

The logo for IJU (Instituto de Física da Universidade Federal de Juiz de Fora) is located in the top left corner. It consists of the letters 'IJU' in a bold, white, sans-serif font, set against a black rectangular background. The background of the entire cover is a high-contrast, close-up photograph of a forest fire, showing bright orange and yellow flames and dark, charred wood.

ADVANCES IN FOREST FIRE RESEARCH

2022

Edited by
**DOMINGOS XAVIER VIEGAS
LUÍS MÁRIO RIBEIRO**

The firefighters on the frontline of forest fires – preliminary characterization of Bio4FOX study population

Filipa Esteves^{1, 2, 3, 4*}; Joana Madureira^{1, 2, 3}; João Paulo Teixeira^{1, 2, 3}; Solange Costa^{1, 2, 3}

¹Environmental Health Department, National Institute of Health. Rua Alexandre Herculano, 321, 4000-055 Porto, Portugal, {filipa.esteves, joana.madureira, joao.teixeira, solange.costa}@insa.min-saude.pt

²EPIUnit – Instituto de Saúde Pública, Universidade do Porto (ISPUP). Rua das Taipas 135, 4050-600 Porto, Portugal, {filipa.esteves3@hotmail.com},{jvmadureira; jpft12; solange.costa2}@gmail.com

³Laboratório para a Investigação Integrativa e Translacional em Saúde Populacional (ITR), Universidade do Porto. Rua das Taipas 135, 4050-600 Porto, Portugal

⁴Department of Public Health and Forensic Sciences, and Medical School, Faculty of Medicine, University of Porto. Alameda Prof. Hernâni Monteiro, 4200-072 Porto, Portugal, {up201406771@up.pt}

Corresponding author

Keywords

Wildland firefighters; Occupational exposure; Health effects; Biomonitoring; Public Health

Abstract

The increased frequency and intensity of forest fires have been concerning populations particularly in countries typically affected by this natural disaster. Portugal has been harshly afflicted by wildfires specially in the north and central regions. In the frontline of forest fire combat there is one of the riskiest occupations in the world – firefighters. Firefighting involves high physical and psychological demanding activities typically performed in hostile environments. The proximity to fire exposes them not only to high temperatures but also to high concentrations of hazardous pollutants, most of which are listed as probable or known carcinogens. Given the above, IARC classified occupational firefighting activity as possibly carcinogenic to humans. However, it is still among the least studied occupations, existing very little information on exposure induced mechanisms that lead to health diseases. Thus, the general aim of Bio4FOX study is to identify a set of (bio)markers for the surveillance of Portuguese Wildland firefighters' occupational exposure during three phases, pre-, during and post- fire season. Here, we aim to describe the preliminary data on sociodemographic and occupational context of the Bio4Fox study population in the pre-fire season.

For the 1st phase of the study were enrolled around 175 wildland firefighters from 14 fire stations located in the northern region of Portugal. Information on sociodemographic data, health status, lifestyle and occupational exposure were obtained via a comprehensive questionnaire. The study group was composed by 143 men and 32 women; the mean age of the group was 37.46±10.85. Most of the firefighters reported to be voluntary (88%; n=155) beginning their activities at young ages; more than half (n=92) started within 17 - 22 years old and 15% (n=26) of the individuals attended firefighters' activities at earlier ages (12-16 years old). The average length of service as firefighter was 15.94±10.23 years. Around 45% (n=79) claimed to spend more than 10 hours in their duties, while 35% (n=62) and 13% (n=22) spend 8-9hours and < 8 hours, respectively. Concerning their risk perception related to exposure to occupational hazards, 80% (n=140) believed to be exposed to smoke, gases, and/or particles and 19% (n=33) to solvents (e.g., combustible). Self-reported symptoms (of last 30 days, not related with cold/flu) were: expectoration (14%; n=24), tiredness (13%; n=22), breath difficulty (9%; n=16), cough (7%; n=13) and wheezing (6%; n=10).

Our preliminary data describes the sociodemographic factors and occupational activities of a group of Portuguese firefighters before the fire-season. This data will be integrated together with the biological and environmental findings collected over different time points of a wildfire season. Bio4FOX will contribute to the establishment of recommendations/good practices to improve firefighters' working conditions, as well support the definition of better policies/prevention strategies highly needed in this sector.

