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The wildland firefighter exposure and health effect (WFFEHE) study: cohort characteristics and health behavior changes in context

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Abstract

Objectives: Work is an under-recognized social determinant of health. There is limited research describing US wildland firefighter (WFF) workforce demographics or how to work associates with WFF health behaviors. In this study researchers characterized a WFF cohort and tested hypotheses that WFFs used tobacco, alcohol, and sugar-sweetened beverages (SSBs) differently over the course of the fire season and that different fire crews may exhibit different behavior patterns.

Methods: Researchers collected data in the field with 6 WFF crews during 2 consecutive fire seasons (2018 and 2019). WFF crews completed questionnaires before and after each season. WFFs with an initial preseason questionnaire and at least 1 follow-up questionnaire were included (n = 138). Descriptive statistics summarized WFFs' baseline demographic, employment, and health characteristics. Linear mixed models were used to test for changes in WFFs' substance use over time and assess crew-level differences. A meta-analysis of WFF longitudinal studies' population characteristics was attempted to contextualize baseline findings.

Results: WFFs were predominately male, less than 35 yr of age, non-Hispanic White, and had healthy weight. Smokeless tobacco use and binge drinking were prevalent in this cohort (52% and 78%, respectively, among respondents). Longitudinal analyses revealed that during the fire season WFFs' use of tobacco and SSBs increased and the number of days they consumed alcohol decreased. Crew-level associations varied by substance. The meta-analysis was not completed due to cross-study heterogeneity and inconsistent reporting.

Discussion: WFF agencies can promote evidence-based substance use prevention and management programs and modify working conditions that may influence WFF stress or substance use.

What's Important About This Paper?

Despite their important role in public safety, there is limited knowledge about the population characteristics of wildland firefighters (WFFs). Using a longitudinal design, this study addresses this gap by describing work histories, health behaviors, and other characteristics among a sample of WFFs. The observed characteristics, including seasonal changes in health behaviors, can inform health protection and promotion strategies for WFFs.

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Introduction

Tobacco, alcohol, and sugar-sweetened beverages (SSBs) contribute substantially to chronic disease morbidity, mortality, and lost productivity worldwide (Benziger et al. 2016; GBD 2016 Alcohol Collaborators 2018; Malik and Hu 2022). The prevalence of tobacco use (Syamlal et al. 2016) and binge drinking (Shockey and Esser 2020) vary widely between workers in different industries and occupations. The workplace is an important venue for preventing chronic diseases. Longitudinal studies with seasonal workers provide an opportunity to explore how health behaviors can change at work.

Wildfires are burning more acres across the United States and wildland firefighters (WFFs) are at the frontline suppressing and managing these threats. The US WFF population is understudied. The lack of standardized industry and occupation codes to distinguish WFFs from structural firefighters renders population-based surveys, such as the National Health Interview Survey, unable to produce representative demographic or health statistics for this increasingly important workforce. While individual investigators have reported characteristics of individual study populations, it is unclear how these populations compare to each other or to the US WFF population overall. Published studies have not yet reported WFFs' off-season activities or detailed work histories. For many WFFs, employment follows a seasonal cycle lasting from approximately May to October. Each season WFFs develop trust and social norms as a crew that strengthen their ability to work together in extreme environments. During the season, WFF crews are periodically deployed to wildfires, which can include physically demanding work, long hours, hazardous exposures, noise, injury risks, and stress. In a large cross-sectional study, researchers reported a high prevalence of substance use among WFFs, including 37% reporting smokeless tobacco use and 57% reporting binge drinking (O'Brien and Campbell 2021). These health behaviors may be maladaptive coping responses to psychological stressors encountered during fire incidents (e.g. witnessing human remains), physical demands of the work, or other factors related to being a WFF (Milner et al. 2020; O'Brien and Campbell 2021; Hamieh et al. 2022). A recent systematic review, however, found there have been no cross-season studies of WFF mental health (Koopmans et al. 2022). It is plausible that WFFs' use of tobacco, alcohol, and SSBs changes during the fire season in response to work-related stressors.

In this study, researchers from the Centers for Disease Control and Prevention (CDC) and National Institute for Occupational Safety and Health (NIOSH) used data from a longitudinal study of WFFs to address 2 objectives. First, researchers characterized a cohort of the wildland firefighter exposure and health effect (WFFEHE) study by demographics, employment histories and offseason activities, health behaviors, and health status, making comparisons to other US WFF research cohorts using meta-analytic techniques. Second, researchers examined longitudinal patterns of substance use (defined as the use of tobacco, alcohol, or SSBs) before and during 2 fire seasons. Hypotheses were that WFFs used tobacco, alcohol, and SSBs differently over the course of the fire season and that differences between fire crews may help explain differences between individuals.

Methods

Study design

The WFFEHE Study was designed as a 3-yr prospective cohort study to assess longitudinal changes in occupational exposures, chronic disease risk factors, and health outcomes (Navarro et al. 2021). Data collection started in 2018 and concluded after 2 fire seasons (2018 and 2019) due to safety concerns during the coronavirus disease 2019 (COVID-19) pandemic. WFF crews completed pre and post wildfire season questionnaires each study year. Due to the pandemic disruption, only participants with a baseline questionnaire in 2018 could complete 2 yr of data collection.

