INSTITUTO POLITÉCNICO DE LISBOA

ESCOLA SUPERIOR DE TECNOLOGIA DA SAÚDE DE LISBOA

EXTREME WEATHER EVENTS, OCCUPATIONAL HAZARDS IN FIRE SITUATIONS AND THE IMPLICATIONS FOR FIREFIGHTERS' RESPONSIVENESS: A SYSTEMATIC REVIEW

Sandra Paula dos Santos Braço Forte

Orientador: Prof. Vítor Manteigas

Mestrado em Segurança e Higiene no Trabalho

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“Perfection is not achieved, but it is pursued”

Taichi Ohno

Abstract

The biggest topic of our time is climate change, and humanity is at a defining moment. The impacts of climate change are global in nature and unparalleled in scale, from changing weather patterns that threaten food production to increasing sea levels that raise the risk of catastrophic flooding. The number of firefighting interventions is growing because of the extreme climatic events triggered by global climate change. The spike in extremes affects not just the conditions of the interventions, but also the interveners and the firefighters themselves. It is also necessary to tackle the investigation of the latter in order to preserve or improve the efficacy of interventions. Therefore, the aim of this study is to identify the occupational risks, namely of Firefighters, in exposure to extreme weather events, climate change and the consequences for the physical and psychological health of this professional class, both in the present and posteriorly.

This study reports the search of available data published regarding extreme weather events, occupational hazards in fire situations and the implications for firefighters' responsiveness, following the PRISMA methodology.

Regarding the analysis of the results, it is possible to highlight that the highest risk of occupational exposure was observed in the exposure to wood smoke. Regarding occupational hazards, several hazards associated with health threats, such as exposure to toxic chemicals, shift work, extreme heat, physical and emotional strain were identified. Concerning the time of exposure, most studies refer to workshifts and years of activity. Sampling devices and records/interviews were the most common sampling strategies used in these studies, and the most common health outcome reported were oxidative stress and mental health damage.

Climate change is becoming more evident all over the world as time goes by and that fires are the top natural disaster that is definitely affecting firefighters. This systematic review also reinforces the need to assess extreme weather events, occupational hazards in fire situations and the implications for firefighters' responsiveness all over the world, since there is a lack of research regarding such important matter.

Keywords: Firefighters; Fireman; Extreme Weather Events; Occupational exposure and Climate change.

Resumo

O maior tema do nosso tempo é a mudança climática, e a humanidade encontra-se num momento decisivo. Os impactos das alterações climáticas são de natureza global e sem paralelo em escala, desde a alteração dos padrões climáticos que ameaçam a produção alimentar até ao aumento do nível do mar que aumenta o risco de inundações catastróficas. O número de intervenções de combate a incêndios está a aumentar devido aos eventos climáticos extremos desencadeados pelas alterações climáticas globais. O pico nos extremos afecta não só as condições das intervenções, mas também os intervenientes e os próprios bombeiros. É igualmente necessário abordar a investigação destes últimos, a fim de preservar ou melhorar a eficácia das intervenções. Portanto, o objectivo deste estudo é identificar os riscos profissionais, nomeadamente dos bombeiros, na exposição a eventos climáticos extremos, alterações climáticas e as consequências para a saúde física e psicológica desta classe profissional, tanto no presente como posteriormente. Este estudo relata a pesquisa de dados disponíveis publicados sobre eventos meteorológicos extremos, riscos ocupacionais em situações de incêndio e as implicações para a capacidade de resposta dos bombeiros, seguindo a metodologia PRISMA. Quanto à análise dos resultados, é possível destacar que o maior risco de exposição profissional foi observado na exposição ao fumo da madeira. Relativamente aos perigos profissionais, foram identificados vários perigos associados a ameaças à saúde, tais como exposição a produtos químicos tóxicos, trabalho por turnos, calor extremo, tensão física e emocional. Relativamente ao tempo de exposição, a maioria dos estudos refere-se a turnos de trabalho e anos de actividade. Os dispositivos de amostragem e os registos/entrevistas foram as estratégias de amostragem mais comuns utilizadas nestes estudos, e os resultados de saúde mais comuns comunicados foram o stress oxidativo e os danos para a saúde mental. As alterações climáticas estão a tornar-se mais evidentes em todo o mundo à medida que o tempo passa e que os incêndios são o principal desastre natural que está definitivamente a afectar os bombeiros. Esta revisão sistemática também reforça a necessidade de avaliar os eventos climáticos extremos, os riscos profissionais em situações de incêndio e as implicações para a capacidade de resposta dos bombeiros em todo o mundo, uma vez que existe uma falta de investigação sobre um assunto tão importante

Palavras-chave: Bombeiros; Bombeiro; Eventos climáticos extremos; Exposição ocupacional e mudanças climáticas.

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Abbreviations

CFCs – Chlorofluorocarbons

CO - Carbon monoxide

EMA - Emergency Management Agency

NGOs - Non-Governmental Organizations (American Red Cross)

NIOSH - National Institute for Occupational Safety and Health

NOAA - National Oceanic and Atmospheric Administration

PAH’s - Polycyclic Aromatic Hydrocarbons

PM - Particulate matter

PRISMA - Preferred Reporting Items for Systematic Reviews and Meta-Analysis

PROCIV – Proteção Civil

PSTD - Post-Traumatic Stress Disorder

QUOROM - Quality Of Reporting Of Meta-analyses

RET - Repeated Exposure to Trauma

1. Chapter I: Introduction

The Earth's climate has been evolving since it was formed 4.5 billion years ago. Natural causes, such as volcanic eruptions, changes in the Planet's orbit and variations in the surface of the Earth (known as plate tectonics), have until recently been the cause of these changes. The Planet has undergone a sequence of ice-ages ('glacial periods') and warmer periods ('interglacial') over the past one million years. Owing to shifts in the Earth's orbit around the sun, glacial and interglacial cycles cycle about every 100,000 years (1).

The Planet has been in an interglacial phase with a steady temperature for the last few thousand years. The global temperature has however, risen at a much faster pace since the Industrial Revolution in the 1800s. Human action has rapidly become the leading cause of changes to our atmosphere by burning fossil fuels and changing how we use the earth (1).

The objective of the study is to identify the occupational risks, namely of Firefighters, in exposure to climate change and the consequences for the physical and psychological health of this professional class, both in the present and posteriorly.

1.1. Climate Change

Climate change has always been present in our planet and these changes exposed a healthy seasonality before the emergence of technical and efficient instruments created by man. Production processes had to use energy sources, such as oil, coal, and, currently, biofuels progressively, with the advent of industrialization (2).

In the Earth's atmosphere, certain molecules trap heat and stop it from escaping into space are called 'greenhouse gases'. These emissions, known as the greenhouse effect', serve as a warming blanket around the World. Greenhouse gases derive from natural and human sources. In the atmosphere, gases like carbon dioxide, methane and nitrous oxide exist naturally. Other compounds, such as chlorofluorocarbons (CFCs), which are produced solely by human activity, are carbon-based compounds containing chlorine and fluorine, which are responsible for reducing the ozone layer and were historically used in aerosols and gases for cooling systems, and are currently banned for use in several countries (1).

Man produces greenhouse gases harmful to the atmosphere, in various ways and in various activities, which cause radical climate changes, such as the use of fossil fuels like oil, gas and coal, which contain carbon and which is submerged in the soil for thousands of years, when they are removed from the earth and burned, they are released into the atmosphere. Also, the fact that there is more and more deforestation, that same carbon dioxide that was absorbed by the forests, accumulates, with the aggravation that the carbon that the trees absorb, when they are burned, they release it and will join the existing one (1).

