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Cardiovascular risk factors among wildland firefighters compared to the US general population

Md. Zahid Hasan, MS[1], **Erin O. Semmens, PhD**[1], **Kathleen Navarro DuBose, PhD**[2], **L. Kaili McCray, PhD**[2], **Curtis W. Noonan, PhD**[1,*]

[1]Center for Population Health Research, School of Public and Community Health Sciences, University of Montana

[2]Office of Wildland Fire, Department of the Interior

Abstract

Objective: To compare subclinical measures of cardiovascular health among wildland firefighters (WFFs) to the US general population.

Methods: Our cross-sectional study compared body mass index (BMI), total cholesterol, and blood pressure in 11051 WFFs aged 17 to 64 years using Department of the Interior Medical Screening Program (DOI MSP) clinical screening examinations between 2014 – 2018 to National Health and Nutrition Examination Survey (NHANES) of 2015–2016 cycle using adjusted logistic regression analyses.

Results: The logistic regression model shows significantly higher odds of hypertension and prehypertension in WFFs (2.84 times more with 95% CI: 2.28; 3.53) than US general population. There were no consistent differences in BMI or total cholesterol between the two population.

Conclusion: Hypertension and prehypertension were more prevalent in WFFs compared to the US general population which suggests the need for actions for protecting against cardiovascular disease among WFFs.

Keywords

Wildland firefighters (WFFs); hypertension; Body Mass Index (BMI); total cholesterol; blood pressure

Introduction

The area burned by wildfires each year has grown more than five-fold in the United States (US) from the year 1983 to 2021.[1] In 2021 alone, approximately 59 thousand wildfires burned a total area of 10.1 million acres.[2] As the climate continues to warm due to global warming, and due to widespread drought across the western U.S.[3] the frequency and impact of wildfires will continue to grow.[4,5] This increase in fire affects the people

*Corresponding author: Curtis W. Noonan, Center for Population Health Research, University of Montana, Missoula, MT 59812; curtis.noonan@umontana.edu.

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living in communities near where wildfires occur and wildland firefighters (WFFs) who are directly or indirectly involved in suppressing wildland fires.[6,7] The common workplace hazard of WFFs include smoke, arduous duty, high physical stress, sleep disturbance and deprivation, shift work, heat exposure, and dehydration.[8,9,10, 11] Approximately 19,000 federal WFFs worked under the Department of Agriculture's Forest service and four agencies of Department of Interior (DOI).[12]

Wildland firefighting is a physically demanding, and young and healthy individuals tend to self-select into this arduous duty occupation. Nevertheless, WFFs are at risk of stroke, myocardial infarction, and thermal stress.[13] The National Wildfire Coordinating Group[14] reports that cardiovascular disease was the largest contributor to sudden deaths in WFFs from 2007 to 2016. Beyond these acute outcomes, WFFs may be increased long-term risk of cardiovascular disease. Applying estimated WFF $PM_{2.5}$ (particulate matter in the air which is less than 2.5 micron in aerodynamic diameter) exposures to epidemiologically-based risk estimates for $PM_{2.5}$ and lifetime cardiovascular mortality, WFFs may be at a 16–30% increased risk of lifetime cardiovascular mortality.[15]. Few studies have measured subclinical cardiovascular risk measures among WFFs, and underlying disease risk may better inform both acute and long-term cardiovascular disease risk estimates in this population.

We present here a cross-sectional study to test the hypothesis that cardiovascular risk measures (Body Mass Index (BMI), total cholesterol, and systolic and diastolic blood pressure) among WFFs are different from those observed in a representative sample of the US general population. BMI, total cholesterol, and blood pressures are three important indicators of cardiovascular health.[16] The risks of cardiovascular diseases such as vascular damages, hypertension, coronary artery disease, congestive heart failure, stroke, arrhythmias and sudden cardiac death have direct linkage with the high BMI or obesity.[17] Cholesterol is a crucial component for physiological function. but high cholesterol level is adverse to cardiovascular health and can lead to atherosclerosis.[18] Elevated blood pressure is related to increased risk for stroke, atrial fibrillation, and heart failure.[19] A better understanding of the status of subclinical indicators/risks of cardiovascular in WFFs may inform actionable, preventive health efforts to reduce risk of cardiovascular morbidity and mortality in this high-risk worker population. See STROBE checklist in Supplementary Digital Content (SDC) file.

