# Wildland Firefighter Work History and Clinical Indicators of Cardiovascular Health

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**Objective:** To determine the association between the occupational history as a wildland firefighter (WFF) and clinical indicators of cardiovascular health. **Methods:** Among 2862 WFFs, we evaluated associations between the number of total days assigned on fire and high-risk categories of three clinically measured cardiovascular indicators. **Results:** Almost one-third (32%) of WFFs had one or more clinical measures that would place them in high-risk categories for body mass index, blood pressure, and total cholesterol. WFF work history was associated with some of these measures: odds ratio (and 95% confidence interval) for highest versus lowest tertile of days on fire were 1.4 (1.2, 1.8) and 1.2 (1.0, 1.5) for high-risk categories of body mass index and cholesterol, respectively. **Conclusion:** More frequent screening and targeted health promotion programs for WFFs are warranted to increase awareness of cardiovascular risk and prevention strategies.

**Keywords:** cholesterol, blood pressure, body mass index (BMI), occupational history, wildland firefighters (WFFs)

## LEARNING OUTCOMES

After reading this article, the audience will be able to:

- Describe the prevalence of risk factors such as hypertension, hypercholesteremia, and obesity among wildland firefighters (WFFs).
- Evaluate the association between history of WFF days assigned to fire and clinical indicators of cardiovascular health.
- Understand the potential for cardiovascular health monitoring programs among WFFs to protect long-term health.

In 2021, wildland firefighters (WFFs) were deployed to wildfires that burned approximately 10 million acres of land across the United States to perform fire suppression duties.[1] Work conditions are often arduous, requiring that WFFs be physically fit, strong, and in good cardiovascular health.[2,3] These work conditions involve exposure to different environmental factors such as ambient temperature and toxic gases that negatively impact cardiorespiratory health of WFFs.[4–7] The increasing trend of very large wildfires and longer fire seasons across the United States[8] implies that WFFs will continue to face exposure to health hazards on the job.

Through work tasks regularly performed on wildfires, WFFs are directly exposed to health hazards such as smoke exposure, heat exposure, and high demand of physical labor or arduous duty. Each of these factors could acutely (ie, during or shortly after the wildfire event) increase risk of a cardiovascular event, among the leading cause of WFF fatalities.[9] In contrast, an occupation with high physical demand such as wildland firefighting should translate to a lower risk of lifetime cardiovascular disease.[10,11] Several studies have documented specific air pollutant exposures among WFFs actively engaged in fire suppression activities, including fine particulate matter ($PM_{2.5}$),[12] polycyclic aromatic hydrocarbons,[13] carbon monoxide,[14] and volatile organic compounds.[15] Although WFF smoke exposure is known to be hazardous, the impact of long-term, repeated exposures on WFF health is not well studied. Recent research by Navarro et al[16] estimated increased risk of lung cancer and lifetime cardiovascular disease mortality among WFFs based on cumulative $PM_{2.5}$ exposure estimates across working years and relative risk estimates from population-based epidemiological studies. However, very few studies with direct clinical measures have explored the long-term cardiovascular health impacts of wildland firefighting.

Notably, although many of the respiratory health risks to WFFs have been documented cross-sectionally, the relationship between the length of a WFF's career fighting fires and impacts on cardiovascular health has not been well-studied. To understand the possible effect of time spent as a WFF and cardiovascular health, we evaluated associations between the number of total days assigned on fire and three clinically measured cardiovascular indicators (body mass index [BMI], total cholesterol, and systolic [SBP] and diastolic blood pressure [DBP]). Here, we hypothesize that greater number of days assigned to a wildfire will be associated with greater cardiovascular risk.

## METHODS

### Study Population and Study Design

This cross-sectional study followed the STROBE (STrengthening the Reporting of OBservational studies in Epidemiology) reporting guidelines (Supplemental Digital Content, http://links.lww.com/JOM/B638). There are two main data sources for this study: the Department of Interior Medical Standards Program (DOI

MSP) and the Incident Qualifications and Certification System (IQCS). One of the purposes of DOI MSP is to ensure that arduous duty WFFs (ie, performing work in difficult environmental conditions over long shifts) are medically fit to perform their work.[17] Therefore, DOI MSP conducts a comprehensive medical screening of WFFs at

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Reporting follows the STROBE guidelines. The data underlying this article will be shared on reasonable request to the corresponding author.

