

THE EFFECT OF FIRE SMOKE EXPOSURE ON THE INCIDENCE OF LUNG DISEASES AMONG FIREFIGHTERS

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Abstract

Firefighters are routinely exposed to fire smoke containing a complex mixture of hazardous substances, including particulate matter, carbon monoxide, volatile organic compounds, and other toxic gases that pose serious risks to respiratory health. Continuous and repeated exposure to these substances may increase the incidence of lung diseases among firefighters, both in acute and chronic forms. This study aims to explore the effect of fire smoke exposure on the occurrence of lung diseases among firefighters using a descriptive qualitative approach. The research focuses on understanding firefighters' experiences, perceptions, and health complaints related to occupational smoke exposure during fire suppression activities. In addition, firefighters reported limited awareness regarding the long-term health risks associated with smoke exposure, which further exacerbates vulnerability to lung diseases. The study also highlights that organizational factors, including insufficient occupational health monitoring and inconsistent enforcement of safety protocols, play a crucial role in increasing health risks. Overall, this research emphasizes the urgent need for improved preventive measures, consistent use of personal protective equipment, routine respiratory health examinations, and enhanced occupational health education for firefighters. Strengthening these strategies is essential to reduce the incidence of lung diseases and improve the long-term health and safety of firefighters.

Keywords: Fire Smoke Exposure, Lung Diseases, Firefighters, Occupational Health

INTRODUCTION

Firefighters play a critical role in protecting lives, property, and the environment from fire-related disasters. However, behind their essential public service, firefighters face significant occupational hazards that can adversely affect their health, particularly respiratory health. One of the most prominent risks encountered by firefighters is exposure to fire smoke during suppression, rescue, and overhaul activities. Fire smoke contains a complex and hazardous mixture of toxic gases, fine particulate matter, and chemical residues that can penetrate deep into the respiratory system, leading to both short-term and long-term lung health problems.

Fire smoke exposure occurs not only during active firefighting but also during post-fire operations, where smoldering materials continue to release toxic substances. According to previous

occupational health studies, fire smoke commonly contains carbon monoxide (CO), sulfur dioxide (SO₂), nitrogen oxides (NO_x), hydrogen cyanide (HCN), polycyclic aromatic hydrocarbons (PAHs), and fine particulate matter (PM_{2.5}). These substances are known to cause inflammation, oxidative stress, and structural damage to lung tissue, which may eventually result in chronic respiratory diseases. Prolonged or repeated exposure places firefighters at higher risk of developing lung diseases compared to the general population.

Several studies have reported that firefighters frequently experience respiratory symptoms such as persistent cough, wheezing, chest tightness, and shortness of breath. In some cases, these symptoms progress into more severe conditions, including chronic bronchitis, asthma, chronic obstructive pulmonary disease (COPD), and reduced lung function. A study by Adetona et al. (2016) found that firefighters exposed to wildfire smoke exhibited significant declines in lung function, particularly forced expiratory volume (FEV₁), indicating compromised respiratory capacity. Similarly, research by Burgess et al. (2018) highlighted an association between cumulative smoke exposure and increased prevalence of respiratory symptoms among structural firefighters.

Despite the known risks, firefighters often underestimate the long-term impact of smoke exposure on their respiratory health. This perception is influenced by the occupational culture within firefighting organizations, where physical endurance and resilience are emphasized, sometimes at the expense of health protection. As a result, the consistent use of respiratory protective equipment, such as self-contained breathing apparatus (SCBA), is often neglected, particularly during overhaul phases when smoke is perceived as less dangerous. Studies by Slaughter et al. (2014) revealed that incomplete or inconsistent use of respiratory protection significantly increases inhalation exposure to toxic substances, thereby elevating the risk of lung disease.

Previous research has also emphasized the role of exposure duration and frequency in determining respiratory health outcomes. Firefighters who have longer years of service and higher numbers of fire incident responses are more likely to develop respiratory disorders. A longitudinal study conducted by Guidotti (2019) demonstrated that cumulative occupational exposure among firefighters was strongly associated with progressive declines in lung function over time. These findings suggest that lung disease among firefighters is not merely the result of isolated incidents but rather the accumulation of repeated exposures throughout their careers.

In addition to chemical exposure, environmental and situational factors further exacerbate respiratory risks. Firefighters often work in unpredictable conditions, including confined spaces, high temperatures, and inadequate ventilation. These conditions can intensify the concentration of toxic smoke and increase inhalation rates. Furthermore, limited recovery time between emergency responses may prevent adequate physiological healing, contributing to chronic respiratory inflammation. Research by Navarro et al. (2020) emphasized that insufficient rest and recovery can worsen respiratory symptoms and delay lung tissue repair among firefighters.