1. Introduction

Portugal is a Mediterranean country extremely prone to forest fires (Schmuck et al., 2014). Unmanaged forest lands with extent fuel loads, high number of unwanted fire ignitions and the hot season periods characterized by dry weather contribute for the incidence and escalation of wildfires. Worryingly, the risk of fire is expected to worsen in the upcoming years and decades fuelled by climate changes through rising temperatures and low

humidity and precipitation levels (Flannigan et al., 2006). The frequency, extent and severity of wildfires, brings an urgent need to focus among a crucial human resource in fire management: wildland firefighters.

Firefighters are the backbone of any firefighting system. In Portugal the number of firefighters (both volunteer and professional) have been decreasing through the years requiring more efforts/longer periods of work from those on service. Firefighting is a physically and psychologically demanding activity and a potentially hazardous occupation (Naeher et al., 2007). During their activities wildland firefighters typically experience long work shifts (up to 24 hours), sleep deprivation, heat stress, exhausting hiking, and exposure to smoke via different routes of exposure (i.e., inhalation, dermal absorption and ingestion) (IARC, 2010). Smoke is a complex mixture that includes several hazardous combustion byproducts, including particulate matter, nitrogen dioxide, carbon monoxide, and volatile organic compounds (VOCs) such as polycyclic aromatic hydrocarbons (PAHs), formaldehyde, toluene, acrolein, xylene. But firefighters are not only exposed during wildfire combat. Their exposure continues long after a fire is extinguished, mainly from contaminated equipment/vehicles. Some of the symptoms reported include eye and respiratory irritation, shortness of breath, nausea, headaches, and dizziness (Reinhardt, 2000). It is known that many of the combustion by-products are associated to adverse health effects (Manisalidis et al., 2020) being some of these compounds classified as potentially/possibly carcinogenic to humans by the International Agency for Research on Cancer (IARC) (IARC, 2010). Several epidemiological studies have described an elevated risk of cardiorespiratory diseases/outcomes (Reinhardt, 2000; Gaughan et al., 2008; Navarro et al., 2019) as well as different types of cancers (e.g., prostate, testicular, non-Hodgkin's lymphoma) (LeMasters et al., 2006). Given the above, IARC has classified occupational firefighting activity as possibly carcinogenic to humans (IARC, 2010). However, firefighter is still among the least studied occupations concerning the exposure-induced mechanisms that lead to adverse health effects. The existing research gaps limits the ability to develop effective measures to protect the health of these workers. The timely occupational risk assessment is utmost importance for early interventions such the suggestion of preventive measures to mitigate the risk of possible adverse health outcomes in firefighters.

Different factors that may modify the relationship between health effects and pollutants exposure must be considered such individual characteristics (e.g., age, body mass index, health status, lifestyle) and other contextual factors such occupational-related variables (e.g., type/frequency of occupational exposures, use of personal protective equipment (PPE), tasks performed, etc.). The application of questionnaires is among the most used methods to collect relevant information in epidemiological studies. Questionnaires is a non-expensive tool that can provide useful information on the duration (past, recent or current) and frequency of certain exposures providing an overview of different risk factors. In combination with other exposure assessment methods such biological and environmental monitoring may provide a comprehensive characterization of firefighters' occupational risks.

Bio4FOX project is an ongoing study that aims to identify a set of appropriate biomarkers for the surveillance of Portuguese wildland firefighters' occupational exposure, evaluating the biological impact of different time-points of exposure through a longitudinal approach (pre-, during and post- fire season). Here, we aim to describe the preliminary data concerning the Bio4Fox study population characterization - sociodemographic and occupational related - in the pre-fire season. Preliminary data collected via self-administered questionnaires will be further used to perform a comprehensive assessment of firefighters' occupational exposure and related health impacts.

2. Methods

Around 175 wildland northern Portuguese firefighters, from 14 fire stations, were involved in this study. Participants were initially fully informed about the nature and the study – in a face-to-face approach - stressing the possibility of stop at any time. In case of acceptance, individuals were asked to sign an informed consent approved by the University of Porto Ethic Committee. The individual characteristics of the participants were collected through a comprehensive questionnaire that was applied in the first phase of the study (pre-exposure; 2021) comprising questions on sociodemographic factors, lifestyle, health status, occupational history (as firefighter or/and other profession) and environmental exposures.