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entry and afterward at 3-year intervals. The DOI MSP examination includes tests for hearing, cardiovascular measures, vision, respiratory function, endocrine measures, some infectious diseases such as tuberculosis, and other important aspects of physical health. A standard protocol is followed at health facilities across the United States contracted to conduct the DOI MSP screening examinations. Concurrent with these clinical assessments, the examination also records demographic characteristics such as age, sex, race, health history, and health behaviors such as smoking history.[17] We include here data from 11,051 WFFs between the ages of 17 and 65 years who had a DOI MSP screening examination conducted between 2014 and 2018.

Worker history was captured from the IQCS, an interagency information system that tracks responder incident qualifications for the federal partners of the National Wildfire Coordinating Group.[18] IQCS retains the occupational history of active WFFs including types of events to which WFFs are deployed, types of fuels of the events, qualification of WFFs (arduous duty or nonarduous duty positions), and operational period or days assigned to those fire events.[18] We queried the IQCS system on December 1, 2020, for matches to WFFs that were part of the 2014 to 2018 MSP program. As the IQCS system retains only active WFFs, we captured only DOI MSP participants who were still active at the query date. From those data, for each WFF, we calculated the number of total days assigned on fire for arduous duty (n = 3901; Fig. 1). The IQCS occupational history records start in 2002, and each WFF's IQCS record was right-censored at the time of their MSP DOI examination. Among the 3901 WFFs, 1039 did not have working history before DOI MSP or were out of age range 17 to 65 years (Fig. 1). After merging the two datasets, 2862 WFFs were retained for analysis.

## Health Measures of Interest

There are eight commonly measured cardiovascular health indicators: BMI, total serum cholesterol, SBP and DBP, glucose level, diet, physical activity, nicotine exposure, and sleep health.[11] Diet, sleep health, and physical activity were not captured in the DOI MSP medical screening examinations. We present self-reported smoking exposure, but the primary measures of interest for this study were the objective clinical measures of BMI, total serum cholesterol, and SBP and DBP as DOI MSP. High-risk categories of BMI, cholesterol, and blood pressure are associated with decreased life expectancy and cardiovascular disease mortality and morbidity.[19–21] BMI was calculated from recorded height and weight of WFFs. Total cholesterol and blood pressure (SBP and DBP) are clinically measured following laboratory procedures.[17] Data were screened for out-of-range values following Centers for Disease Control and Prevention guidelines.[22–24] The continuous clinical measures were also grouped into clinically relevant categories: obese (≥30 kg/m$^2$), overweight (25 to 29.9 kg/m$^2$), and normal weight (<25 kg/m$^2$) for BMI, hypercholesterolemia (≥240 mg/dL), borderline-high (200 to 239 mg/dL), and normal cholesterol (<200 mg/dL) based on cholesterol level, and hypertension (SBP ≥140 mm Hg odds ratio [OR] DBP ≥90 mm Hg), prehypertension (SBP 120 to 139 mm Hg and/or DBP 80 to 89 mm Hg), and normal blood pressure (SBP <120 mm Hg and DBP <80 mm Hg) based on SBP, and DBP.[25]

## Statistical Analyses

In descriptive analyses, we evaluated the distribution of age, sex, race, days on fire, and cardiovascular risk factors in the study sample. We evaluated the association between work history (days assigned on fire) and measures of cardiovascular health using linear regression for continuous outcomes and logistic regression for categorical outcomes. Continuous outcomes included BMI, total cholesterol, and blood pressure measures. Categorical outcomes were generated from these continuous measures as described previously. We selected covariates for inclusion in analyses that were hypothesized to be related to both worker history and cardiovascular health. All data were analyzed using R Studio 4.1.0 (The R Foundation for Statistical Computing, Vienna, Austria) and STATA 15.1 statistical software (StataCorp, College Station, TX).