From an occupational health perspective, lung diseases among firefighters represent a significant public health concern. Respiratory disorders not only reduce work performance and operational readiness but also affect quality of life and long-term wellbeing. In many developing regions, including parts of Southeast Asia, occupational health surveillance for firefighters remains limited. Periodic lung function testing, early detection of respiratory diseases, and long-term health

monitoring are often insufficient or inconsistently implemented. This gap increases the likelihood that respiratory conditions remain undiagnosed until they reach advanced stages.

Several previous studies have focused on the quantitative assessment of lung function among firefighters using spirometry and epidemiological methods. While these approaches provide valuable clinical data, they often fail to capture the lived experiences, perceptions, and behavioral factors that influence exposure and health outcomes. Qualitative research can complement quantitative findings by exploring how firefighters perceive smoke exposure, how they manage occupational risks, and what barriers exist to effective health protection. A study by McDiarmid et al. (2017) emphasized the importance of qualitative approaches in understanding occupational health risks among emergency responders, as these methods reveal contextual and organizational factors that are often overlooked.

In the context of developing countries, qualitative studies on firefighters' respiratory health remain scarce. Differences in equipment availability, safety training, and institutional support may lead to higher exposure levels compared to firefighters in developed nations. Therefore, there is a critical need to examine the impact of fire smoke exposure on lung diseases within specific local contexts. Understanding these dynamics can inform the development of targeted prevention strategies and occupational health policies that are culturally and operationally appropriate.

Based on the existing literature, it is evident that fire smoke exposure poses a serious threat to firefighters' respiratory health. However, gaps remain in understanding how exposure occurs in daily operational practices, how firefighters perceive respiratory risks, and how organizational systems influence protective behavior. Addressing these gaps requires an in-depth, descriptive qualitative approach that prioritizes firefighters' experiences and perspectives.

This study aims to examine the effect of fire smoke exposure on the incidence of lung diseases among firefighters using a descriptive qualitative methodology. By exploring firefighters' experiences, health complaints, and occupational practices, this research seeks to provide a comprehensive understanding of the factors contributing to respiratory diseases. The findings are expected to contribute to the development of improved occupational health interventions, enhanced safety protocols, and increased awareness of respiratory risks among firefighters, ultimately supporting the protection of their long-term health and professional sustainability.

RESEARCH METHODS

This study employed a descriptive qualitative research design to explore the effect of fire smoke exposure on the incidence of lung diseases among firefighters. A qualitative approach was chosen to gain an in-depth understanding of firefighters' experiences, perceptions, and health-related responses to occupational smoke exposure. This method allows for a comprehensive exploration of complex occupational health issues that cannot be fully captured through quantitative measurements alone.

The research was conducted among firefighters actively involved in fire suppression and emergency response operations. Participants were selected using purposive sampling, with inclusion criteria consisting of firefighters who had a minimum of one year of service and direct experience with fire smoke exposure during firefighting activities. This criterion ensured that participants possessed sufficient experiential knowledge relevant to the research objectives.

Data collection was carried out through in-depth, semi-structured interviews, direct observations, and document analysis. Interviews focused on participants' experiences with fire smoke exposure, respiratory symptoms, use of personal protective equipment, and perceptions of occupational health risks. Observations were conducted during training sessions and routine activities to understand real-world practices related to smoke exposure and safety compliance. Documentation included health records, operational guidelines, and safety protocols relevant to firefighters' respiratory health.

Data analysis followed the interactive model proposed by Miles and Huberman, which includes data reduction, data display, and conclusion drawing. During data reduction, interview transcripts and observation notes were coded and categorized to identify recurring themes. The data were then organized into thematic displays to facilitate interpretation. Conclusions were drawn through continuous comparison and validation of findings across data sources to ensure credibility.

To enhance trustworthiness, triangulation of data sources and methods was applied. Ethical considerations were addressed by obtaining informed consent from all participants, ensuring confidentiality, and allowing participants the right to withdraw from the study at any stage. This methodological approach provides a reliable foundation for understanding the relationship between fire smoke exposure and lung disease among firefighters.

RESULTS AND DISCUSSION

1. Characteristics of Fire Smoke Exposure Among Firefighters

The results of this study indicate that fire smoke exposure is an unavoidable occupational hazard for firefighters and occurs in various operational stages, including fire suppression, rescue, and post-fire overhaul activities. Most participants reported frequent exposure to dense smoke, particularly during structural fires involving residential buildings, industrial facilities, and waste-burning sites. These types of fires tend to produce higher concentrations of toxic gases and fine particulate matter due to the combustion of synthetic materials, plastics, and chemicals.