Setting

Researchers, the United States Forest Service (USFS), and the Department of the Interior National Park Service (DOI/NPS) recruited 6 WFF crews with duty stations in Colorado (n = 3) and Idaho (n = 3). Crews were selected based on the geographical locations of their duty stations, which were relatively close to each other and to researchers, however, crews were available to respond to fire incidents in other locations during the season. Researchers collected data at or near the duty stations and in the field. Five crews were Type 1 Interagency Hot Shot Crews (IHC), which perform more complex tasks than other crew types and are expected to meet higher fitness standards. One crew was a Type 2 Initial Attack Crew (T2IA), which has lower fireline qualification requirements and generally performs tasks with less complexity (USFS 2016).

Study population

Eligible WFFs were employed with 1 of the 6 selected crews and met physical fitness requirements. Researchers informed potential participants about the study's procedures, benefits, and risks, and invited WFFs to participate in the study. Participation was strictly voluntary. The study was approved and overseen by the NIOSH Institutional Review Board and protected by a Certificate of Confidentiality. Among

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the 154 WFFs who consented and participated in the WFFEHE Study, 138 completed an initial preseason questionnaire (baseline) and at least 1 follow-up questionnaire. Participants completed preseason questionnaires between April and May and postseason questionnaires between September and October.

Cohort characterization

Researchers described the WFFEHE cohort using self-reported sociodemographic characteristics, work histories, exposure histories, health conditions, and health behaviors. Unless described in this paragraph, results were reported as worded in the questionnaires. Age was derived from birth date and questionnaire date. Researchers measured participants' heights (cm) and weights (kg) to calculate baseline BMI in kg/m^2. Due to the relatively small number of WFFs identifying with racial or ethnic minority groups, race and ethnicity were categorized into 2 groups: "non-Hispanic White" and "all other races and ethnicities", including non-White race, multiple races, or Hispanic or Latino ethnicity. Participants reported their most recent non-WFF occupations with free text values. Researchers assigned free text values to major occupational groups using standard occupation codes with the NIOSH Industry and Occupation Computerized Coding System (NIOCCS) (NIOSH 2022). Participants indicated whether, in the prior 2 wk, they had used any medications or supplements from a prespecified list. Specific medications and supplements were grouped into the following categories: pain relievers (i.e. acetaminophen and nonsteroidal anti-inflammatory agents); cold, cough, or allergy medications; aspirin; creatine; stimulants (over-the-counter or prescription); and asthma inhalers.

In the absence of representative estimates of WFF demographic characteristics to assess the generalizability of study findings, researchers attempted a meta-analysis to compare the demographic characteristics of the WFFEHE cohort with other WFF studies included in 2 recent systematic reviews (Groot et al. 2019; Koopmans et al. 2022). One systematic review aimed to summarize the evidence of health impacts of occupational exposure to wildland fires (Groot et al. 2019). The other aimed to identify the impact of occupational exposure to wildland fires on physical, mental, and emotional health (Koopmans et al. 2022). These relatively broad foci suggested the reviews were likely to capture the vast majority of studies with populations, designs, exposures, and outcomes comparable to the WFFEHE study—namely longitudinal studies of US WFFs. Researchers abstracted demographic factors from all longitudinal studies involving US WFFs with measurements on 2 or more occasions. A researcher reviewed potentially eligible manuscripts to identify unique cohorts. Factors identified a priori included the number of participants in a cohort, as well as age, sex, racial, and ethnic distributions. After preliminary review, researchers determined smoking status and BMI were reported frequently enough to potentially be included in the meta-analysis. Researchers compared the WFF cohorts' age and BMI distributions using means and SD. Proportions were used for comparisons by sex and smoking status. Researchers analyzed statistical heterogeneity using Cochran's Q and I^2 tests (Borenstein et al. 2009). Statistical heterogeneity was considered high if the I^2 statistic was ≥50% and $P < 0.10$ on Cochran's Q test, moderate for $I^2 \geq 30\%$ or $P < 0.10$, and low if the I^2 statistic was <30% (Dickersin and Berlin 1992). Researchers created forest plots to visualize meta-analysis results.

Exposures

The primary exposure of interest in the regression analyses was WFF employment season, measured categorically by preseason and postseason periods. Time points were ordered in reference to participants' baseline questionnaires and could include a maximum of 4 measurements per participant [T1 (preseason baseline), T2 (year 1 postseason), T3 (year 2 preseason), and T4 (year 2 postseason)]. A secondary exposure of interest was the fire crew at baseline. We hypothesized that crew-level factors (e.g. social and workplace norms, exposure to psychologically harmful incidents, identical work and break schedules) may partially explain differences in behaviors among individual WFFs. Researchers anonymized workers' crews for the purposes of this study and treated the crew variable categorically.

Outcomes

Tobacco use at baseline, participants reported whether they had ever used any of 4 types of tobacco: cigarettes (at least 100 in their lives); cigars, cigarillos, or little filtered cigars (referred to as "cigars" throughout); e-cigarettes; or smokeless tobacco (CDC 2022). Researchers treated each tobacco type as a binary variable. Participants were categorized as never smokers if they indicated having never smoked 100 cigarettes, and current smokers if they had and also reported smoking cigarettes every day or some days at baseline. Participants reported having smoked 100 cigarettes but not currently were categorized as former smokers. Tobacco-related questions differed between baseline and follow-up. In follow-up questionnaires, all participants were asked whether they had used a given tobacco product in the prior 30 d (treated as a binary variable).