Although agriculture and animal husbandry are essential for human survival, they release many different types of gases into the atmosphere, which will also cause the greenhouse effect, such as the case of methane produced by animals, which is 30 times more powerful than carbon dioxide, or the case of nitrous oxide used in fertilizers which is ten times more harmful and almost three hundred times worse than carbon dioxide. In addition to these productive causes of greenhouse gases, we also have the production of cement that contributes to 2% of carbon dioxide emissions, which contributes negatively to these climate changes (1).

The biggest topic of our time is climate change, and humanity is at a defining moment. The impacts of climate change are global in nature and unparalleled in scale, from changing weather patterns that threaten food production to increasing sea levels that raise the risk of catastrophic flooding. Adapting to these impacts in the future would be more complicated and expensive without a drastic action now(2).

Climate change has raised the danger to the health and safety of employees. Workers are at increased risk of heat stress and other heat-related illnesses, occupational injuries, and reduced productivity at work, especially those who work outdoors or in hot indoor environments. To quantify and evaluate the occupational heat exposure of employees and the risk of heat-related disorders, a number of approaches have been developed (3).

Furthermore, increased ambient temperatures can increase the exposure of workers to dangerous chemicals and the adverse health effects of chemicals. The spread of weeds, insect pests and diseases would be influenced by global warming and new pests will be introduced, both of which will alter the types and quantities of pesticides used thus affecting the health of farm workers and others (3).

Scientists can also forecast region-specific hazards, such as increased frequency, duration, and intensity of severe weather events (such as heat waves, worse air pollution, and evolving regional trends of vector-borne diseases), in addition to global threats (4).

The US National Institute for Occupational Safety and Health (NIOSH) identified how these modifications are likely to affect the exposure of workers to hazards (5,6). Most outdoor workers (especially those in construction, agriculture and tourism), emergency and recovery response (firefighters), workers in the fishing-and-forestry, utility-delivery, and transportation sectors, are specific categories of workers expected to be particularly affected. (3)

In several ways, climate change is influencing human lives and health. It threatens the basic ingredients of good health - clean air, healthy drinking water, the provision of nutritious food and safe shelter - and has the potential to undo decades of global health progress. Climate change is projected to cause nearly 250,000 additional deaths annually between 2030 and 2050, from malnutrition, malaria, diarrhea and heat stress alone. By 2030, the cost of direct harm to health is expected to be between USD 2-4 billion per year (7).

A new area of climate science research arose in the early 2000s, which started to investigate human fingerprints in severe weather events such as floods, heatwaves, droughts and storms (8).

Many people around the world have woken up to a bleak fact last decade: climate change is here it is happening now, and it could get much worse, very quickly. According to Borunda (2020), a series of lethal, dramatic, devastating events punctuated in the last 10 years. The neighborhoods they barreled into were profoundly altered by hurricanes such as Sandy, Maria, and Harvey, leaving behind wounds that have yet to heal. Greater and stronger heat waves suffocated populations across the country and around the world (9).

Extreme weather can have a significant effect on society. During the summers of 2003 and 2010, Europe and parts of Russia suffered unprecedented heat waves. Germany, Hungary, and other nations were devastated by record-breaking floods in 2013. The United Kingdom endured a series of catastrophic floods across the nation during the summer of 2007, so that defenses were overwhelmed. These brief examples show that extreme weather can affect lives and livelihoods, farming, habitats, and cause property damage and loss of life on a large scale (10).

These examples also show the need for adaptation to today's climate variability, regardless of the nature of any patterns. Extreme weather occurrences are seen, as a part of everyday life in which communities have learned to cope and adapt to some degree. However, it is a crucial question whether increases in such natural events occur along with a warming world (10).

1.1.1. The most frequent extreme weather events

Scientists have published more than 300 peer-reviewed studies looking at extreme weather around the world, from wildfires in Alaska and hurricanes in the Caribbean to flooding in France and heatwaves in China. The result is mounting evidence that human activity is raising the risk of some types of extreme weather, especially those linked to heat. Every extreme-weather attribution study conducted to date was mapped by Carbon Brief, to track how the evidence on this fast-moving subject is stacking up (8).

Carbon Brief is a website based in the United Kingdom which covers the latest developments in climate science, climate and energy policy. In order, to enhance the understanding of climate change, both in terms of science and policy response, they specialize in simple, data-driven papers and graphics. They publish a wide variety of content as well as regular and weekly email summaries of newspapers and web coverage, including science explanators, interviews, research and fact checks (8).

The review study made by Carbon Brief (2020) revealed that of the 355 extreme weather events and patterns included in the map that they create, 69% were found to be made more likely or more severe by climate change caused by human. Nine percent of events have become less likely or less severe due to climate change, which means that 78% of all events have suffered some human impact. The remaining 22% of events showed no discernible human influence or were inconclusive. Heatwaves account for 47% of such occurrences, while 15% are made up of droughts and heavy rainfall or floods (8).

Of the 125 attribution studies that looked at extreme heat across the world, 93% found that the occurrence or pattern was more probable or more serious due to climate change. 54% discovered human activities had made the incident more likely or more serious for the 68 studies looking at rainfall or flooding. It's 61%, for the 61 drought events studied. This study was first released in July 2017, and that is the third edition to incorporate new studies. The goal is to serve as a tracker for the emerging 'extreme event attribution' sector. The literature is heavily dominated by studies of extreme heat (35%), rainfall or floods (19%) and drought (17%), integrating the data from the past 20 years. These together make up more than two-thirds (72%) of all published studies (8).

1.1.1.1. Drought

A drought is seen by most individuals as a time of exceptionally dry weather that lasts long enough to cause problems such as crop damage and scarcity of water supply. But since, for various reasons, dry conditions grow, there is more than one concept of drought. "Drought is caused not only by a lack of precipitation and high temperatures, but also by overuse and overpopulation", said David Miskus, a drought expert and meteorologist at the Climate Prediction Center of the National Oceanic and Atmospheric Administration (NOAA) (11).

There are four major drought categories, namely: (i) meteorological drought, depending on the amount of annual precipitation that is the norm for that location, and it is unique to different regions; (ii) Agricultural drought, accounts for the water needs of crops during different growing cycles. For instance, not enough moisture at planting time can hinder germination, leading to low plant populations and a reduction in yield. In rivers, lakes, and reservoirs; (iii) Hydrological drought refers to water levels that are persistently low; (iv) Socioeconomic drought happens when the water demand exceeds the supply. Examples of this form of drought are too much irrigation or when low river flow forces hydroelectric power plant operators to reduce energy production. (11).

Higher temperatures contribute to higher evaporation rates, including a greater loss of moisture from plant leaves. These increases in surface evaporation and loss of water from plants, even in areas where precipitation does not decrease, contribute to faster soil drying if the effects of higher temperatures are not compensated by other improvements (such as decreased wind speed or increased humidity). When the soil dries out instead of evaporating its moisture, a greater proportion of the incoming heat from the sun goes into heating the soil and surrounding air, resulting in hotter summers under drier climate conditions (12).

An example of the recent drought occurred in 2011, when there were more than 100 days above (37.8ºC) in several areas in Texas and Oklahoma. Since record keeping started in 1895, both states have set new records for the hottest summer. Water loss rates, due partly to evaporation, were twice the long-term average. Water supplies were

exhausted by heat and drought and led to over $10 billion in direct losses to agriculture alone (12).