# RESULTS

We excluded out-of-range data according to Centers for Disease Control and Prevention guidelines (*Laboratory Procedure Manual: Cholesterol*, 2017; *Anthropometry Procedures Manual*, 2016; *Blood Pressure Procedure Manual*, 2019).[22–24] The acceptable ranges for height and weight were more than 0 to 107.1 inches (higher than 0 to 2.7 m) and 32 to 790 lb (14.5 to 358.3 kg), respectively. The

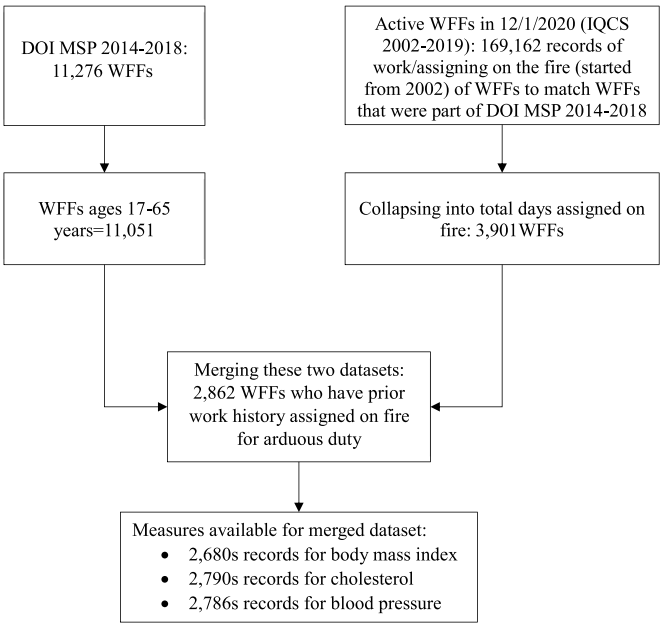


**FIGURE 1.** Flowchart showing merge of datasets and final analytical sample. WFF, wildland firefighter; DOI MSP, US Department of Interior Medical Standards Program; IQCS, Incident Qualifications and Certification System.

**TABLE 1.** DOI WFF Demographic Characteristics and Work History (N = 2,862)

| Demographic Characteristics | WFFs, n (%) |
|---|---|
| Race | |
| Non-Hispanic African | 28 (1.0) |
| Asian | 20 (0.7) |
| Non-Hispanic Caucasian | 1,918 (67.0) |
| Hispanic | 151 (5.3) |
| Not recorded | 157 (5.5) |
| Others | 588 (20.6) |
| Total | 2,862 (100) |
| Sex | |
| Female | 172 (6.0) |
| Male | 2,469 (86.3) |
| Not recorded | 221 (7.7) |
| Total | 2,862 (100) |
| Age | |
| 17–29 y | 1,378 (48.2) |
| 30–39 y | 1,087 (37.0) |
| 40–49 y | 279 (9.8) |
| 50–64 y | 118 (4.1) |
| Work history | |
| Days on fire, median (IQR) | 59.5 (158) |
| Total | 2,862 (100) |

IQR, interquartile range.

acceptable range for cholesterol was 5 to 1000 mg/dL. We accepted SBP where DBP is available, or vice versa, SBP is higher than DBP, both of the measures are more than 0, and SBP is less than or equal to 300. We also removed observations for both SBP and DBP when DBP was recorded as less than 40 mm Hg. Following these data cleaning steps, we retained 2680 BMI, 2790 cholesterol, 2778 SBP, and 2778 DBP measures. Table 1 summarizes demographic characteristics for the 2862 WFFs with occupational history. The majority of the WFFs were non-Hispanic Caucasian (67%), with the second largest group reporting more than one race, other (20.6%). The majority of WFFs were male (87%) and 17 to 29 years old (48.2%).

Table 2 shows that the median (interquartile range [IQR]) BMI was 26.7 kg/m$^2$ (10 kg/m$^2$). The median (IQR) cholesterol for WFFs was 180 mg/dL (46 mg/dL), which lies in the normal range of cholesterol. The median (IQR) SBP and DBP are 122 mm Hg (16 mm Hg) and 78 mm Hg (12 mm Hg), respectively. Table 2 also represents the numbers of WFFs (and corresponding percentages) that fall into clinical categories according to measures of BMI, cholesterol, and blood pressure. Approximately 65%, 29%, and 67% of WFFs were outside the normal range for BMI, total cholesterol, and blood pressure, respectively. When we consider the three clinical measures for obesity, hypercholesterolemia, and hypertension, 32% of WFFs had at least one of the three cardiovascular risks (27.3% with one, 4.3% with two, and 0.5% with all three high-risk measures). Tobacco smoking was reported to be 18% of WFFs. However, we did not have the information of nicotine pouches and chew of smoking history among this worker population.

