Firefighters and Cancer Risk

Report to the Legislature regarding expanding RCW 51.32.185 to include buccal, pharyngeal, esophageal, and pancreatic cancers

Washington State Advisory Committee on Firefighter Presumption

SHARP Technical Report 101-05-2024

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Safety & Health Assessment & Research for Prevention

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ABBREVIATIONS

CDC	Centers for Disease Control and Prevention
CI	Confidence Interval
FD	Fire Department or Fire District
HR	Hazard Ratio
L&I	Washington State Department of Labor and Industries
NIOSH	National Institute for Occupational Safety and Health
NR	Not reported
PMR	Proportionate mortality ratio
RR	Risk ratio
SHARP	Safety and Health Assessment and Research for Prevention
SIR	Standardized incidence ratio
SMR	Standardized mortality ratio
WA	Washington State

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KEYWORDS

SHARP, Cancer, Firefighter, Firefighting, Presumption

EXECUTIVE SUMMARY

In Washington State (WA), certain medical conditions diagnosed in career firefighters are presumed to be occupational diseases according to the firefighter presumption law (RCW 51.32.185). In a 2019 amendment, the law established the creation of the Firefighter Presumption Advisory Committee, a committee comprised of experts from various disciplines of occupational safety and health, to provide a scientifically based recommendation to state lawmakers about whether additional diseases or disorders should be added to the firefighter presumption law. The committee is chaired by the research director of the Washington State Department of Labor and Industries' (L&I) Safety and Health Assessment and Research for Prevention (SHARP) program and is supported by SHARP research staff.

On February 1st, 2023, the Washington State Legislature requested that the Firefighter Presumption Advisory Committee review the scientific literature regarding firefighters' risk for adenocarcinoma and esophageal, buccal, pharyngeal, and pancreatic cancer. L&I mobilized the Firefighter Presumption Advisory Committee and facilitated their review of the best available research. The Firefighter Presumption Advisory Committee reviewed scientific evidence regarding firefighters' risk for esophageal, buccal, pharyngeal, and pancreatic cancer compared to other occupations and populations, and whether firefighter-related workplace exposures are associated with the development of these cancers. The purpose of this study was to (1) determine if firefighters are at a higher risk for developing these cancers as compared to other workers and (2) provide a recommendation about whether these cancers should be expanded in the firefighter presumption law.

Key Findings

By Cancer Type:

Buccal Cavity and Pharyngeal Cancer

- We identified five meta-analyses, 34 cohort studies, and seven case-control studies describing buccal and pharyngeal cancer risk in firefighters. The majority of these studies showed that firefighters are not at an increased risk of developing buccal or pharyngeal cancer compared to non-firefighter populations.
- The WA Occupational Mortality Data from 1950-2010 yielded proportionate mortality ratio (PMR) estimates suggesting male firefighters do not have a proportionally higher risk of buccal cavity and pharyngeal cancer mortality compared to other workers.

Esophageal Cancer

- We identified six meta-analyses, 36 cohort studies, and five case-control studies describing esophageal cancer risk in firefighters. Few studies reported an elevated risk of esophageal cancer in firefighters compared to non-firefighter populations. The majority

of studies that stratified results by years of employment reported a lengthy firefighting career was not associated with an increased risk of esophageal cancer.
- Between 1950 and 2010, a larger proportion of WA firefighters died of esophageal cancer compared to other workers, and PMRs were highest in men ages 30-39 and 40-49. Over half of the esophageal cancer deaths reported in WA's Occupational Mortality Database occurred between 2000 and 2010.

Pancreatic Cancer

- We identified six meta-analyses, 35 cohort studies, and seven case-control studies comparing pancreatic cancer risk among firefighters and non-firefighters. The majority of these studies found that firefighters are not at an elevated risk of pancreatic cancer incidence or mortality. Select cohort studies reported elevated risk in certain strata of firefighters, but these results were not consistent across multiple studies.
- Between 1950 and 2010, a larger proportion of WA firefighters between the ages of 20 and 63 years old died of pancreatic cancer compared to other workers.

