January 2025

Firefighter Research Results 2022-2023

The goal of the Research & Development (R&D) Activity within the Fire Prevention & Safety (FP&S) Grant Program is to reduce firefighter line-of-duty fatalities and injuries through research to improve firefighter safety, health, or well-being.[1]

The Federal Emergency Management Agency (FEMA) made nine research and development awards under the Fiscal Year (FY) 2018 FP&S Grant Program for a total of $8,671,722. The projects below were awarded in 2019 and completed in 2022 and 2023.

Per- and Polyfluoroalkyl Substances (PFAS): Firefighter Exposure and Toxicity, University of Arizona, EMW-2018-FP-00086, Principal Investigator (PI): Jefferey Burgess

Figure 1. Aircraft rescue and firefighting (ARFF) live fire training.

A survey of 440 participating U.S. fire departments indicated 48% were using Aqueous Film Forming Foam (AFFF) or Alcohol-Resistant Aqueous Film Forming Foam (AR-AFFF), mainly during response calls involving aircraft fires, hazmat events, and vehicle fires. AFFF and AR-AFFF are known sources of per- and polyfluoroalkyl substances (PFAS), which have been associated with cancer in firefighters.

Testing of AFFF and Synthetic Florine-Free Foams (SFFF) revealed that some SFFF may have even greater toxicity than AFFF. For this reason, SFFF should be evaluated using toxicity testing before it is recommended for use in firefighting.

Additionally, firefighters may have increased serum PFAS levels from environmental sources such as PFAS found in fire station drinking water. A comprehensive assessment is needed to understand where firefighters are exposed to PFAS to mitigate future health risks.

Additional Information: Firefighters face cancer risks from harmful chemicals. Here's how they're working to limit exposure, https://www.azcentral.com/story/news/local/arizona-environment/2023/10/16/firefighters-and-scientists-collaborate-to-reduce-pfas-exposure/70905073007/.

[1] Learn more at: https://www.fema.gov/grants/preparedness/firefighters/safety-awards/research-development

Investigation of Design, Comfort, and Mobility Issues for Female Firefighter Personal Protective Clothing (PPC), Florida State University, EMW-2018-FP-00202, PI: Meredith McQuerry

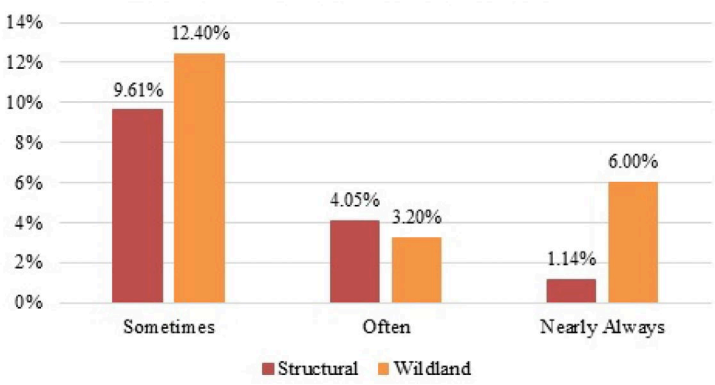

Figure 2. Female firefighters: Survey results showing how frequently female firefighters choose not to wear a piece of PPC due to fit issues.

Firefighting gear was originally designed for the male human form. To support the development of women's PPC, this project produced the first and largest U.S. female firefighter anthropometric database.

Grant results indicate that female firefighters are wearing PPC with significant fit issues that not only reduce their comfort and restrict their mobility but pose increased safety risks related to occupational exposure. Women in the fire service experience injuries at rates higher than their male counterparts. Coats and pants were identified as the areas of female firefighter protective clothing with the greatest opportunities for design and fit improvement according to end user feedback and anthropometric data.

Additional Information: Personal Protective Clothing Inequities for Female Structural and Wildland Firefighters, https://digital.clarionevents.com/clarionsupplements/2023_ppe (see pages 16-17).

Total Worker Health (TWH) for Wildland Firefighters, Oregon Health and Science University, EMW-2018-FP-00284, PI: Kerry Kuehl

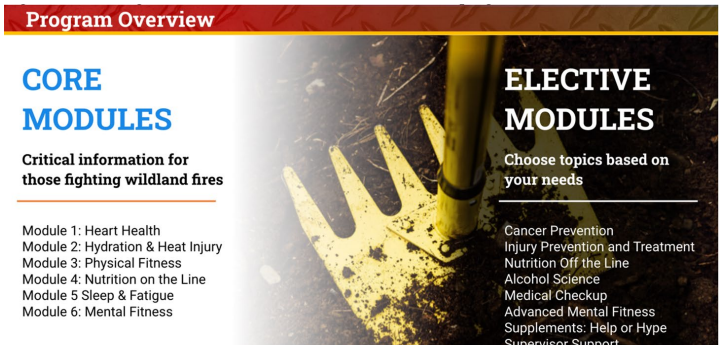

Figure 3. Modules of the Total Worker Health training program developed under this grant.

