Slightly Yes	Gender, Other	Not examined	Meta-regression tested sex effect, but specific results are not detailed.	Not examined	PSP categories used, no significant differences found.	Not examined
Russell et al. (62)	Yes	EMS vs Firefighters	EMS had higher infection/COVID-19 risks.	Not examined	Not examined but mentioned about one study: age ↑ hospitalization/mortality .	Not examined	Not examined
Beckett et al. (43)	Slightly Yes	Age	Professional firefighters mainly; no data on volunteers.	Not examined	Older age → higher MetSyn prevalence (not sig., meta-regression (p = 0.403)	Higher BMI → ↑ MetSyn prevalence	Shift work/lifestyle noted
Hwang et al. (53)	Yes	Structural Firefighters (FF) vs Wildland FF	Structural FFs: higher urinary OHPAHs (e.g., 11.11× for OHPYR).	Not examined	Not examined	Activity duration (>30 min) ↑ OHPAHs	Live training > emergency in exposure
Alkholaiwi et al. (54)	Yes	Firefighter vs Other Blue-Collar	FFs had highest CRS association.	Not examined	Not examined	Not examined	Not examined
Irizar et al. (32)	Yes	Armed Forces vs First Responders	Armed Forces highest harmful alcohol misuse	higher proportion of males was significantly associated with higher hazardous alcohol use.	Younger age → more harmful alcohol use.	Not examined	Not examined

		vs Care Workers	(34%), FFs 26%, healthcare 13%.				
Huang et al. (19)	Slightly Yes	Gender, Age	Not examined	Males: more sleep issues; Females: more insomnia/EDS.	OSA ↑ with age	Not examined	Shift and night shifts impactful.
Hwang et al. (55)	Slightly Yes	Instructor vs Trainee	Instructors ↑ PAH exposure (repeated sessions).	Not examined	Not examined	Fuel type (e.g., particle board) ↑ PAHs.	Region: North America stricter EPA/NIOSH protocols than EU.
Khoshakhlagh et (44)	Yes	Age	Not examined	Not examined	<39 yrs: 50% MSD; ≥39: 34%.	Years of service	Shift work, PPE use, Region: Middle East ↑ MSD (54%) vs Europe/North America (42%).
Ledda et al. (56)	Slightly Yes	Age	Not examined	Not examined	Prostate cancer risk ↑ with stress < age 65.	Chemical exposures (e.g., pesticides).	Night shifts, UV exposure.
Khoshakhlagh et al. (45)	Slightly Yes	Gender	Not examined	Males: 36% sleep disorder; Females: 20.4%.	Not significantly associated (p = 0.725)	PTSD, depression linked to sleep issues.	HIC vs. LMIC: Sleep disorders: LMICs: 41.17%) vs. HICs: 29.48% Poor sleep quality: Higher in HICs (55.83%) vs. LMICs (40.85%).

Ramezanifar et al. (61)	Slightly Yes	Gender	Not examined	Women: lower OC	Not examined	Not examined	Weather, activity types (hiking, rescue) impact physiology.
Garmon-Jones et al. (37)	Slightly Yes	Career vs Auxiliary	Career FFs ↑ psychological distress.	Not examined	Older age/service ↑ distress.	Years of service, alcohol use.	Shift disorder → burnout, mental health.
Barbosa et al. (58)	Yes	Wildland vs Urban	No significant difference.	Not examined	Older FFs ↑ FEV_1 (not sig.).	Not examined	Australia ↑ FEV_1 vs Europe, NA, Asia.
Frost et al. (46)	Yes	Wildland vs Urban	Wildland focus; urban underrepresented.	Not examined	Not examined	Not examined	Long shifts ↓ sleep, sleeping environment.
Weseman n et al. (40)	Yes	Firefighter vs Police, Age	FFs ↑ PTSD (14.3% vs 7.2%); Police ↑ hostility.	Women ↑ PTSD (15.5% vs 10.3%).	Older age ↑ PTSD risk	Not examined	Social isolation ↑ PTSD.
García-Iglesias et al. (41)	Yes	Volunteer vs Career, Age	Career FFs ↑ burnout.	Not examined	Middle-aged (35–55) ↑ burnout.	Rank, Years of service	Night/rotating shifts, org. demands, family duties ↑ burnout.

Résumé

Titre: Explorer les impacts du métier de pompier sur la santé: une revue de la littérature exploratoire.

Contexte: Les pompiers sont exposés à un large éventail de risques professionnels, incluant des dangers chimiques, physiques, biologiques, psychosociaux et liés à la sécurité, les exposant à des effets néfastes sur la santé. De plus, leurs rôles opérationnels vont souvent au-delà de la lutte contre les incendies pour inclure les services médicaux d'urgence, les opérations de sauvetage et les interventions de sécurité publique, élargissant ainsi le champ des expositions professionnelles au-delà du contexte incendie. Bien que ces risques aient été étudiés, les preuves restent éparses et manquent souvent d'analyses spécifiques par sous-groupes et de perspectives contextuelles plus larges.

Objectif: Cette étude visait à cartographier et à synthétiser systématiquement les connaissances existantes sur les risques professionnels pour la santé des pompiers, à identifier les lacunes de la recherche et les variations selon les sous-groupes.

Méthodes: Une recherche approfondie a été menée dans PubMed et Scopus en suivant le cadre méthodologique d'Arksey et O'Malley ainsi que les directives PRISMA-ScR. La revue a inclus uniquement les revues systématiques et méta-analyses publiées en anglais entre 2021 et 2025. Les données ont été extraites selon le type d'exposition, les effets sur la santé, les caractéristiques de la population (y compris les données démographiques), et les variations selon les sous-groupes (âge, genre, rôle professionnel — par exemple, pompier volontaire vs professionnel, ou pompier vs autres professions).

Résultat: Cette revue a inclus un total de 37 études. Selon les résultats, les expositions psychosociales, chimiques et physiques étaient les risques professionnels les plus fréquemment étudiés. Le cancer, les troubles musculo-squelettiques (TMS) et les troubles du sommeil figuraient parmi les effets les plus fréquents et bien documentés, en particulier chez les pompiers professionnels exposés à des agents cancérigènes, au travail posté, à des efforts physiques répétitifs et à des contraintes physiques. Les risques biologiques, les dangers liés à la sécurité et les effets positifs sur la santé étaient peu explorés. Les analyses selon les caractéristiques démographiques et les rôles professionnels étaient rares et souvent incohérentes.

Conclusion: Cette revue a mis en évidence des lacunes prioritaires en matière de risques spécifiques aux sous-groupes, de diversité géographique et d'indicateurs de santé positifs. Les recherches futures devraient cibler des populations diversifiées, adopter des définitions standardisées de l'exposition et approfondir les analyses de vulnérabilité des sous-groupes afin de soutenir des politiques de santé professionnelle fondées sur des preuves pour les pompiers.

Mots-clés: Santé au travail, Exposition professionnelle, Pompier.