Occupational exposures associated with cancer

- Firefighters are exposed to numerous carcinogens from combustion products of building materials, chemicals, and other hazards. Personal protective equipment can mitigate exposure to carcinogens in certain situations, but is not completely effective nor is it used in all settings. Carcinogens have been observed in numerous firefighter biomonitoring studies.
- The *International Agency for Research on Cancer* (2023) found after thoroughly reviewing the available scientific literature, classified occupational exposure as a firefighter as carcinogenic to humans. However, they did not report a causal relationship between firefighting and pancreatic, buccal, oropharyngeal or esophageal cancers.
- Shift work, inadequate and disrupted sleep are also associated with the development of cancer.

Advisory Committee Recommendation

This report and the subsequent recommendation only address the risk of buccal, pharyngeal, esophageal, and pancreatic cancer in firefighters as a collective group under the presumption law. The content of this report and the recommendation presented here are not intended to and should not be used for a causal determination of buccal, pharyngeal, esophageal, or pancreatic cancer in an individual firefighter with varying susceptibility and occupational exposures. Individual susceptibility and unique exposures during a firefighter's career may elevate an individual firefighter's risk for these malignancies, which would be obscured when analyzing data at the population level. Recent improvements in capturing work histories on death certificates, standardizing systems for linking datasets (including cancer registries, vital records, and hospital data), and future cohort studies or meta-analyses will further clarify the relationship between occupational exposures and cancer risk in firefighters over time.

Based on a review of the current scientific literature, the committee found sufficient evidence to support that firefighters are regularly exposed to carcinogenic agents at work, but did not find evidence from epidemiologic studies that firefighters have an increased risk of buccal cavity, pharyngeal, esophageal, or pancreatic cancer incidence or mortality. Therefore, the committee has not found sufficient evidence for an association between firefighting and buccal cavity cancer, pharyngeal cancer, esophageal cancer, or pancreatic cancer to warrant inclusion of any of these cancer types into WA's presumption law. Subsequent requests for a review of these four types of cancer for inclusion into Washington presumption law may be necessary as more research evidence emerges.

INTRODUCTION

Washington State Presumption Law

In Washington State, workers seeking workers' compensation benefits must provide evidence to demonstrate that their injury or illness was caused by work. This can be challenging for certain workers, such as career firefighters, who are at risk of developing chronic illnesses years after hazardous workplace exposures. As a result, WA has enacted a law establishing a prima facie presumption that certain illnesses among firefighters are occupational diseases (RCW 51.23.185). First passed in 1987, this law has been expanded several times and now includes: respiratory diseases; any heart problems experienced within 72 hours of exposure to smoke, fumes, or toxic substances or experienced within 24 hours of strenuous physical exertion due to firefighting activities; certain types of cancers for firefighters after serving at least 10 years; select infectious diseases; and post-traumatic stress disorder for firefighters after serving at least 10 years.

Starting in 2019, the law also established an advisory committee on occupational disease presumptions to review the scientific evidence and to make recommendations to the legislature on additional diseases or disorders for inclusion. Ranking members of the appropriate WA legislative committees may initiate a request for the advisory committee to review scientific evidence of a specific disease or disorder for inclusion by notifying the director. Once formally initiated, the advisory committee is tasked with reviewing the "*scientific literature on the disease or disorder, relevant exposures, and strength of the association between the specific occupations and the disease or disorder proposed for inclusion in this section*" (RCW 51.32.185). The committee must consider the relevance, quality, and quantity of the scientific literature and data, and may consult nationally recognized subject matter experts if necessary. The recommendation must be made by a majority of advisory committee's voting members and summarized in a written report documenting the relevant scientific evidence and rationale for their recommendation. Individual advisory committee members may provide a written dissent if desired.