Table 3 shows the crude and adjusted ORs and 95% confidence intervals (95% CIs) by tertile (T) of days on fire for nonnormal versus normal categories of BMI, cholesterol, and blood pressure. The second tertile (T2: OR, 1.3; 95% CI, 1.1 to 1.7) and third tertile (T3: OR, 1.4; 95% CI, 1.2 to 1.8) relative to first tertile (T1) of days assigned to fire were associated with significantly increased odds of being obese or overweight. WFFs in the third tertile of days assigned to fire relative to the first tertile were 1.2 (95% CI, 1.0 to 1.5) times more likely to have hypercholesteremia or borderline-high cholesterol. We also conducted the linear regression analyses for cholesterol, which shows that the days assigned on fire of WFFs is significantly associated with cholesterol level. In analyses adjusted for age category, sex, and race, the cholesterol level increases 0.016 mg/dL (95% CI, 0.006 to 0.026 mg/dL) per day increase of assigned on fire. Although the ORs were in the expected direction, logistic regression analyses of hypertension and prehypertension compared with normal blood pressure did not show significant associations with tertile of days assigned to fire.

## DISCUSSION

Demands on WFFs are intense and growing, yet the long-term impact of wildland firefighting on worker health is unclear. Although many studies explore the acute health effects of wildland firefighting (such as the effect of $PM_{2.5}$ exposure and impacts on acute respiratory health), very few studies explore the effect of WFF days assigned to

**TABLE 2.** WFF Measures and Cardiovascular Risk Categories (N = 2,862)

| Cardiovascular Risk Categories | 2,862 (%) | Minimum, Maximum |
|---|---|---|
| BMI, median (IQR) | 26.7 kg/m$^2$ (10 kg/m$^2$) | 19.2, 48.5 |
| Normal weight | 935 (34.9) | |
| Overweight | 1,085 (40.5) | |
| Obese | 660 (24.6) | |
| Cholesterol, median (IQR) | 180 mg/dL (46 mg/dL) | 112, 486 |
| Normal cholesterol | 1,980 (71.0) | |
| Borderline-high cholesterol | 596 (21.3) | |
| Hypercholesterolemia | 214 (7.7) | |
| Blood pressure | | |
| Systolic blood pressure, median (IQR) | 122 mm Hg (16 mm Hg) | 80, 201 |
| Diastolic blood pressure, median (IQR) | 78 mm Hg (12 mm Hg) | 40, 149 |
| Normal blood pressure | 920 (33.1) | |
| Prehypertension | 1,717 (61.8) | |
| Hypertension | 141 (5.1) | |
| Combined risk factors* | | |
| High-risk category for one or more of the measures | 819 (32.0) | |
| One high-risk category | 698 (27.2) | |
| Two high-risk categories | 109 (4.3) | |
| All three high-risk categories | 12 (0.5) | |
| Self-reported smoking history | 260 (18.1) | |

*Combinations of obesity, hypercholesteremia, and/or hypertension.
BMI, body mass index; IQR, interquartile range.

**TABLE 3.** Adjusted (by Age Category, Sex, and Race) ORs for High-Risk Categories of Cardiovascular Measures by Tertile of Occupational History

| | Adjusted OR With 95% CI |
|---|---|
| BMI: obesity and overweight vs normal weight | |
| 0–28 d assigned on fire (first tertile) | Reference |
| 29–122 d assigned on fire (second tertile) | 1.3 (1.3, 1.7) |
| ≥123 d assigned on fire (third tertile) | 1.4 (1.2, 1.8) |
| Cholesterol: hypercholesterolemia and borderline-high vs normal cholesterol | |
| Days assigned on fire (first tertile) | Reference |
| Days assigned on fire (second tertile) | 1.1 (0.9, 1.3) |
| Days assigned on fire (third tertile) | 1.2 (1.0, 1.5) |
| Blood pressure: hypertension and prehypertension vs normotensive | |
| Days assigned on fire (first tertile) | Reference |
| Days assigned on fire (second tertile) | 1.2 (1.0, 1.5) |
| Days assigned on fire (third tertile) | 1.1 (0.9, 1.3) |

CI, confidence interval; IQR, interquartile range; OR, odds ratio.



