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Risk of Cancer Among Firefighters in California, 1988–2007

Rebecca J. Tsai, PhD[1], **Sara E. Luckhaupt, MD, MPH**[1], **Pam Schumacher**[1], **Rosemary D. Cress, PhD**[2,3], **Dennis M. Deapen, DrPH**, and **Geoffrey M. Calvert, MD, MPH**[1]

[1]Division of Surveillance, Hazard Evaluations and Field Studies, National Institute for Occupational Safety and Health, Centers for Disease Control and Prevention, Cincinnati, Ohio

[2]Public Health Institute, Cancer Registry of Greater California, Sacramento, California

[3]Department of Public Health Sciences, UC Davis School of Medicine, Davis, California

Abstract

Background—Most studies of firefighter cancer risks were conducted prior to 1990 and do not reflect risk from advances in building materials.

Methods—A case–control study using California Cancer Registry data (1988–2007) was conducted to evaluate the risk of cancer among firefighters, stratified by race.

Results—This study identified 3,996 male firefighters with cancer. Firefighters were found to have a significantly elevated risk for melanoma (odds ratio [OR]=1.8; 95% confidence interval [CI] 1.4–2.1), multiple myeloma (OR 1.4; 95%CI 1.0–1.8), acute myeloid leukemia (OR 1.4; 95%CI 1.0–2.0), and cancers of the esophagus (OR 1.6;95%CI 1.2–2.1), prostate (OR 1.5; 95%CI 1.3–1.7), brain (OR 1.5; 95%CI 1.2–2.0), and kidney (OR 1.3; 95%CI 1.0–1.6).

Conclusions—In addition to observing cancer findings consistent with previous research, this study generated novel findings for firefighters with race/ethnicity other than white. It provides additional evidence to support the association between firefighting and several specific cancers.

Keywords

cancer; firefighters; occupation; registry; risk

Correspondence to: Rebecca J. Tsai, PhD, National Institute for Occupational Safety and Health, 1090 Tusculum Avenue, R-17, Cincinnati, OH 45226. rtsai@cdc.gov.

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INTRODUCTION

Firefighting is considered one of the most hazardous occupations [Guidotti, 1993]. In 2013, there were about 354,600 (31%) career firefighters and 786,150 (69%) volunteer firefighters in the United States [National Fire Protection Association, 2014]. Firefighters are expected to perform under stressful conditions and are at risk for physical, biological, and chemical-related injuries and illnesses, including cancer [Melius, 2001].

Firefighters are often exposed to known carcinogens in their line of work [Stefanidou et al., 2008]. Additionally, the introduction of newer building materials beginning approximately 40 years ago (e.g., engineered thermoplastics such as polyvinylidene fluoride, and laminated veneer lumber), may expose firefighters to potentially new carcinogenic combustion products [Beaumont et al., 1991; Grundahl, 1992]. The burning of plastics found in home appliances, furniture, and electronics may also introduce firefighters to new carcinogens [Korst, 2012]. While the use of a self-contained breathing apparatus (SCBA) can eliminate or significantly decrease respiratory exposure to toxic particles during firefighting [Bates, 2007], SCBAs are not always worn, especially during overhaul. Overhaul is a late-stage in fire suppression when the burned area is inspected for flammable sources that can rekindle a fire. During overhaul, firefighters can be exposed to combustion products through disassembling walls or removing furniture [Bates, 2007]. Furthermore, even when SCBAs are worn, firefighters can absorb combustion products through the unprotected skin on their neck [Fent et al., 2014]. Several combustion products are classified by the International Agency for Research on Cancer (IARC) as carcinogenic to humans (Group 1), probably carcinogenic to humans (Group 2A) or possibly carcinogenic to humans (Group 2B). These combustion products include benzene (Group 1), benzo[a]pyrene (Group 1), vinyl chloride (Group 1), formaldehyde (Group 1), 1, 3-butadiene (Group 1), and polychlorinated biphenyls (PCBs) (Group 1) [Melius, 2001; Stefanidou et al., 2008; International Agency for Research on Cancer, 2015]. Firefighters may also be exposed to asbestos (Group 1) and lead (Group 2A) when present in burning buildings [International Agency for Research on Cancer, 2015]. Non-fire-related exposures may also increase cancer risk, as firefighters can be exposed to diesel exhaust from fire trucks, and diesel exhaust was found to be associated with increased cancer risks [International Agency for Research on Cancer, 2015].

Studies have found that firefighting is significantly associated with an increased risk for developing the following cancers: colorectal [Vena and Fiedler, 1987; Burnett et al., 1994; Baris et al., 2001; Daniels et al., 2014], lung [Pukkala et al., 2014; Daniels et al., 2015], melanoma [Howe and Burch, 1990; Sama et al., 1990], prostate [Grimes et al., 1991; Demers et al., 1994; LeMasters et al., 2006], testis [LeMasters et al., 2006; Ma et al., 2006], urinary bladder [Vena and Fiedler, 1987; Sama et al., 1990; Ma et al., 2006], kidney [Burnett et al., 1994; Delahunt et al., 1995; Daniels et al., 2014], brain [Grimes et al., 1991; Demers et al., 1992; Aronson et al., 1994; Ma et al., 2006], myeloma [LeMasters et al., 2006], non-Hodgkin lymphoma [Burnett et al., 1994; Figgs et al., 1995; Golden et al., 1995], and leukemia [Morton and Marjanovic, 1984; Golden et al., 1995; Baris et al., 2001; Daniels et al., 2015]. In recognition of these cancer risks, as of 2015, a total of 33 states cover firefighters for one or more cancers under workers' compensation as a result of presumption legislation [International Association of Fire Fighters, 2015]. In 20 of these states, the

language in the presumption legislation contains broad or nonspecific language that can be interpreted to cover any cancer experienced by a firefighter. In the other 13 states, only certain specific cancers are covered, most commonly leukemia (12 states), brain cancer (10 states), bladder cancer (9 states), non-Hodgkin lymphoma (9 states), and gastrointestinal cancer (8 states).