The advisory committee is composed of five voting members who are not employed by L&I (two epidemiologists, two preventive medicine physicians, and one industrial hygienist) and is chaired by the research director of L&I's Safety and Health Assessment and Research for Prevention (SHARP) program. The current advisory committee members are as follows:

Dr. Cathy Wasserman

Cathy Wasserman, PhD, MPH, is the State Epidemiologist for Policy and Practice at the Washington State Department of Health, where she provides leadership, oversight, and technical assistance regarding disease surveillance, epidemiologic methods and standards, non-infectious disease cluster investigations, population surveys, and related policy. She is an Affiliate Assistant Professor in Epidemiology at the University of Washington School of Public Health, and completed her graduate studies at the University of California, Berkeley.

Dr. Lee Friedman

Professor Lee Friedman, PhD, MSc, is faculty at the University of Illinois Chicago School of Public Health in the Division of Environmental and Occupational Health Sciences. He has a PhD in occupational epidemiology with more than 20 years of experience in the field of occupational health and safety. His occupational health research principally covers occupational health surveillance, injury prevention at work, and precarious employment. He specializes in analyses of large population based datasets, longitudinal cohorts, surveillance systems, data linkage and multi-center projects. He currently leads the CDC-NIOSH funded state occupational surveillance program in Illinois.

Dr. Chunbai Zhang:

Dr. Zhang, MD, MPH, is the Director of Employee Occupational Health at the Veterans Affairs Puget Sound Health Care System in Seattle. He also serves as an Assistant Professor at the University of Washington School Of Medicine and an Adjunct Professor at the University of Washington School of Public Health. Dr. Zhang received his medical degree from Geisel School of Medicine at Dartmouth and is board certified in internal medicine, occupational medicine, and sleep medicine.

Dr. Robert Harrison:

Dr. Harrison, MD, MPH, is a Public Health Medical Officer with the California Department of Public Health Occupational Health Branch and Clinical Professor at the University of California, San Francisco in the Division of Occupational and Environmental Medicine. He established the UCSF Occupational Health Services, where he has diagnosed and treated thousands of work and environmental injuries and illnesses. He has designed and implemented numerous medical monitoring programs for workplace exposures, and has consulted widely with employers, health care professionals, and labor organizations on the prevention of work-related injuries and illnesses. Dr. Harrison has led many work and environmental investigations of disease outbreaks. He has served as a technical and scientific consultant to Federal OSHA and CDC/NIOSH, and was a member of the California

Occupational Safety and Health Standards Board. His research interests include the collection and analyses of California and national data on the incidence of work-related injuries and illnesses. Dr. Harrison has authored or co-authored more than 50 peer-reviewed journal articles, and more than 40 book chapters/contributed articles/letters to the editor. He is the co-editor of the most recent edition of the textbook Occupational and Environmental Medicine (McGraw-Hill Education, New York, NY, 2021).

Dr. Martin Cohen:

Martin Cohen is a Teaching Professor, Assistant Chair for Stakeholder Engagement, and Director of the Field Research and Consultation Group at the University of Washington's Department of Environmental and Occupational Health Sciences. He is a Certified Industrial Hygienist and Certified Safety Professional and holds a Doctorate of Science (ScD) degree from the Harvard University School of Public Health in Exposure Assessment. He specializes in the assessment of workplace exposures and the development of new assessment methods.

Dr. David Bonauto (Non-voting chair):

David Bonauto, MD, MPH, is the Research Director for the Washington State Department of Labor and Industries' Safety and Health Assessment and Research for Prevention (SHARP) program. He has 23 years of experience in occupational safety and health research, has published numerous peer reviewed articles, and has served on national, regional, and state groups and committees focused on preventing workplace injuries and illness and improving occupational safety and health research and prevention activities.

The advisory committee is supported by SHARP epidemiologist, Claire LaSee, MPH/MSW, and is further assisted by other L&I staff members as needed. For this review, SHARP staff members Amanda Grabow and Daniele Todorov provided invaluable technical assistance and support.

Request for Review: Additional Cancers

On February 1st, 2023, the Department of Labor and Industries (L&I) received a letter from two WA state legislators asking for an evaluation and recommendation for including adenocarcinoma, and esophageal, buccal, pharyngeal, and pancreatic cancer as a presumed occupational diseases for firefighters (Appendix A – Legislative Request). Further, the committee was asked to review the link between PFAS (per- and polyfluoroalkyl substances) exposure and the occurrence of pancreatic cancer in firefighters. This request resulted in the mobilization of the advisory committee on firefighter presumption.