arduous work over multiple years on cardiovascular health. The study conducted by Navarro et al[16] was among the first attempt to explore the effect of long-term $PM_{2.5}$ exposure on WFF cardiovascular health, projecting cumulative risk using an exposure-response relationship from the epidemiological literature. In our previous study, we investigated the status of subclinical measures of cardiovascular health of WFFs by comparing those measures with the US general population. We found that there were higher frequencies of WFFs with indication of hypertensive and prehypertensive status compared with the US general population.[26] To further investigate this association, we explored the association between WFF days assigned on fire for arduous work and clinical measures related to cardiovascular health. We hypothesized that cumulative days in arduous duty work would be associated with markers of cardiovascular health. Our analysis shows that some, but not all, indicators of cardiovascular risk were associated with WFF worker history. BMI and cholesterol level of WFFs were significantly associated with WFF days assigned on fire, adjusting for age, sex, and race. Hypertension and prehypertension are not associated with days assigned on fire for WFFs.

Our finding that cholesterol level of WFFs is significantly associated with days assigned on fire is supported by prior studies that found WFF's cholesterol levels were significantly higher after wildfire season due to deterioration of lipid metabolism.[27,28] When deterioration of lipid metabolism occurs, it accelerates the restoration of lipids in the body, resulting in increased storage of fat in the body. Investigators noted that WFF total body fat increased after wildfire season.[27] Notably, BMI does not distinguish between percentage of muscle, fat, and other body components, and it is possible that fat increases without gains in total body weight due to loss in mass of other components. Prospective investigation of changes in fat and body composition would help to clarify if this association between WWF history and BMI translates to cardiovascular risk.

Prior work by Semmens et al[29] suggests that more years of experience as a WFF are associated with higher odds of self-reported hypertension and arrhythmia among WFFs. We did not see similar associations in our sample. However, although blood pressure was not associated with WFF arduous duty days assigned to fire, we did observe a high frequency of workers with indication of hypertension or prehypertension (67%).

Previous studies have demonstrated that the intensity of WFF seasonal work may affect their cardiovascular health, particularly that arduous work conditions may lead to elevated occurrence of cardiac arrest and stroke among WFFs when they are on duty.[9] Heart attacks account for approximately 26% of WFF fatalities during or shortly after a wildfire event.[9] For longer-term outcomes, we would anticipate that occupations with high physical activity demands align with guidance for protecting against adverse cardiovascular outcomes,[11] although some studies suggest that years-long engagement in physically demanding work may result in greater risk of developing coronary heart disease.[30] Other factors beyond physically intense work may influence WFF cardiovascular health and contribute to elevated rates of cardiac arrest and stroke. During the peak wildfire season, WFFs often engage in work at night and frequently have shift work that is associated with sleep disturbances, disruptions to the biological clock, less physical exercise, and higher BMI.[31,32] Shift work and frequent calls from duty are also responsible for alteration of timing of eating behavior, meal skipping, and eating faster, possible factors that could impact overall diet and, subsequently, cardiovascular health.[33–35] A large portion of WFF's diet when on duty consists of fatty foods to fill the caloric demand of the physical work, thereby increasing cholesterol levels and cardiovascular risk.[36] In addition to these impacts on WFF work patterns and diet, WFFs are exposed to a variety of factors that have relevance to cardiovascular health. For example, wildfire smoke can be characterized by exposure to $PM_{2.5}$, carbon monoxide, and polycyclic aromatic hydrocarbons that are known to be associated with a variety of effects that impact cardiovascular risk, including inflammation, oxidative stress, dysrhythmia, and atherosclerosis.[37–39]

There are several limitations to this study. First, we do not have information of potentially important confounders, mediators, or effect modifiers, including diet, exercise, marital status, education, and household income. Second, we do not have any information on prescription or utilization of medications specific to cardiovascular disease or control of blood pressure or cholesterol. Third, we use days assigned to fire as indication of arduous duty activity, but we do not have access to actual job tasks that can vary considerably when engaging in firefighting duty. Fourth, we are not able to account for work experience prior to employment with DOI. These WFFs could have been employed by another agency prior to employment with DOI.

## CONCLUSION

Wildland firefighting is a highly demanding job that requires WFFs to be physically fit and in good cardiovascular health. In this study, we found significant associations between days assigned on fire for arduous duty and total cholesterol and obese/overweight status. Although we did observe an association between WFF work history and hypertension, we did observe high rates of hypertension and prehypertension among WFFs. This worker population could benefit from further monitoring of cardiovascular risk as well as programs to mitigate these risks. In addition, prospective studies of WFF cohorts would help to further elucidate modifiable individual- and workplace-level factors that influence cardiovascular risk.

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