Ongoing assessment of cancer risks among firefighters is needed because of inconsistent findings across previous studies [International Agency for Research on Cancer, 2010], and because most studies were conducted prior to 1990 which may limit their ability to detect new risks arising from advances in building materials. In addition, few studies have examined the cancer risks among firefighters of other race/ethnicity. This study aims to update and expand a previous study by Bates [Bates, 2007], assessing cancer risks among firefighters using data from the California Cancer Registry (CCR). In addition, this is one of the first studies to include an examination of firefighter risk for subtypes of leukemia, esophageal cancer and lung cancer, and cancer risks among firefighters of other race/ethnicity (e.g., blacks and Hispanics).

MATERIALS AND METHODS

California Cancer Registry (CCR)

CCR is a population-based cancer surveillance system that collects data on all cancers (excluding non-melanoma skin cancers and in-situ cervical carcinoma) among California residents. It is estimated that at least 95% of cancer cases are ascertained by CCR [North American Association of Central Cancer Registries, 2015]. Cancer reporting has been mandated by California law since 1985 and CCR has collected statewide cancer data from doctors, hospitals, and other medical facilities since January 1, 1988. Data collected by CCR include demographics, cancer characteristics, and cancer treatments. Information on the industry and occupation (I&O) of the job held longest by each case are also collected in narrative form. CCR provided the National Institute for Occupational Safety and Health (NIOSH) with de-identified cancer data collected from 1988 to 2007. Because this is a public health surveillance study with analyses conducted on anonymous data without links to personal identifiers, it was exempted from review by the NIOSH Institutional Review Board.

Firefighter Definition

To identify all cancer cases among firefighters, the I&O narrative fields were extensively searched for key words consistent with firefighting. The identified I&Os were coded using 1990 Bureau of Census (BOC) codes. Occupation codes used to indicate a career in firefighting are 413, 416, and 417. All firefighters with these codes were selected regardless of industry. The BOC manual states that the 417 code includes firefighters, fire chief's aides, smoke jumpers, forest-fire fighters, and crash-crew men [U.S. Department of Commerce, 2000]. Their main duties are to control and extinguish fires that threaten life, property or environment, fire prevention, emergency medical service, hazardous material response, search and rescue, and disaster management [U.S. Department of Commerce, 2000]. A total

of 29 search terms (e.g., firefighter, fire crew worker) were used to identify and code individuals as BOC code 417.

Individuals who work at a fire department but do not usually carry out firefighting duties have a BOC occupation code of 413 or 416. BOC code 413 indicates positions that supervise and coordinate the firefighter's activities, as well as participate in fire prevention and control [U.S. Department of Commerce, 2000]. A total of 11 search terms (e.g., fire captain, fire chief, and fire marshal) were used to identify and code individuals as BOC code 413. BOC code 416 refers to positions that inspect buildings and firefighting equipment for fire hazards, enforce state and local fire-related ordinances, determine cause of fires or explosions, and recommend fire prevention measures [U.S. Department of Commerce, 2000]. A total of 23 search terms (e.g., fire inspector, arson investigator, forest fire control officers, fire ranger, fire warden, and fire lookout) were used to identify and code individuals as BOC 416. Many of these individuals (i.e., those with BOC codes 413 or 416) likely started their career as firefighters (BOC code 417) and were labeled as firefighters in this study. Because our findings were very similar whether firefighters were defined as BOC code 417 only versus combining 413, 416, and 417, to maximize sample size we report only the findings for the combined definition.

Cancer cases can have multiple cancer records at CCR if they were diagnosed with the same primary cancer multiple times or diagnosed with two or more primary cancers at different times. A separate cancer record is created for each cancer diagnosis or recurrence. The I&O assigned to these cases with multiple cancer records were the I&O present at the initial diagnosis because I&O information from the earliest record is thought to provide the best indication for longest-held job. In addition, some individuals were found to have more than one primary cancer at initial diagnosis. CCR assigned the cancer with the worse prognosis as the "first" primary.

Exclusion Criteria

This study included only adult male subjects (18–97 years of age) who had I&O information available. Excluded were females, homemakers, those with insufficient I&O narratives (e.g., narratives that mentioned only unemployed, disabled, or retired, or were blank), those who never worked, and those in the military.

Selection of Cases and Control Cancers

In situ and benign tumors were excluded. Cancers that spread into surrounding tissues (malignant/invasive), and were identified as the first "malignant" primary were included in this study. The cancer risk among firefighters was assessed for all cancers that included at least 10 firefighters. Control cancers were selected after reviewing the literature for cancers that appeared to have little or no association with firefighting and its related exposures. These control cancers were cancers of the pharynx, stomach, liver, and pancreas. Cancers and histological subtypes were defined using Surveillance, Epidemiology, and End Results Program (SEER) recodes.