Alcohol use at baseline and each follow-up questionnaire, participants indicated whether they had

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consumed at least 1 drink of beer, wine, malt beverage, or liquor in the prior 30 d (phrased and treated as a binary variable). If they responded in the affirmative, they were asked during the prior 30 d how many days they had consumed at least 1 alcoholic beverage, how many times they had consumed 5 or more drinks (for men) or 4 or more drinks (for women) on any occasion (referred to as "binge drinking episodes" throughout), and the largest number of drinks they had on any occasion (CDC 2022). These values were treated as continuous variables and summarized with means and SD. Binge drinking was also treated as a binary variable, either none or "1 or more episodes" in the prior 30 d.

Sugar-sweetened beverages participants were also asked at each time point whether, during the past 2 wk, they had consumed SSBs on a daily or near-daily basis: *Do you drink any of the following on a daily or near daily basis? Soda (caffeinated): Yes/No; Energy Drinks: Yes/No*. Researchers treated each beverage type as a binary variable.

Statistical methods

Baseline characteristics not reported in the meta-analysis were described using counts, percentages, means, and SDs. Proportions, means, and CI characterizing select substance use behaviors were summarized at each time point in the study and represented graphically. Researchers suppressed data when 10% or more of anticipated values were missing or when cell counts were less than 5 (including at a given time point).

Logistic and linear models were developed to test for changes in substance use over time and to assess for relationships between substance use, time, and crew. Four generalized linear mixed models (GLMM) were used to assess the likelihood of select behaviors in the prior 30 d, including any cigarette use, cigar use, smokeless tobacco use, or binge drinking. Two GLMMs assessed the likelihood of daily behaviors in the prior 2 wk, including the use of soda or energy drinks. Additionally, 3 linear mixed-effects models (LMM) were developed to test for changes in each of the following: a mean number of days (in the prior 30) of alcohol use or binge drinking episodes; and the maximum number of alcoholic beverages consumed on any 1 occasion. Base models (both GLMM and LMM) included time as a fixed effect and random intercepts at the individual level. Variance–covariance matrices were specified as unstructured. After the base models were developed, a categorical variable for the crew was added, within which individuals were nested. The crew was modeled with a fixed effect and random intercepts. For each outcome, the base model and crew model were compared using Akaike's Information Criterion (AIC). Results were reported for the models with the lowest AIC values. Researchers specified, a priori, statistical significance for model parameters to be <0.05, though *P*-values were reported at 3 levels: <0.05, <0.01, and <0.001. Data were managed in Microsoft SQL Server Management Studio (v 18) and R (version 4.1.1) (Team 2021). Statistical analyses were conducted in R with the following packages: meta, tidyverse, lubridate, ggplot2, gridExtra, lme4, and patchwork.

Results

Table 1 displays participants' demographics and employment and exposure histories at baseline. Additionally, the cohort's mean age in years was 28.8 (95% CI: 27.8, 29.8; range: 19 to 48) and the mean BMI (kg/m^2) was 25.0 (95% CI: 24.5, 25.5; range: 17 to 36). Most respondents (93%) had WFF experience prior to baseline. Fewer had structural firefighting experience (13%). USFS was the most common previous WFF employer among returning WFFs (88%). Participants reported a wide range of occupations for their most recent non-WFF job and a variety of employment arrangements during the preceding offseason. The chemical exposures most frequently reported were diesel exhaust (73%) and solvents/paints (70%). Most respondents (93%) reported exposure to loud occupational noise in the past year.

Participants' baseline health conditions and behaviors are summarized in Table 2. While 27% of participants reported having ever experienced heat stress or heat stroke while fighting fires, only 4% reported having ever been told by a licensed healthcare professional that they had heat-related illness due to fighting fires. A quarter of participants reported having ever had an allergic or sensitivity reaction while fighting fires. The same percentage of participants reported tinnitus in the past 12 mo. The proportion of ever-users who reported substance use in the prior 30 d was highest for alcohol (90%) and smokeless tobacco (52%), followed by cigarettes (26%), e-cigarettes (17%), and cigars (10%). Participants who reported at least 1 alcoholic beverage in the prior 30 d drank approximately 13 d on average during that time period (mean = 13, SD = 8), had 4 binge drinking episodes (mean = 4, SD = 5), and drank a maximum of 7 drinks on a single occasion (mean = 7, SD = 3).

Figure 1 displays mean responses over time for health behaviors. Among the 138 WFFs included in this study, 135 had a health behavior measurement at T2, 63 at T3, and 56 at T4. Smokeless tobacco use was the most used tobacco product across all study years. The proportion of WFFs who reported using cigarettes, cigars, or smokeless tobacco appeared consistently higher postseason than in preseason, regardless of their baseline frequency. Any alcohol use in the past 30 d was consistently high across time points

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Table 1. Characteristics of the wildland firefighter population at baseline: demographics and self-reported employment and exposure histories (n = 138[a]).

	Number of respondents	Percent
Demographic Characteristics and BMI		
Age (yr)		
18 to 24	28	20.3
25 to34	86	62.3
35+	24	17.4
Sex		
Male	127	92.0
Female	11	8.0
Race/ethnicity		
White race, no Hispanic or Latino ethnicity	118	86
All other races and ethnicities	20	14
BMI (kg/m^2)		
Underweight, BMI < 18.5	ND	ND
Healthy weight, BMI = 18.5 to 24.9	74	54
Overweight, BMI = 25.0 to 29.9	52	38
Obese, BMI ≥ 30.0	9	7
Employment History at Baseline		
Previous work experience as a firefighter		
As a municipal or volunteer firefighter (structural)	18	13
As a wildland firefighter (n = 137)	129	93
Returning WFFs by prior employer(s)		
US Forest Service	121	88
DOI National Parks Service	24	17
DOI Bureau of Land Management	24	17
Local agency (including volunteer)	19	14
State agency	14	10
Contract fire agency	7	5
DOI Fish and Wildlife Service	5	4
Other (all <5)	11	8
Most recent non-WFF occupation[b]		
Construction and extraction occupations	23	17
Military job with rank and occupation not listed	8	6
Life, physical, and social science occupations	7	5
Education, training, and library occupations	6	4
Food preparation and serving-related occupations	6	4
Installation, maintenance, and repair occupations	6	4
Other	34	25
Missing or insufficient information	48	35
Off-season employment		
I was not employed or a student during the offseason	43	31
Employed part-time at another job	42	30
Student	32	23
Employed full-time at another job	29	21
Employed as a federal firefighter all year	19	14