In parts of the northern hemisphere, the exceptionally hot and dry summer has turned fields and forests into fuel for fires that are raging from the Arctic to North America's Mediterranean and West Coast. These wildfires have caused thousands of deaths and are destroying large areas, with far-reaching effects on the climate, ecosystems, human health and the environment. The world's northern portion is warming faster than the earth as a whole. The heat makes forests dry out and more vulnerable to fire. A new study found that in at least 10,000 years, the Earth's boreal forests are now burning at a pace unheard. Owing to above normal temperatures and drought, Southern Europe had a very active fire season in 2017. Spring and early summer 2018, by comparison, saw below average temperatures and relatively high precipitation. (13).

Climate change can affect droughts in a different way. One is if precipitation were to change due to climate change, then droughts would undoubtedly change. The other is if the evaporative demand of the atmosphere were to change, then droughts could change even if there were no long-term change in precipitation. And that is what it has been seen in western North America, where in the last century, big trends in precipitation were not observed. In terms of whether or not, climate models simulate changes in precipitation as a result of growing greenhouse gases in the atmosphere and they are all over the place (14).

1.1.1.2. Flooding

Floods are the most common form of natural disaster and occur when land that is normally dry is flooded by an overflow of water. Heavy rainfall, rapid snowmelt or a storm surge from a tropical cyclone or tsunami in coastal areas are also the cause of floods.

There are 3 different flood types:

- **Flash floods** are caused by sudden and heavy rainfall, which rapidly increases water heights and can overwhelm rivers, streams, channels or roads.

- **River floods** are triggered when a river is pushed to reach capacity by consistent rain or snow melt.

- **Coastal floods** are caused by storm surges associated with tsunamis and tropical cyclones.

During the past 10 years, about 80-90% of all recorded natural hazard disasters have resulted from floods, droughts, tropical cyclones, heat waves and extreme storms. Floods are now rising in frequency and severity, and due to climate change, the frequency and intensity of extreme precipitation is projected to continue to grow (15).

In many U.S. regions, flooding can worsen, including in areas where total precipitation is expected to decline. Any high flow, overflow, or flooding by water that causes or threatens damage is known as a flood. Both weather and human related factors, are triggered or exacerbated by floods. Heavy or prolonged flooding, snowmelt, thunderstorms, storm surges from hurricanes, and ice or debris jams are major weather influences. Human factors include dam and levee structural defects, altered drainage, and alterations in land-cover (such as pavement) (12).

Floods can have significant environmental effects in addition to economic and social disruption, for example when facilities containing large amounts of hazardous chemicals are inundated. It is likely that the coming decades will see a higher risk of flooding in Europe and greater economic harm (16).

According to Bernardini, between 2002 and 2006, over 100 significant damaging floods have occurred in Europe, including the devastating floods along the Danube and Elbe rivers in the summer of 2002, in the northern Caucasus in July and August 2002, in the Alps in the summer of 2005 and along the Danube in the spring of 2006. Since 2000, at least 700 deaths have been caused by floods in Europe, about half a million people have been displaced and at least EUR 25 billion in insured economic losses have been caused. Some regions were affected more than others. Between 1998 and 2005, the highest concentrations of recurrent flooding occurred in northwestern Romania, southeastern France, central and southern Germany, northern Italy and eastern England (16).

Flooding is a big concern in many parts of the world. Storms and floods caused over one million deaths in the period from 1970 to 2012. Flood plains are also desirable areas for human development and a significant proportion of the world's population relies, directly or indirectly, on a variety of key natural resources that floodplains typically provide. A number of global challenges, including rising population pressure, continued depletion of ecosystem resources and climate instability and change, will lead to a further rise in

global flood risks. This rise is further compounded in many parts of the world by poor flood planning and management activities. Floods, however, are an integral part of a river's natural regime; flood control also plays an important role in protecting people and facilities from floods and flooding. Integrating flood risks into water resource management offers a justification for moving away from a single oriented approach to an integrated flood management approach, such as flood control (17).

1.1.1.3. Extreme heat

Heatwaves, or heat and hot weather that can last for many days, can have a huge effect on society, including an increase in casualties associated with heat. Heatwaves are among the most dangerous natural threats, but seldom get sufficient coverage because they are not always readily evident in their death tolls and devastation (18).

Summertime temperatures that are much hotter and/or humid than normal are described as extreme heat. Since some locations are hotter than others, this depends on whether at that time of year is considered average for a specific spot. It can feel hotter than it actually is due to warm and muggy weather (19).

Heat events, from as little as a day to at least a year have been described over a range of timescales in the literature. This study distinguishes between short term temperature anomalies (days, heat events) and longer duration temperature anomalies (weeks and longer, warm anomalies). Since temperature is a continuous variable, as the event unfolds, the spatial extent of a given heat event or hot anomaly is somewhat subjectively specified and can change over time (20).

During 2020, the American West was ravaged by wildfires, but the United States was not the only burning place on Earth. Other nations have also suffered their worst wildfires in decades, if not in all their recorded history. Parts of the Arctic broke wildfire records last summer, set just the year before (2019), which was the worst fire season in 60 years at the time. In June, and according to Penney (2020), the Russian town of Verkhoyansk became the first to encounter temperatures around 38 Celsius, above the Arctic Circle. In July, the Borneo province of Central Kalimantan declared a state of emergency as fires burned out of control. That followed extreme fires in Indonesia last year and the intermittent warming of the tropical Pacific Ocean that can affect weather worldwide in 2015, the year of a drought in the country that was related to El Niño (21).

The last decade was the hottest ever reported, giving everyone who was paying attention a warning sign blinking. The annual temperatures over the years on average, hover a little less than (1ºC) higher now than they did from 1950 to 1980; the hottest stretch ever recorded was the last five years alone. To date, 2019 is the second hottest year ever, about (0.94ºC) above the long-term average (9).

In recent decades, Continental Portugal's extreme wildfires have increased in frequency and effect, attracting researchers' attention to these fires and their drivers. Extreme wildfires tend to occur in Portugal in conjunction with extreme weather conditions, such as heat waves during the summer fire season and drought during the preceding months (22).

That number may not sound like a lot, but it has major effects. The probability of extreme hot events is increased by any little change in the average. And only a slight change in the total quantity of heat contained in the oceans, air and water can have an immense impact on the world (9).

1.2. Firefighters' performance

The number of firefighting interventions is growing because of the extreme climatic events triggered by global climate change. The spike in extremes affects not just the conditions of the interventions, but also the interveners and the firefighters themselves. It is also necessary to tackle the investigation of the latter in order to preserve or improve the efficacy of interventions (23).

An unplanned fire that burnt in a natural environment like a forest, grassland, or prairie is a wildfire. Wildfires are often sparked by human activity or a natural occurrence, such as lightning, and may occur anywhere or at any time. Fifty percent of the reported wildfires it is not known how they began. Under excessively dry conditions such as drought, and during strong winds, the risk of wildfires increases. Transportation, communications, power and gas supplies, and water supply can be affected by wildfires. They also contribute to air quality degradation and the loss of land, crops, energy, animals and people (24).

The incidence and intensity of wildfires are being increased by climate change. As a result, firefighters and other responders are in the incidence and severity of resulting

workplace health and safety risks, such as falling trees and heat exhaustion, and the number of fatal and non-fatal injuries (25,26). Burns, smoke inhalation, transport-related burns, and cardiac arrest are also sustained by firefighters (25,27). In addition to excessive heat, smoke inhalation from fires is a possible threat for other employees (3,28).