Data Analysis

SAS ® 9.3 (Research Triangle Institute, Research Triangle Park, NC) was used. For each type of cancer analyzed, the proportion of cases who were firefighters was compared to the proportion of control cancer cases who were firefighters. Unconditional logistic regression was used to calculate odds ratios (OR) and ORs were adjusted for age at diagnosis (5-year intervals), year of diagnosis (5-year intervals), and race. The Wald test was used to test the level of statistical significance and was defined by a $P < 0.05$.

The risk of cancer among firefighters was examined in three ways: (i) all firefighters combined, (ii) firefighters of other race/ethnicity (i.e., blacks, Hispanics, Asians/Pacific islanders, Indian/Alaskan natives, other/unknown) and, (iii) white firefighters. Analyses of case and control groups were restricted by race category. That is, when other races/ethnicities were assessed, only other races/ethnicities were included in the case and control groups. The analyses involving only whites were handled similarly. All cancers examined and reported in the "all firefighters combined" group, were also examined and reported in the race-stratified groups.

RESULTS

A total of 2,470,496 cancer reports did not meet the eligibility requirements and were excluded from analysis (Table I). The study sample was selected from 678,132 cancer subjects diagnosed in California who met all eligibility requirements. A total of 48,725 of those in the study sample had a control cancer. Among the control cancers, 31% were diagnosed with pancreatic cancer, 29% with stomach cancer, 23% with liver cancer, and 18% with pharyngeal cancer.

The study sample included 3,996 firefighters. Compared to non-firefighters, firefighters in the study sample were slightly but significantly older (aged 63.3 years vs. 62.6 years) and more likely to be white (90.2% vs. 74%).

Among the 32 examined cancers, three were significantly elevated among all firefighters combined and among firefighters in both race groups (Tables II–IV). These three cancers were melanoma, prostate cancer, and brain cancer.

Three cancers were significantly elevated among all firefighters combined and among white firefighters: adenocarcinoma of the esophagus; non-specific, non-small cell lung cancer; and, acute myeloid leukemia (AML). Three cancers were significantly elevated among all firefighters combined and firefighters of other race/ethnicity: kidney cancer, multiple myeloma, and overall leukemia.

There were six cancers that were significantly elevated among firefighters of other race/ethnicity only: tongue cancer, testicular cancer, bladder cancer, non-Hodgkin lymphoma, chronic lymphocytic leukemia (CLL), and chronic myeloid leukemia (CML). Neither of the two other groups (i.e., all firefighters combined and white firefighters) had a significantly elevated cancer risk that was unique (i.e., that was not observed in at least one of the other two groups).

There were 18 cancers for which a significantly elevated risk was not found among any firefighter group. These were: cancer of the lip; cancer of the salivary gland; gum and other mouth cancer; pharyngeal cancer; esophageal squamous carcinoma; stomach cancer; colorectal cancer; liver cancer; pancreatic cancer; laryngeal cancer; four lung cancer subtypes (i.e., adenocarcinoma, squamous cell carcinoma, small cell carcinoma, and large cell carcinoma); soft tissue sarcoma; mesothelioma; thyroid cancer; and Hodgkin lymphoma.

DISCUSSION

To our knowledge, this study included more firefighters with cancer than any previous study. This allowed us to assess the association between firefighters and the development of 32 cancers in all firefighters combined, white firefighters, and firefighters of other race/ethnicity. Of the 32 cancers assessed in this analysis of CCR data from 1988 to 2007, the risk for 14 cancers was significantly elevated in one or more firefighter groups. Firefighters of other race/ethnicity had significantly increased risk for more cancers than white firefighters. These findings warrant the need for further investigation of cancer risks among firefighters of other race/ethnicity.

Comparison With a Pooled Cohort of Firefighters from San Francisco, Chicago, and Philadelphia

Daniels et al. [2014] reported mortality and cancer registry findings for firefighters who were employed for at least one day between 1950 and 2009 in fire departments that served San Francisco, Chicago, or Philadelphia. Their findings were similar to ours. Both Daniels et al. [2014] and our study found elevated risks for esophageal and kidney cancer among all firefighters combined and prostate cancer among firefighters of other race/ethnicity. In addition, Daniels et al. [2014] also found significantly elevated risks for melanoma and brain cancer incidence among San Francisco firefighters only, which were also elevated in our study of firefighters in the entire state of California. However, differences were identified when we compared the Daniels et al. [2014] overall findings (all three cities combined) with our study results. Daniels et al. [2014], unlike our study, found a significantly increased risk for mesothelioma and cancers of the pharyngeal/buccal cavity (including lip, tongue, other buccal, and pharynx), colon, larynx, and lung. Our study, unlike Daniels et al. [2014], found an increased risk for non-Hodgkin lymphoma and overall leukemia among all firefighters combined, and an increased risk for testicular cancer, bladder cancer, and multiple myeloma among firefighters of other race/ethnicity. Study design dissimilarities that may explain some of the differences in findings include: (i) the types of firefighters included (structural firefighters in Daniels et al. [2014] vs. all firefighters in ours); (ii) location of fire departments (Daniels et al. [2014] studied three major US cities, whereas we studied California); (iii) Daniels et al. [2014] used a retrospective cohort study design whereas we used a case– control study approach involving cancer registry data only; (iv) Daniels et al. [2014] had a smaller sample size of firefighters of other race/ethnicity with cancer; (v) inclusion of study participants for Daniels et al. [2014] was based on year employed (i.e., between 1950 and 2009), whereas ours was based on year of cancer diagnosis (i.e., between

1988 and 2007); and (vi) inclusion of female firefighters in Daniels et al. [2014] but not in our study.