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Table 1. Continued

	Number of respondents	Percent
Exposure History at Baseline		
Exposure to loud noise[c]		
Loud occupational noise in the past 12 mo	128	93
Loud nonoccupational noise for ≥10 h/wk, ever	83	60
Had a prior job or hobby resulting in contact with the following substances by breathing, touching, or swallowing		
Diesel exhaust	101	73
Solvents/paints	96	70
Products of combustion	80	58
Metals	79	57
Rock dust	70	51
Welding fumes	68	49
Pesticides	44	32
Asbestos	25	18
Acids/alkali	24	17
Biological agents	7	5
Coal dust	6	4

[a]The number of respondents may not equal the total sample size (n = 138) for several reasons—missing data, respondents were instructed to select all responses that applied, or data were suppressed (n < 5). Unless otherwise specified, the total sample size was used to calculate percentages.
[b]Free-text occupation data were coded with Standard Occupational Classification codes (major groups) using the NIOSH Industry and Occupation Computerized Coding System (NIOCCS).
[c]Loud noise: Noise so loud that they had to raise their voice to be understood or heard from 3 ft away.
Abbreviations: DOI = United States Department of the Interior; n = sample size; WFF = wildland firefighter.

(data not displayed), as was binary binge drinking. Daily soda uses in the prior 2 wk was consistently low. Daily energy drink use appeared slightly elevated at the postseason relative to preseason. Figure 1b displays detailed patterns of alcohol use during the prior 30 d. The number of days with alcohol use was lower postseason than in preseason, the number of days with binge drinking was relatively stable with a decrease in postseason year 2, and the maximum number of drinks on any 1 occasion appeared slightly higher postseason than in preseason.

Modeling results are presented in Table 3 with additional detail in Supplement 1. Researchers observed no significant changes over time in the odds of binge drinking, the number of days in the previous 30 with a binge drinking episode, the maximum number of alcoholic beverages on a single occasion, or daily soda use. WFFs' other substance use behaviors changed during the fire seasons, with the magnitude and direction of the change varying by substance. CIs were wide, but the odds of energy drink consumption were significantly higher postseason with no crew-level associations.

Adding a crew-level variable improved the fit of GLMMs for cigarette use and smokeless tobacco use. Two crews were significantly less likely than the reference crew to use cigarettes (OR = 0.17, 95% CI: 0.03, 0.8; OR = 0.09, 95% CI: 0.02, 0.5). One crew was significantly more likely to use smokeless tobacco than the reference crew (OR = 40.5, 95% CI: 3.0, 552.3). Adding a crew-level variable improved the fit of the LMM for the mean number of days with a binge drinking episode, as measured by the AIC, though no significant differences from the reference crew were detected.

The attempted meta-analysis could not be completed and pooled demographic and health characteristics could not be calculated, due to a high degree of heterogeneity and inconsistent reporting. The variability of these characteristics is presented in Fig. 2. The analysis included data from 16 manuscripts describing 18 cohorts in addition to data from this study (Rothman et al. 1991; Liu et al. 1992; Betchley et al. 1997; Ruby et al. 2003; Gaughan et al. 2008, 2014; Robinson et al. 2008; Adetona et al. 2011, 2017; Hejl et al. 2013; Smith et al. 2013; Cuddy et al. 2015; Coker et al. 2019; Marks et al. 2020; Nelson et al. 2020; West et al. 2020). Researchers identified high heterogeneity across WFF studies with respect to age [I^2 = 88% (95% CI: 81, 93%); Cochran's Q P < 0.01] and BMI [I^2 = 90% (95% CI: 80, 95%); Cochran's Q P < 0.01] with study

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Table 2. Characteristics of the wildland firefighter population at baseline: self-reported health history and behaviors (n = 138[a])

	Number of respondents	Percent
Health History at Baseline		
Ever experienced heat stress or heat stroke while fighting fires	39	27
Ever experienced an allergic or sensitive reaction to poison ivy, poison oak, or poison sumac while fighting fires	34	25
Experienced tinnitus in the past 12 mo	35	25
A doctor, nurse, or other health professional ever told respondents they had:		
Asthma	19	14
Pneumonia	14	10
Attacks of bronchitis	10	7
Anxiety	8	6
High blood pressure	8	6
Depression	6	4
Heat-related illness due to fighting fires	5	4
Health Behaviors at Baseline		
Cigarette use (n = 137)[b]		
Current	20	15
Former	37	27
Never	80	58
Ever used the following tobacco products		
Cigars, cigarillos, or little filtered cigars	126	91
Smokeless tobacco	120	87
e-Cigarettes	54	39
Substance use in the prior 30 d		
Any alcoholic beverage (n = 138)	124	90
Smokeless tobacco (n = 120)	62	52
Cigarettes (n = 57)	15	26
Cigars, cigarillos, or little filtered cigars (n = 126)	12	10
e-Cigarettes (n = 54)	9	17
Frequency of alcohol use in prior 30 d (n = 120)		
The mean number of days with alcohol use (SD)	13	8
Binge drinking in the prior 30 d		
0 episodes	27	23
1 to 4 episodes	65	54
5 to 9 episodes	16	13
10 or more episodes	12	10
Any episodes	93	78
Mean number of binges drinking episodes (SD)	4	5
Mean maximum number of drinks on a single occasion (SD)	7	3
Daily consumption of sugar-sweetened beverages in the prior 2 wk		
Energy drinks	9	7
Soda	8	6
Use of select medications and supplements, prior to 2 wk		
Pain relievers (e.g. acetaminophen and nonsteroidal anti-inflammatory agents)	66	48
Cold, cough, or allergy medications	32	23
Aspirin or medications containing aspirin	21	15