Methods

Study Population:

The study is based on clinical and survey data from a comprehensive medical screening program conducted by the Department of the Interior Wildland Fire Medical Standards Program (DOI MSP) between 2014 and 2018.[20] The DOI WFFs are federal WFFs employed by Bureau of Indian Affairs, Bureau of Land Management, National Park Service, and U.S. Fish and Wildlife Service.

The DOI MSP is conducted in various health facilities across the US by trained health personnel. Though DOI MSP is conducted at different health facilities across the US, a minimum standard protocol is maintained. DOI WFFs complete DOI MSP screening exams at entry to employment and at three-year intervals thereafter to maintain status as an arduously qualified WFF. The purpose of the medical screening program is to verify that WFFs are free from medical conditions that would put them at risk for acute adverse health outcomes in the work setting. In addition, every DOI WFF must pass the work capacity test to meet a minimum fitness requirement for safe and efficient job performance. This dataset includes 11,051 WFFs between the ages of 17 and less than 65 years.[20]

To compare the cardiovascular health of WFFs with the US general population, we used the 2015–2016 National Health and Nutrition Examination Survey (NHANES). NHANES is an extensive cross-sectional health and nutritional survey, conducted by the Centers for Disease Control and Prevention (CDC), National Center for Health Statistics. NHANES is a complex probabilistic survey that is representative of the noninstitutionalized population of the United States. Notably, NHANES collects data across the US without exclusions based on age, sex, or race/ethnicity. Similar to the DOI MSP screening program data, NHANES includes data from a physical examination at a clinical examination center and augments clinical data with health history and health behavior information ascertained through interview. To align with the DOI MSP dataset, we eliminated children under 17 from the NHANES dataset as well as adults 65 years and older. In total, the 2015–16 dataset included 4,771 participants, ages of 17 to less than 65 years. To facilitate statistical comparison across populations, we created a new variable, “population,” with two categories, “WFF”, and “US general population”.

Measures:

To understand cardiovascular health status of WFFs and the US general population, we evaluated three clinical measures (Body Mass Index (BMI), total cholesterol, and systolic and diastolic blood pressure) and two self-reported measures (smoking and diabetes status). BMI for WFFs was calculated from height and weight measures; BMI was reported directly in NHANES. We categorized BMI into obese (>=30 kg/m^2), overweight (25 to 29.9 kg/m^2), and normal weight (<25 kg/m^2).[16] Both datasets used a single measurement of total cholesterol (more information is added in additional materials section of this paper). Cholesterol and blood pressure measures were also summarized by risk categories according to Lloyd- Jones et al.[13]. We categorized total cholesterol into hypercholesterolemia (≥240 mg/dL), borderline high (200–239 mg/dL), and normal level (<200 mg/dl). Single values for systolic blood pressure (SBP), and diastolic blood pressure (DBP) were reported for the MSP, whereas we averaged across three SBP and DBP measures for the NHANES population. We categorized blood pressure into hypertension (SBP ≥140 mmHg OR DBP ≥90 mmHg), prehypertension (SBP 120–139 mmHg and/or DBP 80–89 mmHg), normal blood pressure (SBP < 120 mmHg and DBP < 80).[16] Data for these clinical measures were censored for out of range values according to CDC guidelines and NHANES.[21, 22, 23] See also SDC for data cleaning procedures.

Smoking status among WFFs was based on self-reporting during their medical exams, asking whether they smoke cigarettes, e-cigarettes, cigars, or any other tobacco products. Smoking status for NHANES participants was based on several questions related to smoking such as number of cigarettes they smoked within particular durations. The WFFs were asked whether they ever had diabetes or not, and NHANES participants were asked whether they were told by a doctor or health professional that they had diabetes other than during pregnancy.