Comparison With Another Large Firefighter Study and a Meta-Analysis

Two other reports are notable for including large numbers of firefighters: Pukkala et al. [2014] and a meta analysis by LeMasters et al. [2006]. Like our study, Pukkala et al. [2014] and LeMasters et al. [2006] found firefighters to be at significantly increased risk for melanoma and prostate cancer. In addition, our study and LeMasters et al. [2014] found a significantly increased risk for brain cancer and non-Hodgkin lymphoma. Additionally, our study (i.e., only in firefighters of other race/ethnicity) and LeMasters et al. [2006] found an increased risk for multiple myeloma and testicular cancer. Unlike our study, neither Pukkala et al. [2014] or LeMasters et al. [2006] found increased risks for leukemia, or cancers of the esophagus, bladder, or kidney. Differences in findings between Pukkala et al. [2014] and our study may be attributed to sample size (2,536 firefighters with cancer in Pukkala et al. [2014] vs. 3,996 in ours), and differences in geographic region studied (Nordic countries in Pukkala et al. [2014] vs. the state of California).

Commonly Observed Increased Cancer Risks Among Firefighters

The only two cancers consistently found significantly elevated in three large studies [Daniels et al., 2014, Pukkala et al., 2014, and ours] and a meta-analysis [LeMasters et al., 2006] were melanoma and prostate cancer. Significant elevations in two of the studies/meta-analysis, were observed for non-Hodgkin lymphoma, multiple myeloma, and cancers of the tongue, esophagus, colon, testis, kidney, and brain. Significantly increased risks identified in at least one large study/meta-analysis but not ours included: larynx [Daniels et al., 2014]; lung and bronchus [Daniels et al., 2014; Pukkala et al., 2014]; mesothelioma [Daniels et al., 2014]; colon cancer [LeMasters et al., 2006; Daniels et al., 2014] and stomach cancer [LeMasters et al., 2006].

Comparison With Bates [2007]

A previous study by Bates also assessed cancer risks among firefighters using CCR data; however, Bates did not conduct analyses by race and did not examine as many cancers [Bates, 2007]. Both Bates and our study found a significantly increased risk for esophageal, melanoma, prostate, and brain cancers among all firefighters combined. Cancers significantly elevated in one or more of the firefighter groups in our study, but not in Bates were bladder cancer, kidney cancer, non-Hodgkin lymphoma, multiple myeloma, and leukemia. No cancers were significantly elevated in Bates and not in our study.

In addition to conducting analyses by race, there were other differences in study design that likely explain at least some of the differences observed between Bates and our study. These include: (i) Our study used a more exhaustive keyword search for firefighters; (ii) Our study used four more years of data, as our study collected data from 1988 to 2007, while Bates only included data from 1988 to 2003; (iii) Differences in the cancers selected to serve as controls. For each examined cancer, Bates used all other cancers as the controls. In contrast, our study used cancers not thought to be associated with firefighting (i.e., cancers of the pharynx, stomach, liver, and pancreas); (iv) Our study examined more cancers. Only one

cancer examined in our study but not by Bates had a significantly elevated risk: cancer of the tongue.

Firefighters of Other Race/Ethnicity

Firefighters of other race/ethnicity had significantly elevated risks for 12 cancers (tongue, melanoma, prostate, testicular, bladder, kidney, brain, non-Hodgkin, multiple myeloma, leukemia [overall], CLL, and CML). In contrast, only six cancers were significantly elevated among white firefighters.

Most of the 365 firefighters of other race/ethnicity in our study were Hispanic (62.2%) or black (27.7%). Since Hispanics and blacks generally have higher incidence rates for cancers than Asians [United States Cancer Statistics Working Group, 2014] and less than 10% of firefighters of other race/ethnicity were Asians, cancer risks observed among firefighters of other race/ethnicity were most likely driven by the Hispanic and black firefighters.

The reasons for the race/ethnicity-associated differences in our findings are unclear. Race/ethnicity is related to general constraints that can lead to differential access to opportunities in society [Jones, 2001]. In addition, those of other race/ethnicity have historically been subjected to prejudice and discrimination [Jones, 2001], including those seeking employment or promotion in fire departments [Ricucci and Saldivar, 2014]. Furthermore, those of other race/ethnicity may have selectively been assigned to busier fire stations. This is supported by studies of other industries that demonstrated that workers of other race/ethnicity may be more frequently exposed to occupational hazards than white workers [Birdsey et al., 2007]. These societally imposed conditions, as experienced by firefighters of other race/ethnicity, may lead to differential exposure to carcinogens or may heighten susceptibility to the effects of carcinogenic exposures.

To our knowledge, only two other studies reported cancer risks among firefighters of other race/ethnicity: Daniels et al. [2014] and Ma et al. [1998]. Ma et al. [1998] looked only at black firefighters, whereas Daniels et al. [2014] did not report the race/ethnicity distribution of firefighters of other race/ethnicity. Our study included more firefighters of other race/ethnicity with cancer (n=365) than Daniels et al. [2014] or Ma et al. [1998] (n=240 and n=66, respectively). Daniels et al. [2014] found only prostate cancer at significantly increased risk among firefighters of other race/ethnicity. Ma et al. [1998] found significantly increased risks for cancers of the prostate and brain among firefighters of other race/ethnicity, as in our study; they also found significant increases in nasopharyngeal and colon cancers, unlike our study. Differences between Ma et al. [1998] and our study may be due to our inclusion of nonwhite race/ethnicity other than blacks in our study, and different study periods. In addition, our larger study population of other race/ethnicity may have allowed us to detect more differences. Moreover, the evolving mix of carcinogenic exposures among firefighters may have also affected the types of cancer that were observed.