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Table 2. Continued

	Number of respondents	Percent
Creatine supplements	15	11
Stimulants (e.g. Adderall, 5-h Energy, and NoDoz)	9	7
Asthma inhaler	6	4

[a]The number of respondents may not equal the total sample size (n = 138) for several reasons—missing data, respondents were instructed to select all responses that applied, or data were suppressed (n < 5). Unless otherwise specified, the total sample size was used to calculate percentages.
[b]Current smokers reported having smoked 100 cigarettes in their lives and also reported smoking cigarettes every day or some days. Former smokers reported having smoked 100 cigarettes in their lives, but not currently. Never smokers reported having never smoked 100 cigarettes in their lives.
Abbreviations: n, sample size.

populations' mean age and BMI ranging from 26 to 33 yr and 24.3 to 27 kg/m^2, respectively. Moderate heterogeneity was observed with respect to sex [I^2 = 47% (95% CI: 8, 69%); Cochran's Q P < 0.10] and current smoking status [I^2 = 43% (95% CI: 0, 74%); Cochran's Q P < 0.10]. The proportion of males ranged from 66% to 100% and the proportion of current smokers ranged from 0% to 14%. With respect to the studies' median values, this study reported a mean age equivalent to the median, a mean BMI value lower than the median, and proportions of male participants and current smokers higher than the median values across studies. WFFs' racial and ethnic distributions were not consistently reported in prior studies, if at all. Other characteristics, including smoking history, were reported using various constructs, making comparison across studies difficult.

Discussion

In this relatively large longitudinal study of WFFs, researchers reported WFF characteristics not previously documented in the literature and observed changes in substance use patterns during the fire season. Many WFFs reported having been employed part-time (30%) or not at all (31%) during the offseason. Their prior occupations (non-WFF) varied widely, including jobs in construction, military, education, and food service. Loud noise exposure in the past year was very common (93%). The proportion of WFFs using tobacco increased during each fire season across all tobacco types. Smokeless tobacco was most commonly used. Researchers observed decreases during the fire season in the number of days WFFs consumed alcohol, though the proportion of WFFs who reported alcohol consumption in the prior 30 d remained consistently high pre and postseason. The daily use of energy drinks was higher postseason than preseason. Researchers found evidence that cigarette use, smokeless tobacco use, and the number of binge drinking episodes in the prior 30 d varied by crew.

This cohort was predominately male. Prior research has identified independent dose–response relationships between the increasing proportion of males in an occupation and decreasing health literacy among male workers (Milner et al. 2020). Efforts to improve health literacy among WFFs could provide a foundation for addressing chronic disease risk.

At baseline, 52% of the WFFEHE cohort reported using smokeless tobacco in the prior 30 d, over 3× higher than the highest industry-wide prevalence estimate in the United States (15.1% of workers in the mining and oil and gas industries reported currently using smokeless tobacco every day, some days, or rarely; 95% CI: 9.0% to 21.1%) (Syamlal et al. 2016). The high frequency of smokeless tobacco use is an opportunity for chronic disease prevention among WFFs. Evidence-based strategies exist for reducing tobacco use (CDC 2014) but best practices for implementing interventions in the WFF work environment are lacking. The increased use of tobacco during the fire season could have several possible explanations. WFFs may use tobacco to cope with stress and trauma. In a cross-sectional study, 77% of WFFs had experienced a "near miss" or "close call" that could have killed them, 48% knew someone who was killed on duty while working in the wildland fire service, and 54% saw dead bodies or human remains (O'Brien and Campbell 2021). Stress could also arise as a result of the seasonal nature of the work, for example having unpredictable income. Researchers have reported that seasonal workers in other sectors experience stress that can vary by season and that can be lower among workers with higher wages (Grzywacz et al. 2010; Ulrich et al. 2018). Exploring relationships between stress, substance use, and compensation practices among WFFs—which can vary depending on factors such as temporary or permanent status—was outside the scope of this study. Even so, WFFs who have relatively low base pay and who can earn hazard pay at a rate 25% higher than their base wages (OPM 1999) may be an important subpopulation to focus on with interventions and