Preliminary data related with the sociodemographic and occupational context are here described through means, standard deviation, percentages, and frequencies. Reported height and weight was used to calculate Body Mass Index (BMI - kg/m²).

3. Results/Discussion

We present preliminary data collected from 175 professionally active firefighters - 143 males and 32 females. A greater proportion of men performing firefighting activities is part of the Portuguese reality; in 2016 there were about 28308 firefighters, being 5119 woman and 23189 men (INE, 2016). The mean age of participants was 37.88±11.03 and 35.62±9.99 for men and woman, respectively. BMI of this group of firefighters was 27.35±4.08kg/m². According to World Health Organization criteria only 27% (n=48) were in the category of normal weight (range, 18.5–24.9 kg/m²) with the remainder, 41% (n=73) and 24% (n=43), being either pre-obese (range, 25.0–29.9 kg/m²) and obese (≥ 30.0 kg/m²) correspondingly. Previous studies also found higher rates of overweight levels (BMI ≥ 25 kg/m²) in firefighters when compared with the general population (Poston et al., 2011; Soteriades et al., 2011).

A total of 56% (n=98) reported to have accomplished the 12th grade, 24% (n=43) claimed to have the 9th grade or less and only 13% (n=23) declared to have completed university education. The majority of the participants (88%; n=155) reported to be voluntary firefighters, a common trend verified in the Portuguese firefighting system. The average length of service in firefighting activities was 15.94±10.23 years indicating a considerable life period of firefighting exposures. In fact, data shows that around 15% (n=26) of the individuals began their firefighters' activities (i.e., learning/training) between 12 – 16 years old, whereas more than a half (52%; n=92) started their activities within 17 and 22 years old. Around 26% (n=46) of individuals only started after turning 23 years old.

Regarding functions performed in firefighter activity, 30% (n=53) reported to have driver functions, 27% (n=47) indicated to provide support to emergency services, 26% (n=46) incorporate the permanent intervention team (EIP), 10% (n=18) mentioned to be telephone operator, 7% (n=12) to perform rescue activities, 7% (n=12) reported to have command activities and 1% (n=2) declared to have administrative functions. Concerning the mean time/day spend in some of the referred activities, long periods of work were reported: the most of firefighters (45%; n=79) spend more than 10 hours in their duties, while 35% (n=62) and 13% (n=22) spend 8-9hours and less than 8hours, respectively.

Firefighters are exposed to different hazards in their occupational context. Figure 1 presents an overview of the occupational exposures that were referred by the participants.

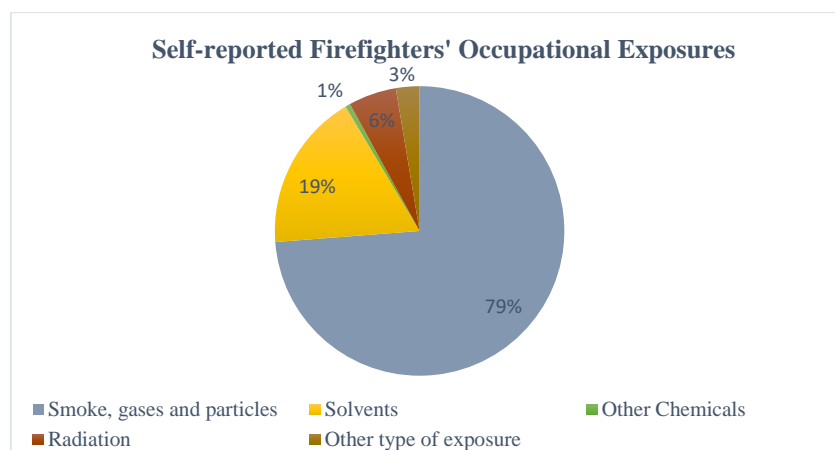


Figure 1 - Percentage of individuals that reported to be exposed to different hazards.