WA's current presumption law includes the following cancers as presumed occupational diseases - specifically - prostate cancer diagnosed prior to the age of 50, primary brain cancer, malignant melanoma, leukemia, non-Hodgkin's lymphoma, bladder cancer, ureter cancer, colorectal cancer, multiple myeloma, testicular cancer, kidney cancer, mesothelioma, stomach cancer, non-melanoma skin cancer, breast cancer in women, and cervical cancer. The presumption applies to firefighters after 10 years of service and is phased-out after retirement. The law also includes a presumption for respiratory disease, which includes lung cancer.

The committee did not pursue an evaluation of adenocarcinoma. Adenocarcinoma is a subtype of cancer that develops in cells that secrete mucus, digestive juices, or other liquids. Adenocarcinomas can occur in different organs, mostly in the prostate, breast, colon, rectum, lung, stomach, and pancreas. The current list of cancers included in RCW 51.32.185 would include many adenocarcinomas with the notable exceptions of pancreatic cancer and prostate cancer for those older than 50 years. Further, the published research assessing an association between firefighter mortality or morbidity and cancer typically does not estimate the risk based on type of cancer, and rather estimate the risk based on body organ, e.g. pancreas, kidney, lung, etc.

Cancer is a leading cause of death in the United States. It is caused by genetic changes that lead to uncontrolled growth of cells. Genetic changes or alterations in DNA may occur as a result of environmental, lifestyle or behavioral exposures, and such exposures can be occupational and non-occupational in origin. Firefighters have occupational exposures that likely increase cancer risk, specifically exposure to agents known to cause cancer, such as asbestos, polycyclic aromatic hydrocarbons, and other combustion products. It is generally accepted that certain aspects of work can contribute to increased cancer risk. For example, shift work is associated with cancer risk. In addition, work affects health-related behaviors such as smoking, diet, and exercise which can influence cancer risk.

Criteria for causation

While the legislature did not specify which criteria to use to weigh the scientific evidence, the committee's general approach is to use Sir Austin Bradford Hill's observations regarding how a causal relationship between an exposure and a disease might be considered (Hill 1965). Hill's nine considerations are as below:

1. **Strength of association:** The association between the exposed population and the disease or injury outcome is of a sufficient magnitude. The stronger the association, the more likely its relation is causal.
2. **Consistency:** The association is consistent across a number of studies in different populations and study designs. Evidence of an association may occur due to statistical chance in any one study, whereas this is reduced if there are multiple studies demonstrating a statistically significant increased risk.
3. **Specificity:** There is a specificity in the association of the exposure with the disease or outcome.
4. **Temporality:** The chemical, physical, and biologic exposure precedes the disease.
5. **Biological gradient:** There is a dose-response relationship, such that an increasing amount of exposure increases the risk.

6. **Plausibility:** There is biologic plausibility that the chemical, physical, or biological occupational exposures are associated with the disease.
7. **Coherence:** The association is coherent with what is known about the disease, existing theory, or knowledge of causation.
8. **Experiment:** Alternative explanations of the potential relationship between the disease and the exposure are eliminated or controlled for. Additional factors related to both the exposure and the disease are accounted for either in the study design or analysis.
9. **Analogy:** When strong evidence suggests a causal relationship between a specific exposure and a disease, then other similar exposures may lead to analogous outcomes.

We evaluated the body of evidence using these nine considerations as a framework upon which to base our recommendation. We primarily used epidemiological studies to assess **strength of the association**, **consistency**, **specificity**, **temporality**, **biological gradient**, and **analogy,** and we looked to relevant exposure data when assessing **plausibility**. Both epidemiological studies and exposure studies were used to assess **coherence**. Due to the nature of the occupational exposure and severity of the disease, we anticipated that it would be unlikely to find any evidence from **experimental** evidence in humans.