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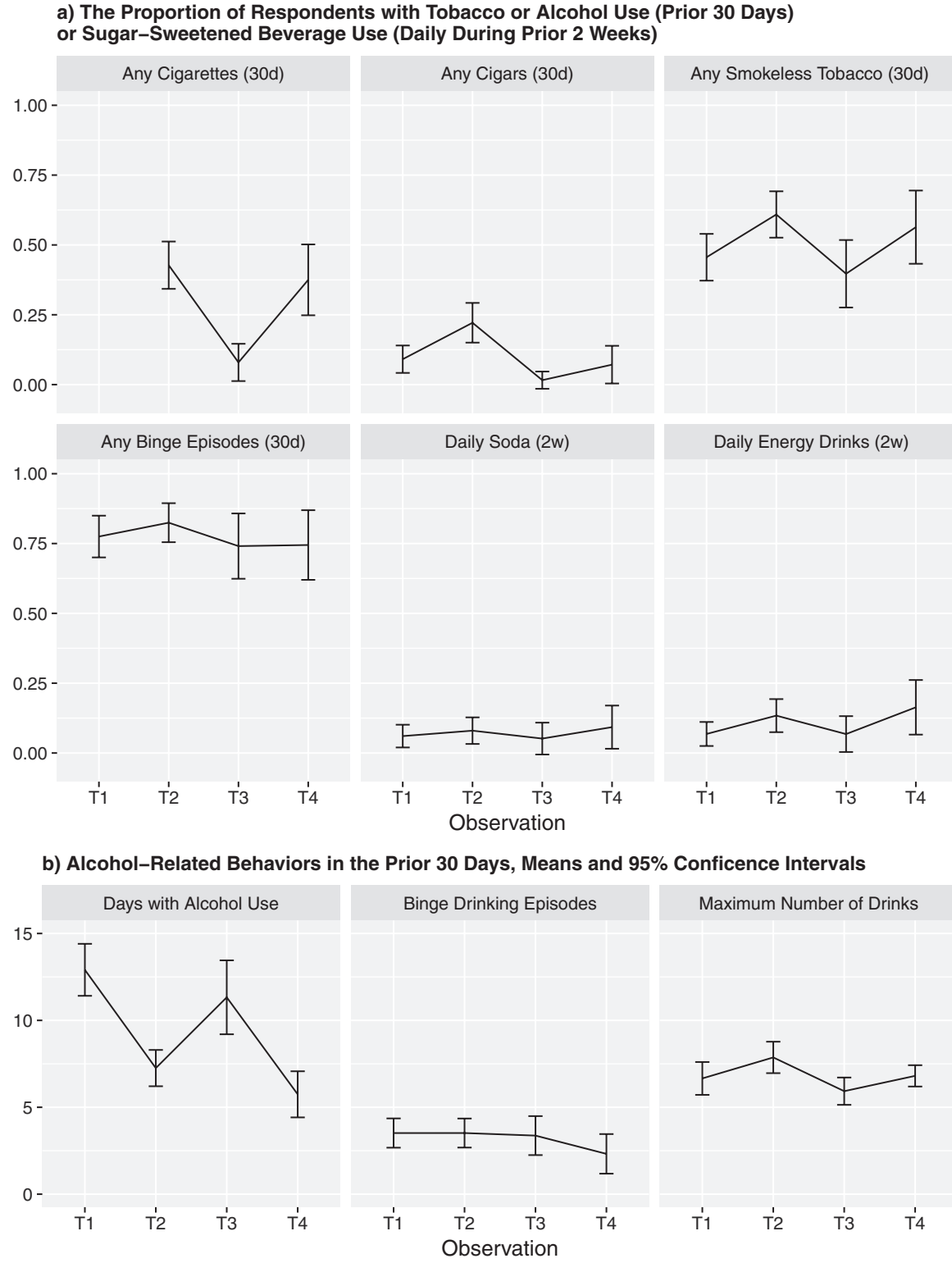

Figure 1. Changes in wildland firefighters' self-reported behaviors during preseason and postseason questionnaires over 2 consecutive fire seasons. Abbreviations: T1, initial preseason questionnaire (baseline); T2, first postseason questionnaire; T3, second preseason questionnaire; T4, second postseason questionnaire; 30 d, behavior in the prior 30 days; 2 wk, behavior in the prior 2 weeks.

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Table 3. Results from generalized linear mixed models and linear mixed models exploring longitudinal relationships in wildland firefighters' substance use over 2 fire seasons.

	Time 1	Time 2	Time 3	Time 4
GLMM results: OR and 95% CI				
Any cigarette use in the prior 30 d	NA	1.00 (REF)	0.04 (0.01, 0.20)[c]	0.74 (0.31, 1.76)
Any smokeless tobacco use in the prior 30 d	1.00 (REF)	3.84 (1.76, 8.37)[c]	0.62 (0.23, 1.68)	3.28 (1.16, 9.27)[a]
Any cigar, cigarillo, or little filtered cigars in the prior 30 d	1.00 (REF)	4.24 (1.64, 11.01)[b]	0.10 (0.01, 1.10)	0.66 (0.16, 2.60)
Any binge drinking episodes in the prior 30 d	1.00 (REF)	1.64 (0.74, 3.62)	0.88 (0.34, 2.28)	0.96 (0.35, 2.60)
Daily soda use in the prior 2 wk	1.00 (REF)	1.40 (0.28, 6.89)	0.99 (0.11, 8.60)	4.18 (0.64, 27.4)
Daily energy drink use in the prior 2 wk	1.00 (REF)	4.95 (1.21, 20.21)[a]	0.80 (0.12, 5.48)	7.05 (1.37, 36.35)[a]
LMM results: Change in mean response and 95% CI				
Mean number of days with alcohol use	REF	–5.69 (–7.17, –4.21)[c]	–0.99 (–2.91, 0.93)	–6.32 (–8.35, –4.30)[c]
The mean number of days with a binge drinking episode	REF	–0.03 (–0.91, 0.85)	0.32 (–0.83, 1.48)	–0.65 (–1.87, 0.57)
Mean maximum number of drinks on a single occasion	REF	0.91 (–0.07, 1.89)	–0.82 (–1.90, 0.26)	–0.20 (–1.17, 0.78)