Covariates:

To enable comparison of cardiovascular variables between WFFs and the US general population, we described both datasets (DOI MSP and NHANES) based on age, sex, and race. For age, we used the following categories: 17–29 years, 30–39 years, 40–49 years, 50- less than 65 years. For sex, we used male and female. Race was categorized as Non-Hispanic Caucasian, Non-Hispanic African, Hispanic, Asian and Others.

Statistical analysis:

To compare the prevalence of cardiovascular health risk categories, we used age standardization based on four categories (17–29 years, 30–39 years, 40–49 years, 50–65 years). We also compared these two populations to understand whether they differed by sex, or race using a chi-square test. We presented the mean, median, minimum, 25th percentile, 75th percentile, and maximum value for continuous variables. For age-standardized continuous measures we compared population means using t-tests, and for categorical variables we compared age-standardized populations using chi-square tests. Finally, we used regression to compare measures between populations while accounting for other covariates such as sex and race. For all analyses with NHANES data, we employed survey weighting to account for the complex survey design. The goal of survey weighting is to increase the representativeness of NHANES dataset to the US general population using primary sampling unit (psu), 2 years sample weight (persWeight or WTINT2YR), and masked variance unit (strata). We used survey command (svy in STATA) to calculate the corresponding number of US general population for demographic and cardiovascular factors. We used logistic regression to assess differences between WFFs and the general population for dichotomous outcomes. Regression models were adjusted by age, sex, and race. Covariates (age, sex, and race) were selected based on their hypothesized relationships with both occupational history and cardiovascular health. For the analysis, we used R 4.1.0 version and STATA 15.1 version.

Results:

Table 1 summarizes the demographic characteristics of WFFs compared to the weighted NHANES sample. WFFs in the age groups 17 to <30 years and 30 to < 40 years were considerably overrepresented (38% and 33% in WFF compared to 27% and 21% in NHANES). The WFFs had few individuals (10%) aged 50 to < 65, compared to approximately one-third of the NHANES sample in this age range. WFFs were more likely to be male (85% to 49%; p <0.001). The two populations had similar proportions reporting race/ethnicity as non-Hispanic Caucasian (61.6% and 60.1%). Compared to the NHANES sample lower proportions of WFFs reported race/ethnicity as non-Hispanic African American, non-Hispanic Asian or Hispanic, but a large proportion of WFFs (31.9%) could not be classified into single race/ethnicity groups or were missing information on race/ethnicity. The chi-square test suggests that the composition of race, and sex are different in WFFs than NHANES population.

Valid measures for BMI, cholesterol and blood pressure were captured for 10,382–10,810 of the 11,051 MSP participants and for 4,236–4,535 of the 4,771 NHANES participants (See SDC Figures S1 and S2, respectively). Table 2 summarizes statistics for five measures for WFFs compared to the US general population. Mean BMI (29.3 vs. 27.8 kg/m^2; P: <0.001) and total cholesterol (191.3 vs. 184.4 mg/dl; P=0.001) were higher in the NHANES sample relative to WFFs. WFFs had a higher average SBP and DBP than the NHANES sample. The proportion with indication for hypertension was higher in WFFs than NHANES ((6.2% vs. 5.8%; P:<0.001). Diabetes was reported among 8% of NHANES population compared to <1% of WFFs. Current smoking was reported among 22% of NHANES population compared to 16% of WFFs.

Table 3 presents percentages of WFFs in the high-risk categories of each cardiovascular risk variable. The percentage of BMI values greater than or equal to 30 kg/m^2 (indicating obesity) was higher (38.2% (95% CI: 34.7%−42%)) in the NHANES population compared to WFFs (28.9% (95% CI: 27.9%−29.9%)). The prevalence of hypercholesterolemia, cholesterol values greater than or equal to 240 mg/dl, was similar in the WFF and NHANES samples. Self-reported smoking and diabetes were more common among US general population compared to WFFs. In contrast with the other measures, high blood pressure was more common among WFFs. The proportion of WFFs with indication of hypertension (SBP ≥140 mmHg or DBP ≥90 mmHg) was higher among WFFs (7.4% (95% CI: 6.8%−8.1%)) compared to NHANES participants (5.8% (95% CI: 5.0%−6.8%)). The categorization of one or more variables as high-risk indicates that at least one high-risk factor such as obesity, hypertension, hypercholesterolemia affected 47.7% (95% CI: 45.2% −50.2%) of the US general population compared to 39% (95% CI: 37.8%−40.2%) of WFFs. Obesity, hypercholesterolemia, hypertension, current smoker, and self-reported diabetes are lower among Female WFFs than US general population and male WFFs.