First responders are faced with an incredibly busy day at work on days when the weather forecasters tell people to stay indoors. When severe weather disasters occur, individuals who become victims depend on first responders to come to their assistance. Tornadoes, thunderstorms, floods, hurricanes and tropical storms, earthquakes, and winter storms can be weather phenomena that affect the first responders. Even if the weather occurrence does not directly impact responders, the aftermath may present various hazards. The thunderstorm is one type of weather factor that can often get overlooked. The damage caused by major events such as tornadoes results in thunderstorms being branded as a "simpler" weather phenomenon somehow, but thunderstorms are anything but plain. Strong winds, torrential downpours, and lightning will carry these storms (29).

Flooding, even in shallower water that may seem less risky than deep water, can present a host of hazards such as drowning and construction evacuations. Many of these weather conditions cause immediate danger when the event is occurring, but after the storm or event has passed, there are still many hazards that remain. First responders need to note that after the tornado, the predominant dangers they will encounter will occur. In whatever job that they do life protection should always take top priority (29).

Take cover and secure themselves during the storm, so that they can support others when it is safe for them to leave. While everyone else sees the storm pass, apparently taking the danger with it, note that for first responders, it is only the beginning. The time has come for them now to discuss the aftermath and provide the best of their capacity with assistance. Responders will face complications, chaos, extreme circumstances, and various hazards at this time that they have to worry about in order to escape injury and further harm (29).

Considering the aforementioned occurrences, the structural stability of the structures must be a primary priority. If they are operating in the aftermath of a hurricane, winter storm, earthquake, or even a thunderstorm, the structural integrity of the buildings affected could be damaged, raising the likelihood of crews performing searches and

rescues and other activities. Every person on the scene must maintain protection from top to bottom. Take special caution and pay attention to whether the storm has dismembered support beams, moved trees onto a building, created holes in walls or other structural components, or put a load of snow on the roof in the case of winter storms, which may increase the risk of collapse (29).

Although they are proud of their history of response to both man-made and natural disasters, it may be time for them all to step back and recognize their positions in four main areas: preparedness for disasters, response, prevention and recovery (30).

1.3. Emergency Management

An emergency situation brings people from many different organizations together, representing different organizational backgrounds, including different language uses (31).

The impending, unpredictable, and potentially extreme consequences of climate change would have to be handled by emergency managers. Many emergency managers, however, are unaware of the full spectrum of potential consequences and are uncertain of their role in the effort to prepare for, respond to, and cope with them. This may partly reflect the reluctance of emergency managers to get caught up in the rancorous and politically charged climate change controversy, but it is mainly due to the common worldview of most emergency managers (32).

Although "civil protection" is a phrase widely used in Europe, "emergency management" or "disaster planning." is the coordinated attempt to deal with collective threats in many other countries around the world (33).

1.3.1. Preparedness: for severe weather incidents preparation

Disaster preparedness consists of a series of steps, whether man-made or triggered by natural disasters, implemented by states, organizations, communities, or individuals to react better and deal with the immediate aftermath of a disaster. The goal is to decrease the loss of lives and livelihoods. Simple measures may go a long way, such as search and rescue training, the establishment of early warning systems, the implementation of contingency plans, or the storing of equipment and supplies. In building the resilience of societies, disaster risk reduction and preparedness play a significant role (34).

Evaluating the forms of natural disasters that have occurred in a particular region does not take long. But it must also be understood that the data show that climate-related emergency trends are evolving or rising in severity from region to region. As such, a response area may be named for incidents and climate-related disasters never seen before in the recent history of that organization. People need to be prepared for such incidents, and they also need to be prepared to respond by means of assistance. The training of residents can be achieved in collaboration with the company through the implementation of new community risk reduction initiatives (30).

The software must provide an established means of notifying people of an imminent environmental or wildfire catastrophe. While the warning may be by means of weather sirens in certain parts in some countries (e.g. the USA), a more accurate notification may be by means of text messages on a mobile phone (e.g. PROCIV Alert - Portugal) or calls from the National Emergency Number. The readiness of firefighters may also enable them to undergo more training in areas such as rapid flood water rescue or search and rescue efforts for the severe destruction of a tornado or wildfire (30).

Investment, development, maintenance and reinforcement of multisectoral, people-centered early warning and forecasting systems, disaster risk and emergency communications structures, social technology and telecommunications threat monitoring systems; development of such systems through a participatory process; adaptation to consumer needs, including social and cultural needs; promoting the use of quick and

low-cost early warning equipment and facilities; and widening the launch platforms for information on early warning of natural disasters (35).

1.3.2. Response: bringing training all-hazards into motion

The impacts of extreme weather, water and climate events such as tropical cyclones, flooding and extreme heat on rising numbers of people are being exacerbated by climate change, population growth, urbanization and environmental degradation. More critical than ever before are better early warning systems and more organized disaster risk reduction (36).

The steady rise in disaster risk, including the increase in exposure to people and properties, together with the lessons learned from previous disasters, it demonstrates the need to further improve disaster preparedness for response, action in advance of disasters, incorporation of disaster response, reducing the risk of response preparedness and ensuring that capacities are in place to ensure efficient answer at all levels and recovery. Disasters have shown that the process of recovery, rehabilitation and reconstruction that needs to be planned in the run-up to a disaster is a Critical potential to "Build Back Better" to make nations and communities resilient to disasters, particularly by incorporating disaster risk mitigation into development initiatives (35).

Regarding the USA context, the response process includes not only performing department preparation, but also getting an updated list of the local mutual-aid fire services, EMA (Emergency Management Agency) or non-governmental organizations (NGOs) such as the American Red Cross resources or specialist teams available to them. The capacity of the fire department to initiate incident command that provides the building blocks for additional response from other agencies is one of the strongest ties in any disaster. In order to initiate triage of any victims and administer lifesaving assistance, firefighters will also be pressed into service. (30).

Prepare or regularly review and update, with the involvement of relevant institutions, preparedness, and contingency for political disasters, plans and services, considering climate change scenarios and their effect on disaster risk, and promoting the participation of all relevant sectors and stakeholders, as appropriate. It is important to encourage the

resilience of new and existing critical infrastructure, including water, transport and telecommunications infrastructure, educational facilities, hospitals, and other health facilities, in order to ensure that they remain secure, functional and functioning throughout and after disasters, in order to provide vital and life-saving services. To develop or improve processes and procedures for coordination and funding relief aid, preparing and preparation for post-disaster recovery and restoration, public policies and acts that promote the role of public servants should be adopted (35).

1.3.3. Mitigation: move to a long-term aid commitment

Mitigation consists of steps taken to avoid or minimize the risk to life, property, social and economic activities, and natural resources from natural disasters. The destructive effects of a natural disaster on societies can be decreased by awareness, education, preparedness and forecasting and alert systems. However, mitigation steps, such as the implementation of zoning, land-use practices, and construction codes, are important to avoid or mitigate real hazard damage. For example, through planning and zoning ordinances, avoiding development in areas prone to landslides and floods will save money on construction and minimize loss of life and damage to properties and natural resources. The basic truth that community mitigation investment pays direct dividends when catastrophe strikes continues to be supported by post-disaster studies (37).

In this phase, there is the intervention of several entities, namely firefighters, and it is part of their service to take the appropriate measures to help mitigate the damage of each disaster. This may take the form of an early identification of the number of impacted homes, corporations, as well as community and governmental facilities. An estimation of how many people will require food, water services and temporary shelter can be made based on of these findings, and where that shelter and distribution point may be placed should be understood and preplanned (30).