This review greatly benefitted from the recent authoritative publication of the International Agency for Research on Cancer's (IARC) evaluation of occupational exposure as a firefighter as a possible causative agent of cancer (IARC, 2023). This monograph is a comprehensive, systematic review of published peer-reviewed scientific literature by an interdisciplinary group of recognized international experts, who provide a consensus overall evaluation of the strength of the evidence of carcinogenicity for the agent under review – the agent in this case is firefighting. The evaluations are based on the strength of the evidence of cancer in humans, the evidence of cancer in experimental animals, and the mechanistic evidence for carcinogenicity.

This report is organized into two components. The first component presents our search and summarization of evidence from epidemiologic studies evaluating whether firefighters are at higher risk for esophageal, buccal, pharyngeal, and pancreatic cancer compared to workers in other occupations. We searched publication databases to identify peer-reviewed, scientific publications that estimate risk of cancer for firefighters. The second component of the evaluation heavily relied on the comprehensive review by IARC to assess if there is a biologically plausible relationship between firefighting and cancer. Assessing whether the cancer presumption should be expanded requires consideration of both (1) increased firefighter cancer morbidity and mortality for the specified cancers and (2) biologic plausibility for causation.

METHODS

Occupational Mortality Databases

We described the number of deaths and proportional mortality ratios (PMRs) of buccal and pharyngeal cancer, esophageal cancer, and pancreatic cancer in firefighters using WA-specific databases assessing the usual occupation and cause of death listed on the death certificate. The WA Occupational Mortality Database (WA DOH, 2011) includes deaths over a 60-year span. PMRs from peer-reviewed scientific publications were also included.

Identifying Epidemiologic Studies

In September 2023, we searched the PubMed Central online database for peer-reviewed research articles about cancer in firefighters using the following search terms:

> *((cancer OR neoplasms[mh]) AND (Firefighter OR firefighting)) AND (case-control study[mesh] OR cohort study[mesh] OR meta-analysis[mh] OR review[pt] OR risk factors[mh] OR neoplasms/epidemiology OR neoplasms/etiology OR neoplasms/CI OR death certificates[mh] OR epidemiologic methods[mh])*

All relevant articles identified in the initial search were reviewed. References cited in these articles were reviewed, this secondary search identified additional references. All of the additional articles identified in this secondary search were reviewed for cancer risk estimates. When an article reported a risk estimate for buccal, pharyngeal, esophageal, or pancreatic cancer in firefighters, data about study design and the study results were extracted and organized into tables. Elements of study design, such as study duration, number of subjects, and data sources, were included to characterize the quality and relevance of the study.

Assessing Biologic Plausibility

There is ample research supporting firefighter exposure to carcinogens. In this review, the committee and staff relied on the IARC monograph *Occupational exposure as a firefighter, Vol 132* for a comprehensive review of firefighter exposure to carcinogens and the relevance of those exposures for causing cancer (IARC, 2023).

RESULTS

Epidemiological Studies

Literature search

We found 242 articles in our initial PubMed literature search. After reviewing the title and abstracts of these articles, we identified 72 articles that were highly relevant to our research question (Appendix A). In our secondary search, we identified 58 additional articles (Appendix B). We were able to obtain full text for all articles except for five articles - one article that was not written in English and three articles which we could not find the full-text version. For all other articles, the full-text versions were reviewed and relevant study design characteristics were recorded (Supplemental Tables). Only studies reporting an estimate for buccal, pharyngeal, esophageal, or pancreatic cancer in firefighters were included. Risk estimates from individual papers were reported by study design: six meta-analyses, two studies reporting proportional mortality ratios (PMR), 42 cohort studies, and nine case-control studies.

Buccal and Pharyngeal Cancer

We identified five meta-analyses, 34 cohort studies, and seven case-control studies describing buccal and pharyngeal cancer risk in firefighters. Table 1. describes the results from five meta-analyses, none of which found that firefighters are at a higher risk of buccal or pharyngeal cancer.