Table 4 shows the regression results for risk categories of BMI, cholesterol, and blood pressure adjusting for age, sex and race. The logistic regression model for BMI (Table 4) shows that there is no significant difference of risks of having obesity or overweight between the WFFs and NHANES groups. Similarly, the logistic regression model for total cholesterol (Table 4) shows that there is no significant difference of risks of having hypercholesterolemia or borderline high cholesterol between WFFs and US general population. The logistic regression model for blood pressure (Table 4) shows that WFFs have 2.8 times more risks of having hypertension or prehypertension (95% CI: 2.3, 3.5) than US general population.

Based on the three cardiovascular health risks (obesity/overweight, hypercholesterolemia/ borderline cholesterol, hypertension/prehypertension), the prevalence of meeting more than 1 risk category is higher in WFFs than US general population, although this was primarily evident among males (Figure 1).

Discussion:

Given the fitness requirements for arduous duty firefighting, we expected that WFFs would be a particularly healthy subset of the general population. WFFs must annually pass a aerobic performance test, known as the arduous pack test, which includes a walking tolerability test with weights.[9] In addition to these tests, some WFFs, for example smokejumpers and hotshots, need to pass more extensive physical tests to make sure they have the strength and endurance necessary to carry out their particular jobs.[9] However, in a large sample of federal WFFs, we found that, relative to the US general population, WFFs had a higher prevalence of hypertension and prehypertension. We observed no difference between WFF and NHANES with respect to overweight/obese and high cholesterol status. In addition, compared to the US male general population, a greater proportion of male WFFs had more than one cardiovascular risk factor.

A variety of job-related factors may put WFFs are greater risk of poor cardiovascular health. For example, the adverse conditions include fatigue, sleep deprivation, and increased mental and physical stress, all associated with decreased cardiovascular functions such as abnormal heart rate variability (HRV).[11, 24] WFFs also experience multiple exposures, such as smoke which can contain numerous pollutants, including carbon monoxide, formaldehyde, nitrogen oxides, polycyclic aromatic hydrocarbons, volatile organic compounds, and secondary particulate matter (PM) with demonstrated links to cardiovascular diseases such as hypertension, dysrhythmia, atherosclerosis, peripheral thrombosis, and myocardial ischemia.[9, 25, 26] Apart from these, cardiovascular health of WFFs may also affected by environmental factors such ambient temperature in their workplace. The heavy physical work in the increased ambient temperature while suppressing wildfire may result in increased internal body temperature which may cause heat stroke, cardiac failure, dehydration, and heat related illness.[27] The subclinical measures reported here were from a medical standards program and not temporally related to the physical and environmental risks of arduous duty wildland firefighting work. Nevertheless, if further study confirms a greater baseline presence of hypertension among the WFF worker population, the work-related physical and environmental factors may translate to greater than anticipated cardiovascular risk.

These findings of our study agree with earlier findings where it was observed that self-reported elevated blood pressure or hypertension was associated with extended work history among WFFs.[28] One hypothesized mechanism whereby WFFs are at greater risk of CVD events is due to job task-related aberrations in heart rate variability (HRV) that is associated with risk of coronary heart disease (CHD), specifically acute myocardial infarction (AMI).[24, 29] Job-specific factors related to WFF cardiovascular risk include dehydration, high intensity of physical activity, acclimatization, humidity, and ambient temperature. All of these factors increase the risk of developing heat-related disorders like heat exhaustion, heat stress, and heat stroke in WFFs.[27] Each of these factors can translate to risk of acute cardiovascular event, particularly among workers that may have underlying risk factors for cardiovascular disease.