Firefighters described that smoke exposure intensity varied depending on fire duration, fuel materials, and environmental conditions such as wind direction and ventilation. In many cases, firefighters were exposed to smoke for extended periods, ranging from several minutes to several hours per incident. Participants with longer years of service reported cumulative exposure, as repeated fire responses over time increased their overall inhalation of hazardous substances. This finding supports previous studies indicating that cumulative exposure is a critical factor in the development of occupational lung diseases among firefighters.

The study also revealed that smoke exposure frequently continued during overhaul phases, when firefighters inspected fire scenes to prevent re-ignition. Many participants acknowledged that they tended to remove respiratory protective equipment during this stage due to discomfort, heat, or the perception that smoke levels were no longer dangerous. However, scientific evidence suggests that toxic compounds remain present even after visible flames are extinguished, posing ongoing respiratory risks. This behavioral pattern significantly increases inhalation exposure and aligns with findings from previous occupational health research.

Another important finding relates to the variability in protective equipment usage. Although self-contained breathing apparatus (SCBA) is officially required during fire operations, participants

reported inconsistent usage due to limited equipment availability, equipment weight, and operational urgency. Some firefighters prioritized speed and mobility over respiratory protection, especially during high-pressure emergency situations. This practice further amplifies the risk of inhaling harmful smoke constituents.

Overall, the characteristics of fire smoke exposure among firefighters in this study demonstrate a combination of high exposure intensity, prolonged duration, and repeated frequency. These factors collectively contribute to increased vulnerability to respiratory health problems. The findings highlight that smoke exposure is not limited to extreme fire events but represents a routine occupational condition. This reinforces the importance of continuous exposure management, strict enforcement of protective equipment use, and enhanced awareness of smoke-related health risks as fundamental components of occupational health protection for firefighters.

2. Respiratory Symptoms and Lung Health Complaints Among Firefighters

The findings reveal that respiratory symptoms are commonly experienced by firefighters as a consequence of repeated fire smoke exposure. Most participants reported experiencing acute respiratory complaints immediately after fire suppression activities, including coughing, throat irritation, shortness of breath, chest tightness, and excessive mucus production. These symptoms were often perceived as temporary and considered part of the normal occupational experience, leading many firefighters to underestimate their clinical significance.

Several participants indicated that respiratory symptoms tended to worsen with increased years of service. Firefighters with longer work experience described more persistent complaints, such as chronic cough and reduced exercise tolerance, suggesting possible progression toward chronic respiratory conditions. Some participants also reported recurrent respiratory infections and prolonged recovery times following fire incidents, which may indicate compromised lung function and weakened respiratory defense mechanisms.

In line with previous studies, these findings support the association between fire smoke exposure and respiratory health impairment. Research by Adetona et al. (2016) and Burgess et al. (2018) demonstrated that firefighters exposed to smoke experience significant declines in lung function and increased respiratory symptoms compared to non-exposed populations. The inhalation of fine particulate matter (PM_{2.5}) and toxic gases has been shown to induce airway inflammation and oxidative stress, which contribute to both acute and chronic lung damage.

Interestingly, many participants reported a lack of formal medical diagnosis despite experiencing ongoing respiratory symptoms. This suggests that lung diseases among firefighters may be underdiagnosed due to limited access to routine occupational health screening or the tendency to normalize symptoms. The absence of regular spirometry testing and respiratory health assessments further increases the risk that early-stage lung diseases remain undetected.

Overall, the prevalence of respiratory symptoms among firefighters underscores the need for improved health surveillance systems. Early identification and management of lung health complaints are crucial to preventing the progression of occupational lung diseases and maintaining firefighters' long-term health and work capacity.

3. Use of Personal Protective Equipment and Exposure Control Practices

The study found that the use of personal protective equipment (PPE), particularly respiratory protection, plays a critical role in mitigating fire smoke exposure. However, participants reported inconsistent use of self-contained breathing apparatus (SCBA) during fire operations. While SCBA was generally used during active fire suppression, it was frequently removed during overhaul and post-fire inspection phases.

Several factors contributed to inconsistent PPE use, including physical discomfort, heat stress, equipment weight, and limited availability. Firefighters expressed that wearing SCBA for extended periods was physically exhausting and interfered with communication and mobility. In high-pressure emergency situations, some participants prioritized rapid response over complete protective measures, increasing their risk of inhaling toxic smoke.