Prostate Cancer

The prostate is a hormone-regulated gland (i.e., testosterone). Chemicals, such as pesticides, cadmium, Bisphenol A (BPA), or PCB, have been shown to be endocrine disruptors [Diamanti-Kandarakis et al., 2009] that interfere with androgen metabolism. This disruption

elevates the bioavailability of androgen which can initiate prostate cancer. The increased prostate cancer risk could also be due to an increased frequency of prostate cancer screening among firefighters as compared to the general population. Such a screening effect is supported by a recent study showing a lack of a positive dose-response relationship between fire-fighting exposure and prostate cancer incidence and mortality [Daniels et al., 2015].

Melanoma

Although exposure to ultraviolet radiation (i.e., sunlight, tanning beds) is commonly associated with melanoma, melanoma has also been found on the unexposed skin of petrochemical refinery workers [Mehlman, 2006]. Researchers have found a significant positive association between melanoma and exposure to benzene, PAH, PCB, aromatic hydrocarbons, and heavy oil [Mehlman, 2006].

Esophageal Cancer

The inhalation of smoke and dust during fire suppression activities and overhaul may have contributed to an increased risk of esophageal cancer. It is possible that mucociliary clearance of combustion products in the trachea led to esophageal irritation and inflammation. The inflammatory response, such as the infiltration of reactive oxygen species and inflammatory mediators, may further damage esophageal tissue [Kavanagh et al., 2014]. A study following a group of firefighters who responded to the 9/11 attack found an increased prevalence of gastroesophageal reflux disease (GERD) symptoms (5.8% prevalence pre-9/11 to a prevalence of 40% 4 years post 9/11) [Webber et al., 2009]. GERD is a strong predictor for esophageal adenocarcinoma, the most common type of esophageal cancer today [Lagergren and Lagergren, 2013]. Our study found that 68% of esophageal cancer in firefighters was adenocarcinoma, and that only esophageal adenocarcinoma, and not squamous carcinoma, was significantly elevated among firefighters.

Limitations

This study has several limitations. First, using other cancer cases as controls may bias our findings towards the null if the selected control cancers are related to firefighting exposures. To minimize this bias, we did a comprehensive literature review of cancers found to be elevated among firefighters. Cancers that consistently showed very weak or no association with firefighters were selected as control cancers. Second, I&O data were missing for approximately 50% of cancer cases in CCR. Individuals in the CCR dataset who had unknown I&O were more likely to be older and of Hispanic descent compared to the CCR cases meeting study eligibility. Ascertainment bias would be present if the proportion of firefighters who were ascertained by the CCR varied across the different cancers. However, the California cancer presumption law enacted in 1982 and amended periodically can award compensation and benefits to any firefighter diagnosed with any cancer within 10 years of their last day worked [William Dallas Jones Cancer Presumption Act, 2010]. It should be noted that the employer can challenge the firefighter’s compensation filing on the basis of an insufficient latency period (i.e., 10 years or less), or if the employer can prove that the association between the cancer and firefighting has been examined scientifically and shown not to exist [Heald, 2005]. Since firefighters can presume that any cancer was caused by work, it is unlikely that ascertainment bias was introduced. Third, because I&O recording is

not standardized, I&O data obtained may not be the longest-held job, but rather the current job. It is reassuring that findings based on large representative samples of U.S. workers found moderate to high correlation between current and longest-held job [Gomez-Marin et al., 2005; Luckhaupt et al., 2013], indicating that current job may be an acceptable surrogate for longest-held job. Fourth, those who worked as volunteer firefighters may have been classified as non-firefighters in our analyses because it is unlikely that volunteer firefighting was captured as the longest-held job. Conversely, some individuals with the designation of firefighter in this study may not have been involved in firefighting. The former misclassification of fire-fighting exposure may have biased the estimates towards the null, and it's not clear how the latter misclassification would bias our findings. Fifth, CCR does not have information on smoking, alcohol consumption, obesity, workplace exposures, length of employment, and actual job duties. Although many cancers of interest are influenced by lifestyle factors, this study was not able to adjust for these potential confounders. Recent studies found that firefighters working in the central region of the United States were less likely to smoke [Haddock et al., 2011], but have high rates of heavy and binge drinking on their off-duty days [Haddock et al., 2012]. Any differences in lifestyle factors could have biased our estimates in either direction. Sixth, due to small sample sizes, we were unable to examine blacks, Hispanics, and Asians separately. Finally, this study did not adjust for multiple comparisons and some findings may have arisen due to chance. Nevertheless, it is reassuring that many of the findings from this study are similar to those of previous studies.

Strengths

CCR is one of the most comprehensive and complete cancer registries with a case ascertainment rate of at least 95% [North American Association of Central Cancer Registries, 2008,2015]. In addition, our study is among the largest cancer studies of firefighters. It is also one of the few studies that reported firefighter risk for cancer subtypes, including for leukemia, esophageal cancer, and lung cancer. Finally, ours is one of the few studies that reported findings for firefighters of other race/ethnicity.