We acknowledge several limitations to this work. First, WFFs perform a variety of tasks according to credentials and experience, and further investigation of how these subclinical measures vary across job titles is warranted. Second, we do not comprehensively define cardiovascular health; rather we focus on select measures of BMI, total cholesterol, and blood pressure. These three objective measures were based on similar clinical procedures between the two populations. However, we do note some procedural discrepancy in blood pressure measures with one recorded measure for WFFs versus an average of three measures for the NHANES sample. The self-reported variables such as smoking and diabetes were less useful for comparison purposes as the corresponding questions were phrased in different ways for the two populations. We also do not have more detailed information on use of nicotine pouches and chew that can be common in this population. Further, the self-reported information may have several biases, including the chance of WFF under-reporting of diabetes or smoking status due to fear of the negative impact on job assignment or qualification. Third, the NHANES may not be an appropriate population to compare to WFFs, and we were unable to account for occupation among the comparison population. Finally, the MSP does not include data on medications the WFFs may have been using for control of hypertension, diabetes, or hypercholesterolemia nor on other potential confounders such as education level or household income. The above data limitations are not surprising given that the agency's medical standards program is charged with determining medical qualifications for WFF arduous duty work and not primarily designed as a surveillance tool. Nevertheless, these data limitations indicate opportunities for improving data collection strategies should the agencies employing WFFs transition to a health surveillance paradigm.

This study is among the earliest attempt to explore the cardiovascular health in a large sample of federal WFFs. This study demonstrates how routinely collected clinical measures as part of a medical standards program can be used to examine the health status of WFFs. These findings indicate the need to explore these and other cardiovascular health measures more deeply to understand the cardiovascular risk profile of WFFs. Future research should also assess how workplace factors and environmental exposures may be associated with cardiovascular risks.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Disclaimer

The findings and conclusions in this report are those of the author(s) and should not be construed to represent any official Department of the Interior or US Government determination or policy.

Data availability

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

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Learning outcomes:

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

- Describe a way to compare cardiovascular health among WFFs and a sample from the US general population.
- Evaluate the prevalence of hypertension among WFFs compared to the US general population.
- Understand that subclinical measures can be used to better describe acute and long-term cardiovascular disease risk among this worker population.

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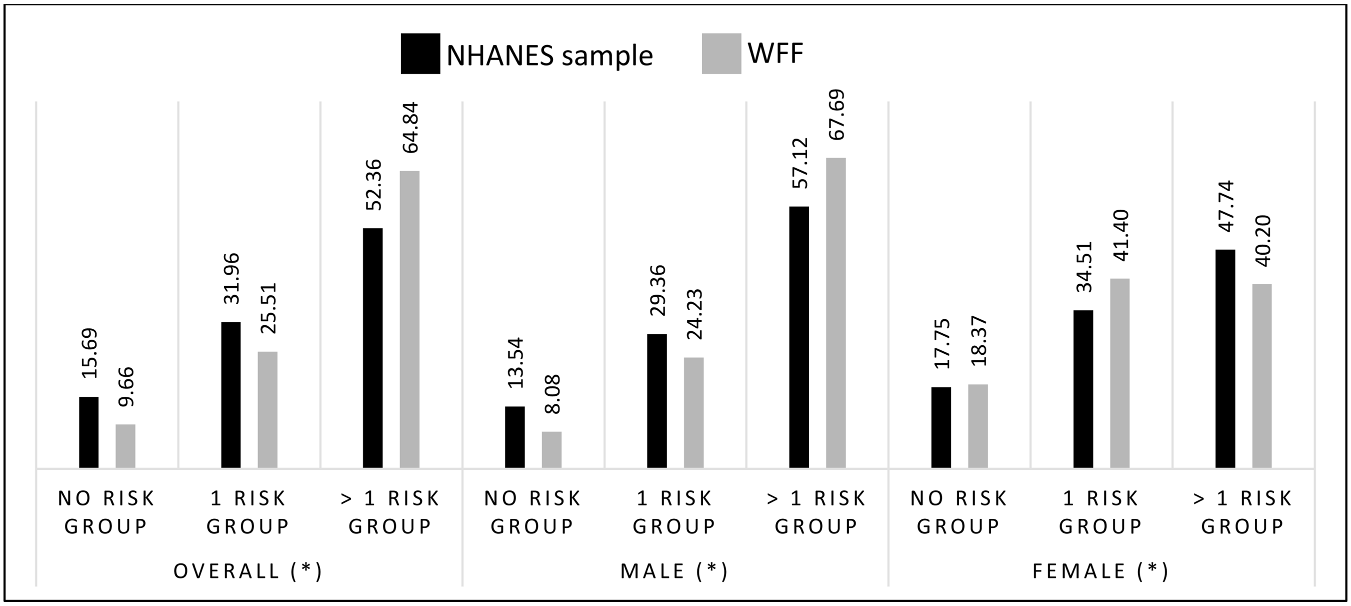