This project developed the first reported TWH program specific to the needs of firefighters in the wildland and wildland urban interface (WUI).

The project surveyed 50 firefighters over four months. After completing the program, 80% agreed or strongly agreed that the program was easy to use. Comparing results with the pre-training survey, participants reported that they better understood their risks for heart disease and cancer, as well as their blood pressure. Importantly, they had greater intentions to get a physical examination following the program. The project produced an online TWH

training program, Advancing the Well-Being of Wildland and WUI Firefighters, available cost free at https://wildland.ohsu.edu/firefighters/health.html.

Additional Information: Improving the Health and Safety of Wildland Firefighters, https://www.iawfonline.org/wp-content/uploads/2022/09/Wildfire-Magazine-Q3-2022-for-web.pdf, (see pages 36-40).

Module for Rapid Detection of Gases from Fire and Smoke, University of Central Florida, EMW-2018-FP-00329, PI: Kausik Mukhopadhyay

Figure 4. Terahertz laser set-up with mixtures of aerosols being recorded in the presence and absence of object interference.

This project investigated the capabilities for rapid and accurate detection of hazardous gases from fires utilizing terahertz (THz) spectroscopy. With sufficient power, terahertz-based gas detectors have the potential to remotely detect the release of hazardous gases from fires with high accuracy and near-zero interference from smoke, soot, and dust. Detection is based on the spectral fingerprints of gases. Laboratory measurements with a low-power THz laser system and published data were used to build a spectral fingerprint library for gases hazardous to firefighters. These are needed to develop a practical detection device.

Low-cost high-power silicon germanium terahertz emitter/detectors could enable a hand-held device that would detect toxic, flammable, and dangerous gases or organics in a few seconds with 95% accuracy without the need for calibration.

Evaluating Interoperability of Firefighter First Responder Ensembles, North Carolina State University, EMW-2018-FP-00401, PI: Roger Barker

Current material-level tests in National Fire Protection Association (NFPA) standards do not capture the full system-level performance of ensembles worn by responders. This project improved firefighter protection through the introduction or advancement of seven system-level test methods that have now been included in Annex G of the newly revised NFPA 1970 standard.

The newly developed dynamic PyroMan™ manikin demonstrated that thermal protection is impacted by movement during a flash fire exposure, and turnout design elements such as those for increased particulate-resistance can mitigate the potential for burns. The project demonstrated the value of systems-level testing of ensembles available to wildland and WUI firefighters to determine the benefits of a modular approach to protective clothing.

Figure 5. Wildland / WUI ensembles evaluated using sweating manikins: NFPA 1977 wildland ensemble (left), particle blocking (middle), and standard turnout outer shell (right).

The sweating manikin ensemble evaluations showed no significant difference in predicted total heat loss values when the wildland pack was worn or not. Additionally, the number of layers was the main determining factor in the ability of heat to escape the ensemble. The wildland and particulate-blocking wildland ensembles showed no significant difference when worn only with the base layer.

Additional Information: TPACC Researcher Unveil "Game-changing" Technology to Test Firefighter Thermal Wear, https://textiles.ncsu.edu/news/2024/03/tpacc-researchers-unveil-game-changing-technology-to-test-firefighter-thermal-wear/

Cancer among Indiana Firefighters: Case-Control Studies, National Institute for Public Safety and Health, Inc., EMW-2018-FP-00562, PI: Steven Moffatt

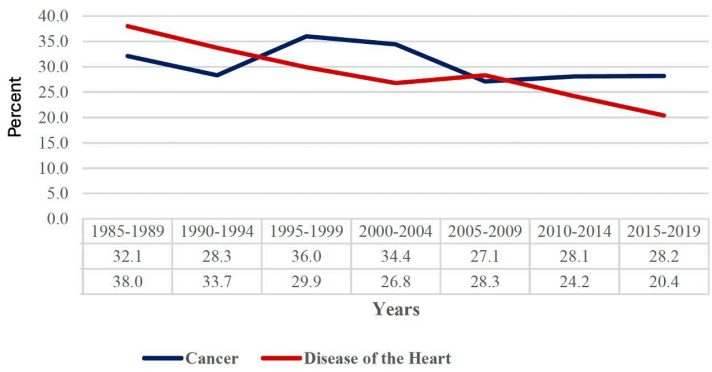

Figure 6. Heart disease and cancer deaths 1985-2019 for male Indiana firefighters.

Evidence suggests that firefighters are exposed to carcinogens at work and have an increased risk of cancer when compared to the general population. This project linked together state registries, fire department and medical records, and cancer risk questionnaires to identify occupational, medical, and lifestyle factors associated with firefighter cancer. The findings can be used to develop cancer prevention guidelines and target health interventions.

Investigators reported a similar downward trend in both cancer and heart disease deaths as other studies have found. The proportion of Indiana firefighter deaths due to cancer surpassed heart disease from 1995-2019. Findings from this project will provide epidemiologic evidence regarding specific cancer risk factors among firefighters and thus, better guide fire service policies and other cancer prevention strategies.