[a]$P < 0.05$.
[b]$P < 0.01$.
[c]$P < 0.001$.
Abbreviations: GLMM, generalized linear mixed models; LMM, linear mixed models; REF, reference group.
Note: Time 1, initial preseason questionnaire (baseline); Time 2, first postseason questionnaire; Time 3, second preseason questionnaire; Time 4, second postseason questionnaire. Due to questionnaire changes specific to cigarette use, the reference is Time 2. Estimates for cigarette use, smokeless tobacco use, and the mean number of binges drinking episodes in the prior 30 d are adjusted for the work crew, due to its improvements in model fit.

future research studies. Additionally, researchers have reported that some workers use tobacco to justify taking work breaks and to build stronger social ties with co-workers (Delaney et al. 2018). Our findings are also consistent with a large longitudinal study that found occupational physical activity was associated with increased tobacco use and increased sugar intake (Hamieh et al. 2022). The authors posited that physically demanding work may increase the need for breaks and strong social bonds, relative to less demanding work, and thus increase opportunities for tobacco use.

These are just a few potential work-related social mechanisms related to substance use. Others include responses to physical pain arising from acute occupational injury or cumulative trauma (Shaw et al. 2020); responses to psychosocial stressors on the job (Shaw et al. 2020); or shift work, which has been associated with higher usage of sleep-promoting drugs, wake-promoting drugs, cigarettes to stay awake, and alcohol to initiate sleep (Brown et al. 2020). The prevalence of binge drinking reported in this study (78% at baseline) was high, even compared to the highest estimate among occupational groups reported by a study using CDC's National Health Interview Survey (NHIS) data (32% among construction and extraction workers, 95% CI: 30, 34) (Shockey and Esser 2020). Binge drinking is associated with many chronic health problems, including high blood pressure, stroke, heart disease, liver disease, and various cancers, as well as injuries, and other outcomes. Fewer mean days with alcohol use postseason may be explained by the fact that drinking is prohibited while on fire assignment. It is unclear why mean drinking episodes decreased during the year 2 postseason survey, but not in the year 1 postseason.

Crew-level associations observed for cigarette use, smokeless tobacco use, and binge drinking suggest that these behaviors may be influenced by the social work environment and that work crews could benefit from future intervention and research. NIOSH has developed a program focused on workplace-supported recovery that highlights ways employers might help prevent the initiation, duration, or severity of substance use, while also increasing access to evidence-based substance use treatment and recovery services (Frone et al. 2022). If WFFs use tobacco as an excuse to take breaks or socialize, agencies could encourage breaks for other purposes and identify healthier opportunities for team building. If WFFs use tobacco to stay alert, agencies could implement fatigue management programs. These findings should be used to motivate additional research about the ways seasonal work, physically demanding jobs, stress, and the social work environment might influence WFFs' substance use.

Furthermore, the heterogeneity observed in the attempted meta-analyses by sex, age, and BMI (moderate, high, and high, respectively), as well as the inconsistently reported racial and ethnic distributions raise questions about the broader population to which this study and others aim to generalize. WFFs have not been assigned standardized industry and occupation classification codes on which national health surveys

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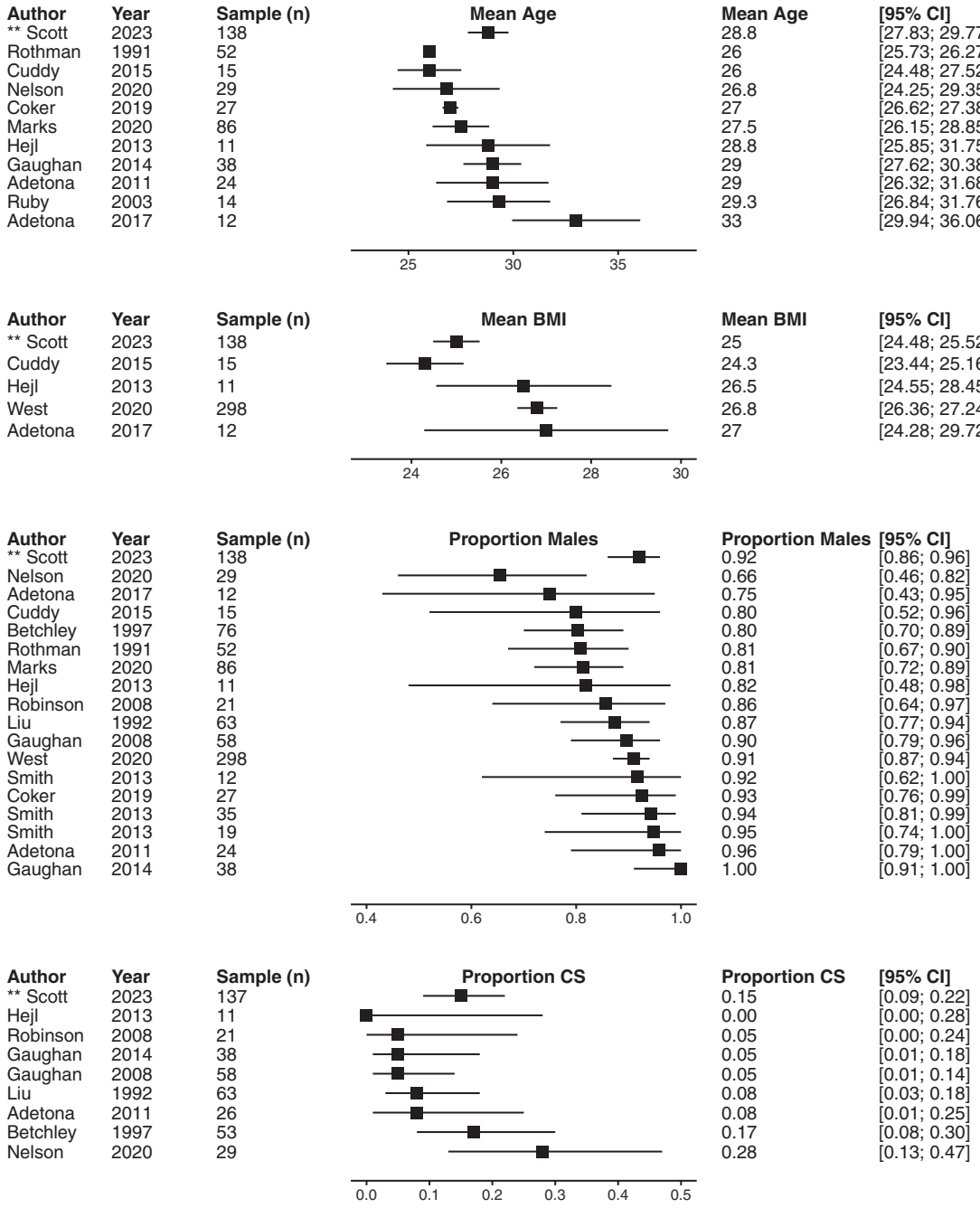