Figure 1.

Comparison of age-standardized prevalence (%) of 3 cardiovascular risks among WFFs and the survey-weighted NHANES sample (risk here consists of poor and intermediate categories of BMI, blood pressure and cholesterol).[a]

* mark represents statistically significant difference based on chi-square test of risks (no risk group, 1 risk group, and more than one risk group) between NHANES sample and WFFs.

[a] BMI >= 30 kg/m^2, obese and BMI: 25.0–29.9 kg/m^2, overweight; Total Cholesterol: ≥240 mg/dL, hypercholesterolemia; Total cholesterol: 200–239 mg/dL, borderline high cholesterol; Blood Pressure: SBP ≥140 mmHg or DBP ≥90 mmHg, hypertension; Blood Pressure: SBP 120–139 mmHg and/or DBP 80–89 mmHg, prehypertension

Table 1:

Distribution of WFFs and U.S. general population by their demographic characteristics.

Demographic characteristics	WFFs, n (%)	Weighted NHANES (%)	p value
Race			<0.001
Non-Hispanic African	81 (0.7%)	12.5%	
Asian	61 (0.6%)	6.2%	
Non-Hispanic Caucasian	6,810 (61.6%)	60.1%	
Hispanic	573 (5.2%)	17.6%	
Not Available	632 (5.7%)	-	
Others	2,894 (26.2%)	3.7%	
Total	11,051 (100%)	100%	
Gender			<0.001
Female	652 (5.9%)	50.8%	
Male	9,425 (85.3%)	49.2%	
Not Available	974 (8.8%)	-	
Total	11,051 (100%)	100%	
Age			<0.001
17–29.99 years	4,214 (38.1%)	27.3%	
30–39.99 years	3,623 (32.8%)	20.9%	
40–49.99 years	2,049 (18.5%)	20.9%	
50–64.99 years	1,165 (10.5%)	30.9%)	
Total	11,051 (100%)	100%	

Table 2:

Summary statistics for cardiovascular variables among WFFs and NHANES samples.

Variables	Statistics	WFFs between 2014–2018	NHANES US Population 2015–2016	Weighted NHANES US Population 2015–2016	P-value (t-test or chi-square)
BMI (kg/m^2)	N Mean, Sd Min, 25th percentile, median, 75th percentile, max	10,382 27.8 ±5.1 8.5, 24.3, 27.2, 30.6, 85.9	4,535 29.3±7.4 14.5, 23.9, 28.1, 33.2, 67.3	187,698,660 29.3 ± 0.3	<0.001
Total Cholesterol (mg/dl)	N Mean, Sd Min, 25th percentile, median, 75th percentile, max	10,810 184.4±37.9 38, 158, 181, 207, 486	4,315 188.9±41.4 77, 160, 185, 213, 545	180,327,896 191.3 ±1.6	0.004
Systolic Blood Pressure (mm Hg)	N Mean, Sd Min, 25th percentile, median, 75th percentile, max	10,804 123.0±13.2 65, 114,122, 130, 224	4,236 120.9±16.0 85, 110, 119, 129, 231	176,479,728 120.0± 0.4	<0.001
Diastolic Blood Pressure (mm Hg)	N Mean, Sd Min, 25th percentile, median, 75th percentile, max	10,804 77.1±10.2 2, 70, 78, 84, 149	4,236 70.5±11.3 11, 63, 71, 77, 117	176,479,728 70.9± 0.5	<0.001
Hypertension	Total n (%)	10804 (6.2%)	4,236 (7.6%)	176,479,728 (5.8%)	<0.001 *
Self-reported Diabetes	Total n (%)	4763 (0.9%)	4,768 (9.8%)	196,766,306 (7.8%)	<0.001 *
Current Smoking	Total n (%)	4582 (16.2%)	4,618 (22.2%)	192,797,119 (21.9%)	<0.001 *