Thinking ahead of the incident is crucial to getting what they need when they need it and should therefore also be taken into consideration during the planning process. After a tragedy, train the department and its personnel for a long-term commitment. One fault is contributing all the workers to a tragedy for an extended time. While everyone would try to step in to help, in order have both work and rest periods, they either must split their workers into shifts, or they will need to prepare for occasional relief from other

departments in the immediate region. After being up for 24 to 36 hours straight, decision making is difficult. Before poor choices cause injuries or harm to the firefighters, firefighters and chief officers alike must take breaks (30).

1.3.4. Recovery: receiving the assistance you need

The recovery process after a disaster will possibly take the longest period, is the fourth phase, which is the restoration to some sense of normalcy of all facets of the effects of the disaster on a community and the return of the local economy. A degree of physical, environmental, economic, and social stability has been achieved by the affected area at this time. The disaster recovery process can be divided into two stages. Usually, the short-term period lasts from six months to at least one year and includes supplying companies with immediate services (38).

The long-term period, which may stretch to decades, involves careful strategic preparation and intervention to cope with more extreme or permanent disaster impacts. Investment in capacity building for economic growth is necessary for promoting economic diversification, attracting new resources, building new alliances, and implementing successful strategies and tactics for recovery. To allow long-term economic recovery, communities must access and deploy a variety of public and private resources (38).

Like de previous phase, there is also the intervention of several entities, and once again, firefighters have a key role in analyzing lessons learned from the incidents during that time, and how to best prepare the community and their department for the next tragedy. To help make the community more disaster-resilient as everybody rebuilds, this may include staff, personnel and equipment, improved area-wide alerts, or even stronger building and fire codes. Fire officers need to note that in any potential repeated incident, such built-in resilience to disasters will save the lives not only of people but also of their firefighters. While all these steps entail training and pre-planning, remember that no matter what kind it might be, when the tragedy strikes, it is them, the fire service personnel, to whom the people and elected officials are looking for response and guidance (30).

2. Chapter II: Methodology

This study is based on a survey of available information and data, on the impact of extreme weather events, namely in fire situations, and the occupational hazards and their implications for the Fire Brigade's responsiveness, to understand if they are prepared for this type of emergency, considering the constraints. The research was carried out in specific databases, such as PUBMED and Sciencedirect, following the PRISMA methodology, and with the help of the RAYYAN application, as a means of screening studies and articles for inclusion in the review, allowing both the author and the advisor to be able to manage the choice of articles to be used in the Systematic Review, in a very short and simplified period of time, becoming an asset for the application of the PRISMA methodology. The keywords used were “firefighters” OR “fireman” AND “extreme weather events” AND “occupational exposure” AND “climate change”.

2.1. PRISMA Methodology

The language used has developed over time to define a systematic review and meta-analysis. The desire to encompass both structural evaluations and meta-analyses was one reason for changing the name from QUOROM to PRISMA. A systematic review is a review of a clearly defined question using systematic and explicit methods for the detection, selection, and critical evaluation of applicable research and the compilation and analysis of data from the studies included in the review (39).

Statistical approaches (meta-analysis) can or may not be used to evaluate the outcomes of the included studies and to summarize them. In a systematic study, meta-analysis refers to the use of statistical methods to incorporate the findings of the studies covered (39).

In 1996, an international group developed a guideline called the QUOROM Statement (Quality Of Reporting Of Meta-analyses), which centered on reporting meta-analyses of randomized controlled trials, to resolve the suboptimal reporting of meta-analyses (39,40).

A revision of these guidelines, renamed PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) has been revised to reflect many methodological and practical developments in systematic review research, is outlined in

this paper. The latest PRISMA checklist varies in many respects from the QUOROM checklist, and Table 1 highlights the specific substantive changes. In general, the PRISMA checklist "decouples" several items present in the QUOROM checklist and, where appropriate, several items in the checklist are related throughout the systematic analysis report to increase continuity (39).

Table 1 - Substantive specific changes between the QUOROM checklist and the PRISMA checklist (a tick indicates the presence of the topic in QUOROM or PRISMA)

Substantive specific changes between the QUOROM checklist and the PRISMA checklist				
Section / Topic	**Item**	**QUORUM**	**PRISMA**	**Comment**
Abstract		✓	✓	QUOROM and PRISMA ask authors to report an abstract. However, PRISMA is not specific about format.
Introduction	Objective		✓	This new item (4) addresses the explicit questions the review addresses using the PICO reporting system (which describes the participants, interventions, comparisons, and outcome(s) of the systematic review), together with the specification of the type of study design (PICOS); the item is linked to items 6,11, and 18 of the checklist.
Methods	Protocol		✓	This new item (5) asks authors to report whether the review has a protocol and if so, how it can be accessed.
Methods	Search	✓	✓	Although reporting the search is present in both QUOROM and PRISMA checklists, PRIMA asks authors to provide a full description of at least one electronic search strategy (item 8). Without such information it is impossible to repeat the authors´ search.
Methods	Assessment of risk of bias in included studies	✓	✓	Renamed from “quality assessment” in QUOROM. This item (12) is linked with reporting this information in the results (item19). The new concept of “outcome-level” assessment has been introduced.
Methods	Assessment of risk of bias in across studies		✓	This new item (15) asks authors to describe any assessments of risk of bias in the review, such as selective reporting within the included studies. This item is linked with reporting this information in the results (Item 22).

Discussion		✓	✓	Although both QUOROM and PRISMA checklists address the discussion section, PRISMA devotes three items (24-26) to the discussion. In PRISMA the main types of limitations are explicit stated, and their discussion required.
Funding			✓	This new item (27) asks authors to provide information on any source of funding for the systematic review.

A checklist of 27 items (Table 2) and a four-phase flow diagram, which is duly completed in section 2.2 (Figure 2) Inclusion and Exclusion Criteria, form the PRISMA Declaration. The purpose of the PRISMA Statement is to enhance the reporting of systematic reviews and meta-analyses to support authors. PRISMA can also be used as a basis for the reporting of systematic reviews of other types of study, particularly intervention evaluations. For critical evaluation of published systematic reviews, PRISMA may also be useful. The PRISMA checklist, however, is not a quality evaluation tool to measure the quality of a systematic analysis (39).

Table 2 - PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) Checklist

Section/Topic	Item No.	Checklist item	Reported on Page No.
TITLE			
Title	1	Identify the report as a systematic review, meta-analysis, or both.	
ABSTRACT			
Structured summary	2	Provide a structured summary including, as applicable: background; objectives; data sources; study eligibility criteria, participants, and interventions; study appraisal and synthesis methods; results; limitations; conclusions and implications of key findings; systematic review registration number.	
INTRODUCTION			
Rationale	3	Describe the rationale for the review in the context of what is already known.	
Objectives	4	Provide an explicit statement of questions being addressed with reference to participants, interventions, comparisons, outcomes, and study design (PICOS).	
METHODS			