Figure 2. Forest plot assessing heterogeneity of US wildland firefighter longitudinal cohorts: age, BMI, Sex, and Current Smoking (CS) Status. Abbreviations: CS, current smokers; *n*, sample size. Heterogeneity estimates: age: I^2 = 88% (95% CI: 81% to 93%), Cochran's Q $P < 0.01$; BMI: I^2=90% (95% CI: 80% to 95%), Cochran's Q $P < 0.01$; sex: I^2 = 47% (95% CI: 8% to 69%), Cochran's Q $P < 0.10$; current smoking status: I^2 = 43% (95% CI: 0% to 74%), Cochran's Q $P < 0.10$. **Results from the present study.

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rely, making it difficult to properly evaluate studies' external validity. Developing and integrating industry and occupation codes for WFFs into existing surveys could be a logical first step.

This study has several limitations. Researchers did not collect information on illicit substance use. Due to the shortened follow-up period, researchers were unable to observe behavior changes across an additional fire season. All data were self-reported. Social desirability bias may have influenced reporting of substance use behaviors but given the high prevalence of smokeless tobacco use and binge drinking, this seems unlikely. Fire seasons are becoming longer, which may limit the generalizability to certain WFFs or geographic regions (Schweitzer 2019). Detailed data on specific types of soda and energy drinks consumed were limited, and their caffeine or sugar content was unavailable. Some drinks may not have been SSBs or even been caffeinated. That said, the significantly higher odds of daily energy drink use and nonsignificantly higher odds of soda use postseason compared to preseason may have been influenced by WFFs' long work hours. Energy drinks that contain both caffeine and sugar could have been consumed by fatigued WFFs desiring the benefits of caffeine, while still being exposed to the risks of sugar. Some of the statistical models, particularly the linear models, encountered issues related to convergence and singularity, likely due to the smaller numbers of WFFs reporting behaviors at time points 3 and 4. Finally, despite the fact that the WFFEHE study was larger than all but 1 longitudinal study in the meta-analysis and included several crew types and agencies, our population was not representative of the WFF population overall. For example, higher fitness standards for IHCs may have increased the likelihood of healthy worker bias even beyond selection into the WFF workforce. Strengths of the study include the relatively large size of the cohort, the diversity of substances being reported, and the longitudinal study design. The systematic reviews were recent and researchers searched for eligible WFF studies published after the reviews, however, there may be relevant articles that were not included in the meta-analysis. The strengths, limitations, and best practices for using meta-analytic techniques, like the ones employed here, to study research populations in comparison to each other or actual populations should be explored further.

Conclusion

In this study, WFFs' substance uses behaviors changed during the fire season. The direction and degree of behavior change depended on the substance and the fire crew. Binge drinking and smokeless tobacco use were common among WFFs. With a better understanding of substance use patterns, occupational safety and health professionals and clinicians supporting WFFs can optimize chronic disease prevention and management efforts in clinical and workplace settings. Evidence-based strategies to reduce harmful substance use, especially smokeless tobacco use and excessive alcohol consumption, may require adaptation and implementation in the WFF environment. Prevention efforts that modify conditions that produce stress or otherwise compel WFFs to seek relief with substances are a priority for future intervention studies.

Disclaimer

The findings and conclusions in this report are those of the authors and do not necessarily represent the official views of the National Institute for Occupational Safety and Health or the United States Department of the Interior. Mention of any company name or product does not constitute endorsement by NIOSH/CDC. The findings and conclusions in this report are those of the author(s) and should not be construed to represent any official US Government determination or policy. This article was written and prepared by US Government employees on official time, and it is therefore in the public domain and not subject to copyright.

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Conflict of interest statement

None declared.

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Data availability

The data that support the findings of this study are not publicly available due to privacy restrictions. Limited data may be available upon request to NIOSH.

Supplementary material

Supplementary material is available at *Annals of Work Exposures and Health* online.

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