(*) Asterisk mark represents chi-square test

Table 3:

Percentage of people in the high-risk categories of each cardiovascular risk variable

Variables	Number of WFFs (n)	WFFs Overall % (95% CI); (Male %, Female %)	NHANES US Population 2015–2016 Overall % (95% CI); (Male %, Female %)
BMI (kg/m2)	10382	28.9% (27.9%−29.9%); (M=29.9%; F=17.3%)	38.24% (34.7%−42%); (M= 36.7; F=39.7%)
Systolic Blood Pressure (mmHg)	10,804	7.4% (6.8%−8.1%); (M=7.9%; F=3.4%)	5.8% (5.0%−6.8%); (M=7.2%; F=4.6%)
Diastolic Blood Pressure (mmHg)	10,804		
Total cholesterol (mg/dl)	10,810	9.8% (9.1%−10.5%); (M=10%; F=7.4%)	12.4% (10.5%−14.5%); (M=12.4%; F=12.4%)
Current Smoking	4582	15.6% (14.3% −16.9%); (M=16.7%; F=5.5%)	21.8% (19.7%−24.1%); (M=24.4%; F=19.3%)
Self-reported Diabetes	4763	1.6% (1.1%−2.3%); (M=1.7%, F=0.7%)	7.8% (6.8%−8.9%); (M=8.4%; F=7.1%)
At least one high risk category among 3 risk categories (obesity, hypertension, hypercholesterolemia)	9996	39% (37.8%−40.2%); (M=40.4%; F=27.6%)	47.7% (50.2%−45.2%); (M=46.8%; F=48.5%)

*High risk categories: BMI >= 30 kg/m^2, obese; Blood Pressure: SBP ≥140 mmHg or DBP ≥90 mmHg, hypertension; Total Cholesterol: ≥240 mg/dL, hypercholesterolemia; Smoking: Current Smoker. M=Male; F=Female; percentages are age-standardized

Table 4:

The influence of wildland firefighter occupational status, relative to the general population, on cardiovascular risk factors.

		Population sample, n (%)		Odds ratio (OR)*	
Measure	**Category**	**WFF**	**NHANES**	**Crude OR**	**Adjusted OR (95% CI)**
BMI	Normal weight	3,378	60,574,176	Ref.	Ref.
	Obesity + overweight	7,004	127,124,484	1.0	1.1 (0.87, 1.30)
Cholesterol	Normal	7,299	109,363,603	Ref.	Ref.
	Hypercholesterolemia + moderately high cholesterol	3,511	70,964,293	0.7	1.0 (0.70, 1.30)
Blood pressure	Normal blood pressure	3,457	92,554,912	Ref.	Ref.
	Hypertension + prehypertension	7,347	83,924,816	2.3	2.8 (2.3, 3.5)

*Logistic regression analyses adjusted for age, race/ethnicity, and sex

*BMI >= 30 kg/m^2, obese and BMI: 25.0–29.9 kg/m^2, overweight; Total Cholesterol: ≥240 mg/dL, hypercholesterolemia; Total cholesterol: 200–239 mg/dL, borderline high cholesterol; Blood Pressure: SBP ≥140 mmHg or DBP ≥90 mmHg, hypertension; Blood Pressure: SBP 120–139 mmHg and/or DBP 80–89 mmHg, prehypertension