Data indicates that firefighters are mostly exposed (according to their risk perception) to smoke, gases and particles in their activities. Indeed, firefighters may be required to participate in firefighting activities (e.g., fire suppression, fuel management) with a certain regularity. As example, around 15% (n=27) of individuals reported to be exposed to fire in the week before, indicating a mean period of exposure of 2.08±6.66 hours/week.

Although in fewer proportions, firefighters also stated to be exposure to solvents (e.g., combustible), radiation and other type of exposures/chemicals.

When asked about the use of PPE during participation on firefighting activities, most individuals (97%; n=170) reported to use PPE, such protective clothes, boots, respiratory protection, gloves, protective glasses and helmet. PPE to be used by firefighters during their activities is regulated (Despacho nº3974, 2013) however, there is a general reluctance to wear protection since it adds physiological demands and heat stress upon the user (IARC, 2010) and the respiratory protection typically used is not ideal to effectively protect firefighters in wildfires context (Austin, 2008).

Concerning the health problems, 3% (n=6) of the individuals reported having diagnosed respiratory problems and 2% (n=3) heart disease. Figure 2 shows the felt symptomatology in the last month (non-related with colds/flu).

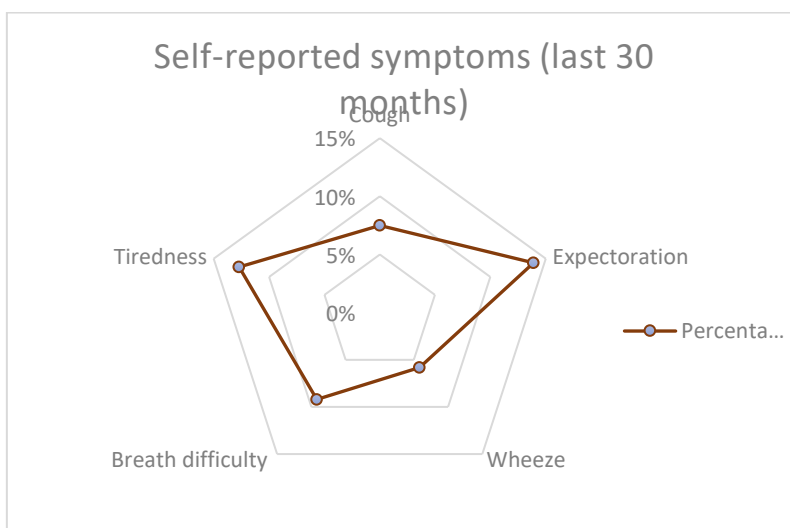


Figure 2 – Percentage of self-reported symptoms in the last 30 days among study group.

Expectoration (14%; n=24) and tiredness (13%; n=22) were the most common symptoms reported, followed by breath difficulty (9%; n=16), cough (7%; n=13) and wheezing (6%; n=10).

Regarding some aspects of their lifestyle, 31% (n=55) declared drinking alcohol regularly; 18% (n=31) have a daily consumption of wine whereas 23% (n=41) have a daily consumption of beer. In this group, thirty-eight percent (n=67) of individuals never smoked, 22% (n=38) were former smokers and 37% (n=65) current smokers (mean of 15 cigarettes/day).

4. Conclusions and future perspectives

There are no doubts that firefighters have one of the most dangerous and demanding occupations in the world being exposed to a variety of hazards. In the present study, we observed a high percentage of firefighters that indeed assumed to be exposed to particles, smoke and gases in their occupational context. This finding is particularly concerning due the long periods of work and the length of service that were described. Firefighters may have different physical and psychological demanding tasks that are many times accompanied by dangerous exposures. The stressful nature of this occupation may be related with some individual behaviours (e.g., smoking habits, alcohol consumption, high BMI) that were here observed.

Overall, present findings offer a glimpse of Bio4Fox study population. The characterization of population is a very important step to have a broad perspective of the relevant factors that must be considered in further analysis.

This ongoing study is expected to contribute for a comprehensive risk assessment of firefighting occupational exposure and for the establishment of recommendations/good practices to improve firefighters' working conditions as well as for the definition of policies and prevention strategies highly needed in this sector. The characterization of Portuguese firefighters' occupational exposure and potential health risks is particularly relevant because Portugal is one of the European countries more highly affected by forest fires. Finally, it is also essential to promote a wise fuel management in forests, because reducing the amount of fuel or changing

its arrangement before a wildfire can prevent or attenuate severe fire behaviors as well its impacts on human health.