Additional Information: Cancer and Potential Prevention with Lifestyle among Career Firefighters: A Narrative Review, https://doi.org/10.3390/cancers15092442.

Development and Testing of the Fire Service Health Drinking Toolkit (FSHDT), Pacific Institute for Research and Evaluation, EMW-2018-FP-00593, PI: Raul Caetano

Figure 7. Alcohol & the Fire Service: A Research Monograph

The problem of heavy drinking persists in the fire service. Problematic alcohol use patterns are strongly related to other behavioral health issues common among firefighters, such as stress, trauma, sleep disorders, depression, and suicide. This project developed and tested the FSHDT that would provide firefighters with instructional materials on alcohol consumption and consequences to educate and effectively motivate firefighters to take positive steps to reduce heavy drinking. As part of the project alcohol use norms among firefighters were assessed. Many firefighters were surprised to learn their typical levels of consumption were considered "binge drinking" by medical professionals.

Firefighters showed increased knowledge of the impact of alcohol on all health topics after completing online training. Over 70% of participants indicated they were likely or extremely likely to reduce their alcohol intake. Nearly 80% of participants indicated they were likely or extremely likely to avoid heavy drinking.

Additional Information: Alcohol & the Fire Service: A Research Monograph
https://static1.squarespace.com/static/5fecb650c2646617cb1e0599/t/6392430fc24b8d417a1a155c/1670529821120/Alcohol101_FINISHED-2022.pdf.

Development of Hand-Specific Model and Systems Tool, Iowa State University of Science and Technology, EMW-2018-FP-00649, PI: Guowen Song

The aim of this project was to devise a methodology for the evaluation of performance and innovative designs for firefighter protective gloves. A hand specific model was developed to simulate the thermal responses and potential injuries to hands under various environmental conditions and glove designs.

Numerical models offer an efficient, cost-effective, and safe method to explore hand thermal responses under various environmental conditions and physiological parameters. A testing chamber was constructed to house the hand-form manikin and equipment to simulate exposure hazards. Data from the hand-form manikin and human hand exposures were used to build the numerical model.

Figure 8. Model prediction of bare hand surface temperatures after 60 minutes exposure to a 0.05 m/s wind at 10 °C (left), 0 °C (middle), and -10 °C (right).

This project resulted in tools that can inform the design of next generation high performance gloves for the fire service. There is potential for a notable decrease in the incidence of hand burns and injuries. These injuries are among the most common and detrimental to firefighters, who rely heavily on hand function to perform their duties safely and effectively.

Additional Information: Analysis of glove local microclimate properties for various glove types and fits using 3D scanning method, https://www.cell.com/heliyon/pdf/S2405-8440(23)10804-8.pdf.

Characterization of Toxicants in the Particle Matter of Wildfire Smoke, Middle Tennessee State University, EMW-2018-FP-00668, PI: Mengliang Zhang

Knowledge of toxicants in the particulate matter of wildfire smoke is key to understanding the health and safety issues associated with smoke exposure. This project characterized levels of volatile organic compounds (VOCs) as well as polar organics, polycyclic aromatic hydrocarbons (PAHs), and metals carried by particulate matter (PM) contained in wildland fire smoke. Smoke samples were collected from the Silverado, Bond, Monument, and Windy wildfires in California during 2020 and 2021.

The findings from field samples collected from California wildfires will be used to help firefighters make informed decisions about protecting their health from potential adverse effects due to inhalation exposure.

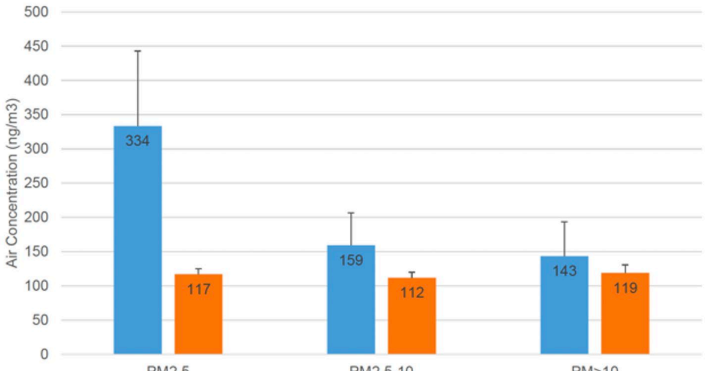

Figure 9. Total PAHs in particulate matter sampled during the Monument wildfire on two dates, one with severe smoke conditions (left) and the other with moderate (right).

Comprehensive findings of the chemical hazards of particulates and gases contained in the wildfire smoke generated by flaming and smoldering combustion have been published.

Additional Information: Evaluation of Mass Spectrometric Methods for Screening Polycyclic Aromatic Hydrocarbons in the Particulate Phase of Wildland/Biomass Smoke, https://link.springer.com/article/10.1007/s10694-022-01327-x.