These findings align with previous research indicating that behavioral and organizational factors significantly influence PPE compliance. Slaughter et al. (2014) reported that firefighters often underestimate the hazards present during overhaul phases, despite evidence showing high concentrations of airborne toxins after fires. This gap between knowledge and practice highlights the need for continuous training and strict enforcement of safety protocols.

Participants also noted variations in PPE quality and maintenance, which affected their willingness to use respiratory protection. Poorly maintained equipment reduced confidence in its effectiveness, further discouraging consistent use. This suggests that exposure control is not solely an individual responsibility but also depends on organizational support and resource allocation. In summary, inadequate and inconsistent use of respiratory protective equipment significantly increases smoke exposure and respiratory health risks among firefighters. Strengthening PPE availability, improving equipment design, and reinforcing safety culture are essential strategies to reduce occupational exposure and protect lung health.

4. Occupational Factors Influencing Lung Disease Risk

Occupational factors such as duration of service, frequency of fire incidents, and work intensity were identified as key contributors to lung disease risk. Firefighters with longer service periods reported greater cumulative exposure, which increased their vulnerability to chronic respiratory conditions. Frequent emergency responses, especially during peak fire seasons, resulted in limited recovery time between exposures.

Participants also highlighted the impact of work schedules and shift patterns on their health. Extended shifts and irregular working hours often led to fatigue, reducing compliance with safety measures and weakening immune responses. This finding supports previous studies that link occupational stress and fatigue with increased susceptibility to respiratory illnesses. Environmental conditions, including confined spaces and poor ventilation during fire suppression, further intensified smoke exposure. Firefighters working in enclosed environments reported higher levels of discomfort and respiratory distress compared to those operating in open areas. These conditions amplify inhalation rates and exposure intensity, accelerating lung damage.

From an organizational perspective, limited occupational health monitoring was identified as a significant gap. Many participants reported that routine health checks focused on general physical fitness rather than specific respiratory assessments. This lack of targeted monitoring increases the likelihood that lung diseases are identified only at advanced stages. Overall, occupational factors

interact cumulatively to elevate lung disease risk among firefighters. Addressing these factors requires comprehensive occupational health policies that integrate exposure management, workload regulation, and regular respiratory health surveillance.

5. Implications for Occupational Health and Preventive Strategies

The findings of this study highlight several implications for occupational health practice and policy. First, fire smoke exposure should be recognized as a significant occupational health hazard requiring systematic prevention and control. Firefighters need continuous education regarding the long-term health effects of smoke exposure, particularly during phases where risks are often underestimated. Preventive strategies should prioritize consistent use of respiratory protective equipment throughout all fire-related activities. Organizational enforcement of safety protocols, combined with regular training and supervision, can improve compliance and reduce exposure. In addition, improving the comfort and usability of respiratory equipment may encourage more consistent use.

Routine respiratory health monitoring, including periodic lung function tests, is essential for early detection of lung diseases. Implementing structured health surveillance programs can help identify early symptoms and prevent disease progression. Furthermore, providing adequate recovery time between fire incidents may support physiological healing and reduce cumulative health impacts.

At the policy level, integrating occupational health protection into firefighting management systems is crucial. Collaboration between fire departments, health authorities, and policymakers can strengthen regulations and ensure adequate resource allocation. Overall, preventive strategies must address both individual behavior and organizational systems to effectively reduce lung disease risk and promote sustainable occupational health among firefighters.

CONCLUSIONS

This study demonstrates that fire smoke exposure has a significant impact on the incidence of lung diseases among firefighters. Repeated and prolonged exposure to toxic smoke during fire suppression and post-fire activities contributes to a wide range of respiratory symptoms, including chronic cough, shortness of breath, and reduced lung function. These symptoms often worsen with increased years of service, indicating the cumulative nature of occupational exposure.

The findings reveal that inconsistent use of respiratory protective equipment and limited awareness of long-term health risks exacerbate firefighters' vulnerability to lung diseases. Organizational factors, such as inadequate health monitoring, limited PPE availability, and insufficient enforcement of safety protocols, further increase exposure risks. As a result, respiratory conditions among firefighters are often underdiagnosed and inadequately managed.

This research highlights the importance of adopting comprehensive occupational health strategies that integrate exposure control, consistent PPE use, routine respiratory health surveillance, and continuous health education. By strengthening preventive measures and organizational support, fire departments can reduce the incidence of lung diseases and improve firefighters' long-term health outcomes.

In conclusion, protecting firefighters from the harmful effects of fire smoke is not only essential for individual wellbeing but also for maintaining operational effectiveness and public safety. Sustainable occupational health interventions are necessary to ensure that firefighters can continue to perform their vital duties while safeguarding their respiratory health throughout their careers.

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