CONCLUSION

This study found that firefighters had a significantly elevated risk for melanoma, multiple myeloma, leukemia (i.e., AML), and cancers of the esophagus, prostate, kidney, and brain. Moreover, firefighters of other race/ethnicity, in addition to being at significantly increased risk for the same cancers identified for all firefighters combined, were found to have a significantly increased risk for non-Hodgkin lymphoma, leukemia (i.e., CLL, CML) and cancers of the tongue, testis, and bladder. The consistency of many of these findings with prior large studies (i.e., melanoma, non-Hodgkin lymphoma, multiple myeloma, and cancers of the prostate, esophagus, testis, bladder, kidney, and brain) strengthens the evidence supporting the association between firefighting exposures and these cancers.

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TABLE I

Number of Individuals Eligible for Study Inclusion, and Number Excluded From Study by Reason

	n	Total n
Total number of cancer records in CCR		3,148,628
Excluded: in-situ, benign, borderline cancers	346,379	
Excluded: multiple records[a]	251,501	
Excluded: non-first primary	168,696	
Excluded gender: Females, other, unknown gender	1,159,007	
Subtotal[b]		1,223,045
Industry and occupation (I&O) exclusions		
Unemployed, or unknown I&O	308,753	
Never worked	29,400	
Homemaker	366	
Retired	193,276	
Military	10,475	
Subtotal after I&O exclusions		680,775
Age exclusions		
Age <18, or >97 years	2,644	
Total eligible for study		678,132

[a] Individuals with more than one cancer diagnosis may have more than one cancer record. The first primary malignant cancer diagnosis recorded in CCR was retained in this study.

[b] Subtotal after benign/in-situ tumors, non-first primary cancer, multiple record, and gender exclusions.

TABLE II

Odds Ratios for Various Cancers Among Firefighters—All Races Combined, California, 1988–2007

		Number of firefighters			
Cancer	**SEER code**	**N**	**%[a]**	**OR[b]**	**95%CI**
Head and neck					
Lip	20010	19	0.96	1.44	0.89–2.33
Tongue	20020	35	0.65	1.18	0.82–1.70
Salivary gland	20030	14	0.70	1.30	0.75–2.25
Gum and other mouth	20050	14	0.56	1.07	0.62–1.85
Pharyngeal	20060–20100	43	0.50	1.06	0.75–1.50
Digestive					
Esophagus	21010	68	0.82	**1.59**	**1.20–2.09**
Esophagus-adenocarcinoma		46	1.04	**1.85**	**1.34–2.55**
Esophagus-squamous carcinoma		12	0.43	0.96	0.53–1.73
Stomach	21020	52	0.37	0.81	0.59–1.11
Colorectal	21041–21252	347	0.55	1.10	0.93–1.31
Liver	21071	39	0.35	1.07	0.75–1.53
Pancreas	21100	79	0.53	1.10	0.83–1.46
Respiratory					
Larynx	22020	25	0.32	**0.59**	**0.39–0.89**
Lung and bronchus	22030	533	0.58	1.08	0.92–1.28
Lung-adenocarcinoma[c]		173	0.58	1.10	0.89–1.35
Lung-squamous cell[c]		95	0.48	0.89	0.69–1.14
Lung-small cell[c]		82	0.69	1.24	0.95–1.61
Lung-large cell[c]		25	0.48	0.84	0.55–1.28
Lung-non-specific non-small cell cancer[c]		42	0.87	**2.01**	**1.38–2.93**
Connective tissue/skin					
Soft tissue, including heart	24000	26	0.54	1.16	0.76–1.77
Melanoma	25010	265	1.06	**1.75**	**1.44–2.13**
Mesothelioma[d]		21	0.75	1.40	0.89–2.21

		Number of firefighters			
Cancer	**SEER code**	**N**	**%[a]**	**OR[b]**	**95%CI**
Urinary/reproductive					
Prostate	28010	1397	0.72	**1.45**	**1.25–1.69**
Testis	28020	85	0.67	1.10	0.73–1.66
Urinary bladder	29010	106	0.56	0.99	0.78–1.26
Kidney	29020	115	0.62	**1.27**	**1.01–1.59**
Cranial/endocrine					
Brain	31010	87	0.75	**1.54**	**1.19–2.00**
Thyroid	32010	41	0.64	1.27	0.88–1.84
Blood					
Hodgkin lymphoma	33011–33012	29	0.52	1.15	0.72–1.83
Non-Hodgkin lymphoma	33041–33042	183	0.60	1.22	1.00–1.50
Multiple myeloma	34000	55	0.64	**1.35**	**1.00–1.82**
Leukemia	35011–35043	122	0.64	**1.32**	**1.05–1.66**
CLL	35012	43	0.74	1.34	0.96–1.87
AML	35021, 35031	42	0.69	**1.44**	**1.02–2.02**
CML	35022	21	0.73	1.51	0.95–2.40

SEER code = recode based on ICD-O-3 (http://seer.cancer.gov/siterecode/). A total of 187 firefighters had rare cancers (i.e., cancers with fewer than 10 firefighter cases) and these rare cancers are not included in this table. The race was not stated for 2,719 individuals. Bolded values indicate a statistically significantly elevated (or decreased) OR at P <0.05.

OR, odds ratio; CI, confidence interval; ALL, acute lymphocytic leukemia; CLL, chronic lymphocytic leukemia; Other LL, other lymphocytic leukemia; AML, acute myeloid leukemia; CML, chronic myeloid leukemia.