Protocol and registration	5	Indicate if a review protocol exists, if and where it can be accessed (e.g., Web address), and, if available, provide registration information including registration number.	
Eligibility criteria	6	Specify study characteristics (e.g., PICOS, length of follow-up) and report characteristics (e.g., years considered, language, publication status) used as criteria for eligibility, giving rationale.	
Information sources	7	Describe all information sources (e.g., databases with dates of coverage, contact with study authors to identify additional studies) in the search and date last searched.	
Search	8	Present full electronic search strategy for at least one database, including any limits used, such that it could be repeated.	
Section/Topic	**Item No**	**Checklist item**	**Reported on Page No.**
Study selection	9	State the process for selecting studies (i.e., screening, eligibility, included in systematic review, and, if applicable, included in the meta-analysis).	
Data collection process	10	Describe method of data extraction from reports (e.g., piloted forms, independently, in duplicate) and any processes for obtaining and confirming data from investigators.	
Data items	11	List and define all variables for which data were sought (e.g., PICOS, funding sources) and any assumptions and simplifications made.	
Risk of bias in individual studies	12	Describe methods used for assessing risk of bias of individual studies (including specification of whether this was done at the study or outcome level), and how this information is to be used in any data synthesis.	
Summary measures	13	State the principal summary measures (e.g., risk ratio, difference in means).	
Synthesis of results	14	Describe the methods of handling data and combining results of studies, if done, including measures of consistency (e.g., I2) for each meta-analysis.	
Risk of bias across studies	15	Specify any assessment of risk of bias that may affect the cumulative evidence (e.g., publication bias, selective reporting within studies).	
Additional analyses	16	Describe methods of additional analyses (e.g., sensitivity or subgroup analyses, meta-regression), if done, indicating which were pre-specified.	
RESULTS			

Study selection	17	Give numbers of studies screened, assessed for eligibility, and included in the review, with reasons for exclusions at each stage, ideally with a flow diagram.	
Study characteristics	18	For each study, present characteristics for which data were extracted (e.g., study size, PICOS, follow-up period) and provide the citations.	
Risk of bias within studies	19	Present data on risk of bias of each study and, if available, any outcome level assessment (see item 12).	
Results of individual studies	20	For all outcomes considered (benefits or harms), present, for each study: (a) simple summary data for each intervention group (b) effect estimates and confidence intervals, ideally with a forest plot.	
Synthesis of results	21	Present results of each meta-analysis done, including confidence intervals and measures of consistency.	
Risk of bias across studies	22	Present results of any assessment of risk of bias across studies (see Item 15).	
Additional analysis	23	Give results of additional analyses, if done (e.g., sensitivity or subgroup analyses, meta-regression [see Item 16]).	
DISCUSSION			
Summary of evidence	24	Summarize the main findings including the strength of evidence for each main outcome; consider their relevance to key groups (e.g., healthcare providers, users, and policy makers).	
Limitations	25	Discuss limitations at study and outcome level (e.g., risk of bias), and at review-level (e.g., incomplete retrieval of identified research, reporting bias).	
Conclusions	26	Provide a general interpretation of the results in the context of other evidence, and implications for future research.	
FUNDING			
Funding	27	Describe sources of funding for the systematic review and other support (e.g., supply of data); role of funders for the systematic review.	

Search filtering takes time, and no single approach meets the primary requirements of speed and accuracy. The need to speed up the availability of current best evidence for policy and clinical decision-making drives the automation of systematic reviews (41).

Rayyan is a free web-tool (beta) that greatly speeds up the process of screening and selecting papers for academics working on systematic reviews, scoping reviews, and other knowledge synthesis projects (41).

Rayyan has shown to be a highly useful tool with a lot of potential for easing the strain on systematic review writers by speeding up the laborious part of the process of selecting research for inclusion in the review and reducing the time spent screening publications. Rayyan's capacity to assist with abstract and title selection, as well as his aptitude to work on the same review, are two of his most distinguishing traits when compared to other competitors (Figure 1) (41).

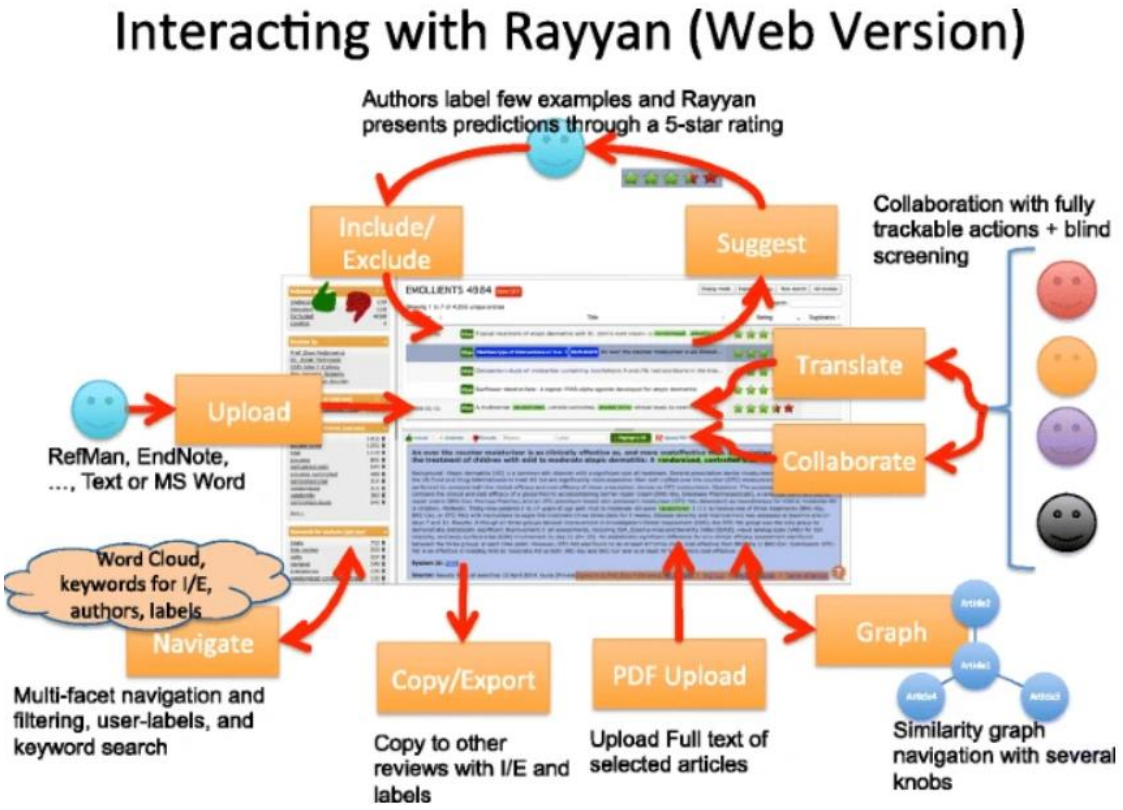

Figure 1 - Rayyan workbench. The workbench shows the different ways users interact with app (41)

2.2. Inclusion and Exclusion Criteria

The criteria for inclusion and exclusion set the parameters for a systematic analysis (Table 3). Typically, after setting the research query, they are decided before the search is conducted, but scoping searches may need to be done to decide sufficient criteria. It is possible to use several different variables as requirements for inclusion or exclusion. Details about the inclusion and exclusion criteria is generally reported in the methods section of the systematic review as a paragraph or table. The meanings, and the source of the term, used for specific terms in the research question may also need to be given.

Other conditions for inclusion/exclusion may include the sample size, the sampling process, or the availability of a specific research comparison group. The results of the articles may be combined or only the latest data may be included if a single research is published in several papers (Figure 2) (42).