5. Acknowledgments

This work received financial support by the project PCIF/SSO/0017/2018 by the Fundação para a Ciência e a Tecnologia (FCT), Ministério da Ciência, Tecnologia e Ensino Superior (MCTES) through national funds. Filipa Esteves, recipient of PhD grant UI/BD/150783/2020, is supported by FCT and by the European Social Fund (ESF). Joana Madureira, under the grant SFRH/BPD/115112/2016, is supported by FCT and by ESF, through Programa Operacional Capital Humano (POCH). The authors also acknowledge the ISPUP (UIDB/04750/2020) and ITR (LA/P/0064/2020).

6. References

- Austin, C. (2008). *Wildland Firefighter Health Risks and Respiratory Protection (Report R-572)*. Montreal, Quebec, Canada: IRSST (Institut de recherche Robert-Sauvé en santé et en sécurité du travail).
- Flannigan, M. D., Amiro, B. D., Logan, K. A., Stocks, B. J., & Wotton, B. M. (2006). Forest Fires and Climate Change in the 21ST Century. Mitigation and adaptation strategies for global change, 11(4), 847-859. doi:10.1007/s11027-005-9020-7.
- Gaughan, D. M., Cox-Ganser, J. M., Enright, P. L., Castellan, R. M., Wagner, G. R., Hobbs, G. R., Bledsoe, T. A., Siegel, P. D., Kreiss, K., & Weissman, D. N. (2008). Acute upper and lower respiratory effects in wildland firefighters. *Journal of occupational and environmental medicine*, 50(9), 1019-1028.
- IARC. (2010). *Painting, firefighting, and shiftwork (Vol. 98)*: IARC Press, International Agency for Research on Cancer.
- INE, I.P., (2016). *Inquérito às entidades detentoras de corpos de bombeiros*.
- LeMasters, G. K., Genaidy, A. M., Succop, P., Deddens, J., Sobeh, T., Barriera-Viruet, H., Dunning, K., & Lockey, J. (2006). Cancer risk among firefighters: a review and meta-analysis of 32 studies. *Journal of occupational and environmental medicine*, 48(11), 1189-1202.
- Manisalidis, I., Stavropoulou, E., Stavropoulos, A., & Bezirtzoglou, E. (2020). Environmental and health impacts of air pollution: a review. *Frontiers in public health*, 8.
- Naeher, L. P., Brauer, M., Lipsett, M., Zelikoff, J. T., Simpson, C. D., Koenig, J. Q., & Smith, K. R. (2007). Woodsmoke health effects: a review. *Inhalation toxicology*, 19(1), 67-106.
- Navarro, K. M., Kleinman, M. T., Mackay, C. E., Reinhardt, T. E., Balmes, J. R., Broyles, G. A., Ottmar, R. D., Naher, L. P., & Domitrovich, J. W. (2019). Wildland firefighter smoke exposure and risk of lung cancer and cardiovascular disease mortality. *Environmental Research*, 173, 462-468.
- Poston, W. S., Haddock, C. K., Jahnke, S. A., Jitnarin, N., Tuley, B. C., & Kales, S. N. (2011). The prevalence of overweight, obesity, and substandard fitness in a population-based firefighter cohort. *Journal of occupational and environmental medicine*, 53(3), 266.
- Reinhardt, T. E. (2000). *Smoke exposure at western wildfires (Vol. 525)*: US Department of Agriculture, Forest Service, Pacific Northwest Research Station.
- Soteriades, E. S., Smith, D. L., Tsismenakis, A. J., Baur, D. M., & Kales, S. N. (2011). Cardiovascular disease in US firefighters: a systematic review. *Cardiology in review*, 19(4), 202-215.
- Schmuck, G., San-Miguel-Ayanz, J., Camia, A., Durrant, T., Boca, R., Liberta, G., Petroliagkis, T., Di Leo, M., Rodriguez Aseretto, R., Boccacci, F., Schulte, E. (2014). *Forest Fires in Europe, Middle East and North Africa 2013*. Retrieved from <https://publications.jrc.ec.europa.eu/repository/handle/JRC91373>.