[a] Controls consist of cancers of the pharynx, stomach, liver, and pancreas; 0.44% of individuals with control cancers were firefighters. This 0.44% applies to the comparison group for all case cancer examined except for pharyngeal, stomach, liver, and pancreatic cancers (which were also control cancers), where 0.42%, 0.46%, 0.46%, and 0.40% of individuals with control cancers were firefighters respectively (i.e., these represent the proportion of firefighters when the case cancer was removed from the control group).

[b] Adjusted for age of diagnosis, race, and year of diagnosis.

[c] Histological subtype of lung cancer. International Classification of Diseases for Oncology (ICD-O3 codes) for Adenocarcinoma = 8050, 8051, 8140, 8141, 8143, 8147, 8200, 8201, 8250–8255, 8260, 8310, 8320, 8323, 8430, 8480, 8481, 8490, 8550, 8551, 8560, 8562, 8570–8576; Squamous Cell = 8052, 8070–8076, 8078; Small Cell = 8002, 8041–8045; Large Cell = 8012–8014; Non-Small Cell Cancer, unspecified = 8046.

[d] Histological subtype of mesothelioma: ICD-O3 code = 9050–9055.

TABLE III

Odds Ratios for Various Cancers Among Firefighters* of Other Race/Ethnicity—California, 1988–2007

		Number of firefighters			
Cancer	**SEER code**	**N**	**%[a]**	**OR[b]**	**95%CI**
Head and neck					
Lip	20010	1	0.67	6.56	0.87–49.58
Tongue	20020	4	0.41	**3.57**	**1.23–10.35**
Salivary gland	20030	2	0.45	3.60	0.83–15.59
Gum and other mouth	20050	1	0.16	1.50	0.20–11.15
Pharyngeal	20062–20100	4	0.15	1.35	0.45–4.05
Digestive					
Esophagus	21010	5	0.26	2.14	0.81–5.65
Esophagus-adenocarcinoma		2	0.37	2.79	0.66–11.87
Esophagus-squamous carcinoma		2	0.18	1.44	0.34–6.14
Stomach	21020	10	0.17	1.61	0.71–3.65
Colorectal	21041–21052	30	0.18	1.41	0.82–2.41
Liver	21071	5	0.08	0.51	0.19–1.39
Pancreas	21100	5	0.12	0.90	0.33–2.45
Respiratory					
Larynx	22020	0			
Lung and bronchus	22030	26	0.13	1.01	0.57–1.78
Lung-adenocarcinoma[c]		8	0.11	0.89	0.40–2.00
Lung-squamous cell[c]		5	0.12	0.78	0.29–2.11
Lung-small cell[c]		1	0.05	0.36	0.05–2.71
Lung-large cell[c]		0			
Lung-non-specific non-small cell cancer[c,d]		5	0.37	2.42	0.86–6.80
Connective tissue/skin					
Soft tissue, including heart	24000	2	0.13	1.39	0.32–5.98
Melanoma	25010	7	0.61	**4.51**	**1.85–10.97**
Mesothelioma[e]		2	0.38	2.86	0.67–12.28

		Number of firefighters			
Cancer	**SEER code**	**N**	**%[a]**	**OR[b]**	**95%CI**
Urinary/reproductive					
Prostate	28010	125	0.27	**2.42**	**1.53–3.84**
Testis	28020	15	0.43	**3.73**	**1.26–11.02**
Urinary bladder	29010	8	0.29	**2.37**	**1.05–5.33**
Kidney	29020	18	0.33	**2.59**	**1.40–4.80**
Cranial/endocrine					
Brain	31010	10	0.38	**3.58**	**1.65–7.74**
Thyroid	32010	5	0.25	1.92	0.66–5.60
Blood					
Hodgkin lymphoma	33011–33012	4	0.25	2.50	0.76–8.28
Non-Hodgkin lymphoma	33041–33042	24	0.30	**2.17**	**1.20–3.92**
Multiple myeloma	34000	13	0.47	**3.77**	**1.91–7.44**
Leukemia	35011–35043	20	0.41	**3.64**	**1.96–6.74**
CLL	35012	7	0.86	**7.04**	**2.99–16.56**
AML	35021, 35031	2	0.11	1.12	0.26–4.76
CML	35022	6	0.61	**4.91**	**1.84–13.12**

SEER code =recode based on ICD-O-3 (http://seer.cancer.gov/siterecode/). Bolded values indicate a statistically significantly elevated (or decreased) OR at P <0.05.

OR, odds ratio; CI, confidence Interval; ALL, acute lymphocytic leukemia; CLL, chronic lymphocytic leukemia; Other LL, other lymphocytic leukemia; AML, acute myeloid leukemia; CML, chronic myeloid leukemia.

[*] Other race/ethnicity consists of individuals who were Black, Hispanic, Asian/Pacific Islander, Indian/Alaskan Native, and Other/unknown race.

[a] Controls consist of cancers of the pharynx, stomach, liver, and pancreas; 0.13% of individuals with control cancers were firefighters. This 0.13% applies to the comparison group for all case cancer examined except for pharyngeal, stomach, and liver cancers (which were also control cancers), where 0.12%, 0.11%, and 0.15% of individuals with control cancers were firefighters respectively (i.e., these represent the proportion of firefighters when the case cancer was removed from the control group).