Table 3 - Inclusion and exclusion criteria

Inclusion Criteria	Exclusion Criteria
Articles published in the English language;	Articles of reviews/ state of the art articles
Articles published from 1st of January 2010 to 31st of December of 2020	Articles related exclusively to climate change
Articles related to the impact of climate change on the response of Firefighters	Abstracts of congress and reports

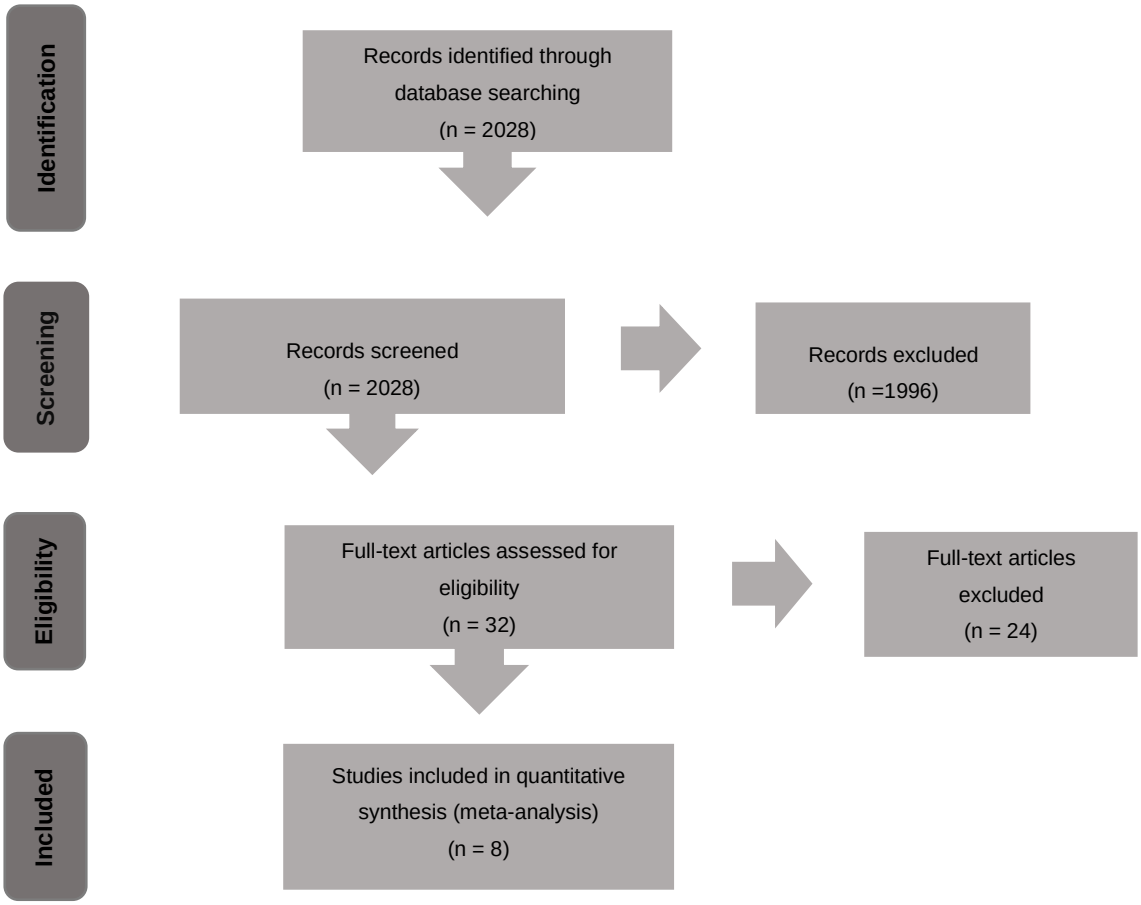

Figure 2 - Flow of information through the different phases of a systematic review

3. Chapter III: Results

Among the 8 articles included in this study (Table 4), an analysis was performed regarding the occupational hazards to which firefighters are exposed, in situations of extreme weather events, namely those that will always result in fire situations, and which are the most prevalent, and such risks have implications for their response to events, as well as for their present and future occupational health.

Regarding the analysis of the results, it is possible to observe that, in relation to occupational risk, 2 out of 8 studies mention an exposure to wood smoke (43,44). Moreover, regarding specific substances, 2 out of 8 studies mention the exposure to carbon monoxide (CO), (45,46), the substance Levoglucosan (LG) is also mentioned in 1 out of 8 studies (46), as well as other substances, such as nitrogen dioxide, exhaled nitric oxide (eNO) (NO_2) and volatile organic compounds (VOC) (45), and polycyclic aromatic hydrocarbons (PAHs - as Naphthalene, retene, and phenanthrene were consistently the highest measured) (47).
Concerning the occupational hazards in general, 1 out of 8 studies mention several hazards associated with health threats, such as exposure to toxic chemicals, shift work, extreme heat, physical and emotional strain (48).
Another occupational hazards that affect firefighters very intensely, and thar were reported in the studies analyzed were the Repeated Exposure to Trauma (RET) (49), and the exposure to natural disaster (where the participant felt they or their loved ones were in danger of death or injury) (50).

Furthermore, taking into account the time of exposure, 3 out of 8 studies are based on workshifts (43,49,51), 2 out of 8 studies mention “three fire seasons in Portugal” (Miranda et al. 2012 (45,47), while 3 out of 8 studies focus on “years of activity” (44,48,50).

As for Sampling these were obtained in different ways, biological samples of Urine (43) and Blood (44) were mentioned in 2 out of 8 studies, whereas in 3 out of 8 studies, the sampling was made through sampling devices (45,47,51), and 3 out of 8 studies used records/interviews (48–50).

Finally, in the last theme of the results matrix is the Health Outcome, which mentions the health effects of the occupational risks mentioned, 1 out of 8 studies focuses on the reduction of the respiratory function (45), whereas 2 out of 8 studies refer oxidative stress

(disorder in the balance between the production of reactive oxygen species) (43,44), 2 out of 8 studies highlights mental health damage (depression, PSTD, etc.) and general well-being (49,50). Other health outcomes such as the increasing of the level of DNA damage and greater oxidative damage (44), the incidences of lung, skin and bladder cancer as short term effects (47) and symptoms of depression in the first 3 years of service for firefighters exposed to disasters compared to those not exposed (50), were also mentioned in the studies analyzed through this review.

Table 4 – Results

Title	Journal	Country	Risk	Time of exposure	Sampling	Health Outcome	References
Wildland smoke exposure values and exhaled breath indicators in firefighters.	Journal of toxicology and environmental health	Portugal	Exposure to carbon monoxide (CO), nitrogen dioxide (eNO), exhaled nitric oxide (NO_2), and volatile organic compounds (VOC)	Three fire seasons in Portugal	Personal sampling device for CO monitoring, and another for VOC and NO_2.	Decrease of four spirometric parameters (FEV1, F25, F50, and MEF), indicating that firefighters experienced a reduction of respiratory function	Miranda et al. 2012 (45)
Occupational exposure to woodsmoke and oxidative stress in wildland firefighters.	The Science of the total environment	USA	Exposure to woodsmoke	Workshift	Urine samples	Oxidative stress	Adetona et al. 2013a (43)
Exposure of wildland firefighters to carbon monoxide, fine particles, and levoglucosan.	The Annals of occupational hygiene	USA	Exposure to woodsmoke: levoglucosan (LG), and carbon monoxide (CO)	Workshift - 30 days	Personal sampling device for PM2,5 (fine particles), CO (carbon monoxide) and LG (chemical tracer for biomass burning in atmospheric)	Potential reduction of lung function, pulmonary and systemic inflammations	Adetona et al. 2013b (46)
Firefighting and mental health: Experiences of repeated exposure to trauma.	Work (Reading, Mass.)	USA	Repeated Exposure to Traumas (RET)	Workshift	Data extracted from the full transcripts of focus groups and key informant interviews	Other mental health outcomes and general well-being (e.g. depression, PTSD)	Jahnke et al. 2016 (49)
Wood smoke exposure of Portuguese wildland firefighters: DNA and oxidative damage evaluation.	Journal of toxicology and environmental health	Portugal	Exposure to woodsmoke	Years of activity	Blood Samples	Increased level of DNA damage and higher oxidative damage	Abreu et al. 2017 (44)
Occupational Exposure to Polycyclic Aromatic Hydrocarbon of Wildland Firefighters at Prescribed and Wildland Fires.	Environmental science & technology	USA	Exposure to polycyclic aromatic hydrocarbons (PAHs) (Naphthalene, retene, and phenanthrene were consistently the highest measured)	Two wildland fires	Personal air samples	Potential long or short-term health effects (incidences of lung, skin, and bladder cancers)	Navarro et al. 2017 (47)