[b] Adjusted for age of diagnosis and year of diagnosis.

[c] Histological subtype of lung cancer. International Classification of Diseases for Oncology (ICD-O3 codes) for Adenocarcinoma = 8050, 8051, 8140, 8141, 8143, 8147, 8200, 8201, 8250–8255, 8260, 8310, 8320, 8323, 8430, 8480, 8481, 8490, 8550, 8551, 8560, 8562, 8570–8576; Squamous Cell = 8052, 8070–8076, 8078; Small Cell = 8002, 8041–8045; Large Cell = 8012–8014; Non-Small Cell Cancer, unspecified = 8046.

[d] Firth bias-correction applied.

[e] Histological subtype of mesothelioma: ICD-O3 code = 9050–9055.

TABLE IV

Odds Ratios for Various Cancers Among White Firefighters—California, 1988–2007

		Number of firefighters			
Cancer	**SEER code**	**N**	**%[a]**	**OR[b]**	**95%CI**
Head and neck					
Lip	20010	17	0.95	1.36	0.82–2.25
Tongue	20020	31	0.70	1.10	0.75–1.61
Salivary gland	20030	12	0.77	1.19	0.66–2.15
Gum and other mouth	20050	13	0.70	1.06	0.60–1.87
Pharyngeal	20062–20100	38	0.66	1.03	0.71–1.48
Digestive					
Esophagus	21010	63	0.99	**1.59**	**1.19–2.12**
Esophagus-adenocarcinoma		44	1.14	**1.84**	**1.32–2.56**
Esophagus-squamous carcinoma		10	0.61	0.94	0.49–1.78
Stomach	21020	42	0.51	0.73	0.52–1.03
Colorectal	21041–21052	317	0.69	1.08	0.90–1.30
Liver	21071	34	0.70	1.21	0.83–1.76
Pancreas	21100	74	0.67	1.14	0.85–1.54
Respiratory					
Larynx	22020	25	0.41	**0.64**	**0.42–0.97**
Lung and bronchus	22030	506	0.71	1.10	0.92–1.30
Lung-adenocarcinoma[c]		164	0.73	1.11	0.90–1.38
Lung-squamous cell[c]		90	0.58	0.90	0.70–1.17
Lung-small cell[c]		81	0.84	1.30	1.00–1.70
Non-large cell[c]		25	0.62	0.89	0.58–1.36
Non-specific, non-small cell cancer[c]		37	1.07	**2.02**	**1.34–3.04**
Connective tissue/skin					
Soft tissue, including heart	24000	24	0.73	1.16	0.75–1.82
Melanoma	25010	254	1.09	**1.71**	**1.40–2.09**
Mesothelioma[d]		19	0.85	1.34	0.83–2.16

		Number of firefighters			
Cancer	**SEER code**	**N**	**%[a]**	**OR[b]**	**95%CI**
Urinary/reproductive					
Prostate	28010	1256	0.87	**1.40**	**1.19–1.64**
Testis	28020	70	0.78	0.91	0.58–1.44
Urinary bladder	29010	98	0.61	0.94	0.73–1.21
Kidney	29020	96	0.74	1.16	0.91–1.49
Cranial/endocrine					
Brain	31010	76	0.85	**1.41**	**1.07–1.87**
Thyroid	32010	36	0.82	1.21	0.81–1.80
Blood					
Hodgkin lymphoma	33011–33012	25	0.64	1.07	0.63–1.80
Non-Hodgkin lymphoma	33041–33042	159	0.71	1.16	0.94–1.45
Multiple myeloma	34000	42	0.73	1.17	0.84–1.64
Leukemia	35011–35043	101	0.73	1.17	0.91–1.49
CLL	35012	36	0.73	1.17	0.82–1.67
AML	35021, 35031	40	0.93	**1.46**	**1.03–2.08**
CML	35022	14	0.74	1.14	0.66–1.99

EER code =recode based on ICD-O-3 (http://seer.cancer.gov/siterecode/). Bolded values indicate a statistically significantly elevated (or decreased) OR at P <0.05.

OR, odds ratio; CI, confidence interval; ALL, acute lymphocytic leukemia; CLL, chronic lymphocytic leukemia; Other LL, other lymphocytic leukemia; AML, acute myeloid leukemia; CML, chronic myeloid leukemia.

[a] Controls consists of cancers of the pharynx, stomach, liver, and pancreas; 0.63% of individuals with control cancers were firefighters. This 0.63% applies to the comparison group for all case cancer examined except for pharyngeal, stomach, liver and pancreatic cancers (which were also control cancers), where 0.62%, 0.67%, 0.62%, and 0.61% of individuals with control cancers were firefighters respectively (i.e., these represent the proportion of firefighters when the case cancer was removed from the control group).

[b] Adjusted for age of diagnosis and year of diagnosis.

[c] Histological subtype of lung cancer. International Classification of Diseases for Oncology (ICD-O3 codes) for Adenocarcinoma = 8050, 8051, 8140, 8141, 8143, 8147, 8200, 8201, 8250–8255, 8260, 8310, 8320, 8323, 8430, 8480, 8481, 8490, 8550, 8551, 8560, 8562, 8570–8576; Squamous Cell = 8052, 8070–8076, 8078; Small Cell = 8002, 8041–8045; Large Cell = 8012–8014; Non-Small Cell Cancer, unspecified = 8046.

[d] Histological subtype of pleural mesothelioma[d] (ICD-O3 code = 9050–9055).