Title	**Journal**	**Country**	**Risk**	**Time of exposure**	**Sampling**	**Health Outcome**	**References**
The Influence of Exposure to Natural Disasters on Depression and PTSD Symptoms among Firefighters.	Prehospital and disaster medicine	USA	Exposure to natural disaster (where the participant felt they or their loved ones were in danger of death or injury)	First three years of fire service	In-person clinical assessments were conducted by doctoral-level clinical psychologists at four time points: before graduating from fire training academy (baseline) and at the end of each of their first three years of fire service (annual one, two, and three)	Depression symptoms worsened over the first three years of fire service for disaster-exposed recruits compared to non-exposed recruits	Pennington et al. 2018 (50)
Mortality in a cohort of Danish firefighters; 1970-2014.	International archives of occupational and environmental health	Denmark	Occupational exposure of firefighters to a complex range of potential health threats from toxic chemicals, shift work, extreme heat, physical and emotional strain	Cause-specific mortality rates were constructed for both reference groups (civil/military vs firefighters) using 5-year age and calendar time intervals.	Through Systematic collection of personnel and membership records from employers and trade unions, past and present male Danish firefighters	Death from stomach cancer (among the full-time firefighters) and a significant increase in prostate cancer death (among part time/ volunteer workers)	Petersen et al. 2018 (48)

4. Chapter IV: Discussion

Firefighters are regularly injured while providing emergency services. Risk perception influences injury and safety behavior. According to the findings, varied degrees of risk perception are connected to diverse practical experiences, acute stress reactions, and training. Firefighters are summoned to respond to a range of events, including small-scale occurrences (such as a home fire) and disasters, and their risk perceptions were connected to their views of training, practical experience, and acute stress reactions (such as floods)(52). As a result, the eight publications in this evaluation reflect part of this reality.

The majority of the studied publications (5 out of 8) are from the United States, with the remaining three research coming from Europe, two from Portugal and one from Denmark. This demonstrates the global scarcity of information on this topic, particularly in Asian and African nations, where no studies were located in this research.

Wildfires are the most common severe weather event in our study, despite all the other extreme weather occurrences (6 out of 8). It is widely established that climate change would increase fire activity (53,54) not only in severity but also in frequency (54,55), as a result, these employees will be exposed to a greater amount of gases and particles. It was discovered in this study that these employees are extensively exposed to woodsmoke (6 out of 8), which has been linked to increased airway responsiveness, decreased lung function, and a substantial cross-shift variation in circulating cytokine levels in prior investigations (47,51,56), this suggests that there may be a link between the danger these employees face and the health outcomes reported in each research.

Carbon monoxide (CO) is a colorless, tasteless, odorless, and nonirritating gas formed when the carbon in a fuel is not completely burned. Particulate matter, which is abundantly produced during wildfires, is highly visible, has an impact on ambient air quality, and has a variety of negative health consequences depending on its size and chemical makeup, and is one of the most common and significant acute dangers for firefighters (45,57,58);); particulate matter, which is abundantly produced during wildfires, is highly visible, has an impact on ambient air quality, and has a variety of negative health consequences depending on its size and chemical makeup.

During forest fires, inhalation is the most prevalent route of exposure, and firefighters are more likely to ingest particles when they are present in the air. Because the detrimental

capabilities of the particles are based not only on their chemical and poisonous qualities, but also on their size, shape, and density (45,59–61); it is difficult to measure the negative health effects attributable to PM in smoking. ; nitrogen dioxide (NO_2 a potent pulmonary toxin that causes tissue necrosis as well as chronic inflammation, according to both clinical evidence and animal exposure studies (45,62,63); volatile organic compounds (VOC), and other chemical compounds (45,64) such as Polycyclic Aromatic Hydrocarbons (PAH's), which may have potential links to certain cancers (65).

Despite the fact that most firemen use a bandana for respiratory protection, this filtering device offers only rudimentary protection. The pore size of this type of bandana is about 200 m, which is roughly 500–2000 times larger than the smaller smoke particles (0.100–0.400 m), according to Reh et al. (66), as a result, gases and microscopic particulate matter pass through the fabric (45).

Even if some experienced firefighters consider air toxics to be merely an annoyance that occasionally causes acute eye and respiratory irritation, nausea, and headache (45,67), some studies point to issues with chronic health outcomes, particularly cancer, from years of exposure (45,64,68) or when large-scale fires erupt in terrain and meteorological conditions that require firefighters to operate in smoky conditions for several days exposure (45,64,68).

It's also worth noting that, despite the short amount of time these personnel are exposed to during wildland firefighting efforts, they have a huge workload in physically demanding situations and locales (44,69,70).

Contaminants can cause a variety of health problems for these employees, depending on the period of exposure. Ocular and respiratory irritation, as well as shortness of breath, are the most common symptoms reported by firefighters, either immediately or after a few hours of exposure. These symptoms progress to headaches, dizziness, and nausea (44,71). In the long term, some epidemiological studies have revealed an elevated risk of cardiovascular disease (44,72,73), cancer (44,64), and respiratory disorders (44,74–76).

5. Chapter V: Final Considerations

This chapter is dedicated to the conclusions, the expected limitations of the study and some suggestions for futures studies.

5.1. Conclusions

Overall, it was possible to conclude that climate change is becoming more evident all over the world as time goes by and that fires are the top natural disaster that is definitely affecting firefighters. And as it becomes more frequent and worse, more affected the response of this professionals gets. It is also evident that these workers are exposed to all kinds of risks, from the exposure to several psychologic traumas, to the exposure to all kinds of particles. Therefore, the assessment of the risk exposure of these workers, is extremely important.

This systematic review also reinforces the need to assess extreme weather events, occupational hazards in fire situations and the implications for firefighters' responsiveness all over the world, since there is a lack of research regarding such important matter.

5.2. Study Limitations

One limitation detected in this study is the number of papers found, it is obvious that this subject has a lack of research all over the world being the United States the country with most of the research in this matter, which leads us to a lack of knowledge and, consequently, to a lack of an uniformized response method for these workers.

5.3. Suggestions for Future Studies

This systematic review puts together all the information available, considering the criteria applied, regarding extreme weather events, occupational hazards in fire situations and the implications for firefighters' responsiveness. Therefore, it shows, in terms of research, what is lacking, and in terms of information, what is working and what can be done differently. Consequently, as a suggestion for future studies, it would be interesting to implement, all over the world, specific studies regarding climate change, to see how it is affecting a specific place and also, how does that affect firefighters in terms of exposure to all kinds of situation and matters.

5.4. Ethical and Legal Considerations

Ethical and legal considerations do not apply to this study.

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