Table 1. Meta Analyses reporting Buccal and Pharyngeal Caner in Firefighters

First author, year	Study pop.	Analysis	Cancer Type (ICD)	# of studies	Studies included (by ID)	Risk Estimate	95% CI
Casjens, 2020	male FFs	mSIR	Buccal cavity & pharynx (C00-C14)	4	12, 20, 32, 41	mSIR=0.87	0.72-1.02
		mSMR	Buccal cavity & pharynx (C00-C14)	6	2, 4, 13, 15, 22, 33	mSMR=0.97	0.68-1.26
Jalilian, 2019	male FFs	SIRE	Buccal cavity & Pharynx (140-149)	11	1, 11, 12, 20, 26, 27, 32, 37, 39, 41, 48	SIRE=1.15	0.91-1.44
		SMRE	Buccal cavity & Pharynx (140-149)	11	2, 3, 4[1],7, 11, 13, 15, 22, 33, 34	SMRE=1.21	0.95-1.55
Lee, 2023	FFs	SIRE	Lip, oral cavity, pharynx (140-149)		NR	SIR=0.80	0.52-1.24
		SMRE	Lip, oral cavity, pharynx (140-149)		NR	SMR=0.65	0.53-0.78
LeMasters, 2006	FFs	Summary Risk Estimate	Buccal cavity & Pharynx (140-149)	9	3, 4, 7, 13, 14, 15, 16[2], 22, 34	mSMR=1.18	0.81-1.66
Soteriades, 2017	FFs	SIR- Good studies only	Oral & Pharyngeal	2	12, 32	SIR=0.80	0.50-1.28

		SIR- Good & Adequate studies	Oral & Pharyngeal	2	12, 32	SIR=0.80	0.50-1.28
		SIR- All studies	Oral & Pharyngeal	2	12, 32	SIR=0.80	0.50-1.28
		MRE- Good studies only	Oral & Pharyngeal	6	NR	SMR=1.07	0.70-1.63
		MRE-Good & adequate studies	Oral & Pharyngeal	7	3, 4, 7, 13, 15, 22, 33	SMR=1.08	0.75-1.56
		MRE- All studies	Oral & Pharyngeal	11	NR	SMR=1.04	0.84-1.30
		Combined SIR & MRE- Good studies only	Oral & Pharyngeal	8	NR	risk estimate=0.96	0.68-1.34
		Combined SIR & MRE- Good & adequate studies	Oral & Pharyngeal	9	3, 4, 7, 12, 13, 15, 22, 32, 33	risk estimate=0.95	0.70-1.30
		Combined SIR&MRE- All studies	Oral & Pharyngeal	13	not reported	risk estimate=0.94	0.77-1.15

NR: not reported

1. includes two different measures

2. It is unclear what point estimate was included from Giles 1993. Giles reports a SIR for cancers of the upper aero digestive tract, but we did not include this in our tables as it was too vague of a description

Table 2. describes the overall risk estimates for buccal and pharyngeal cancer among firefighters reported by cohort studies (Supplemental Table 12. describes all risk estimates for buccal and pharyngeal cancer among firefighters reported by cohort studies.) Of these studies, only two reported an increased risk of buccal and pharyngeal cancer in firefighters (Daniels, 2014; Pinkerton, 2020). These two studies, however, consisted of the same study population of firefighters from San Francisco, Chicago, and Philadelphia from 1950-2009. Few studies reported increased risk in buccal and pharyngeal cancer when stratifying analyses by various firefighter characteristics. Baris (2001) reported an increase mortality of buccal and pharyngeal cancer in firefighters at engine-only companies (SMR=2.00, 95%CI: 1.11-3.63), but an increase in mortality was not reported among firefighters at ladder-only companies or engine and ladder companies. This same study also reported an increased risk of buccal cavity and pharyngeal cancer mortality in firefighters hired before 1935 (SMR=2.11, 95%CI: 1.13-3.91), but not in firefighters hired between 1935 and 1944 and in firefighters hired after 1944 (Baris 2001). Of the four studies that stratified results by length or duration of firefighting employment, none reported that longer duration of employment was associated with an increased risk of buccal or pharyngeal cancer in firefighters (Aronson, 1994; Baris, 2001; Demers, 1994; Petersen, 2018a).

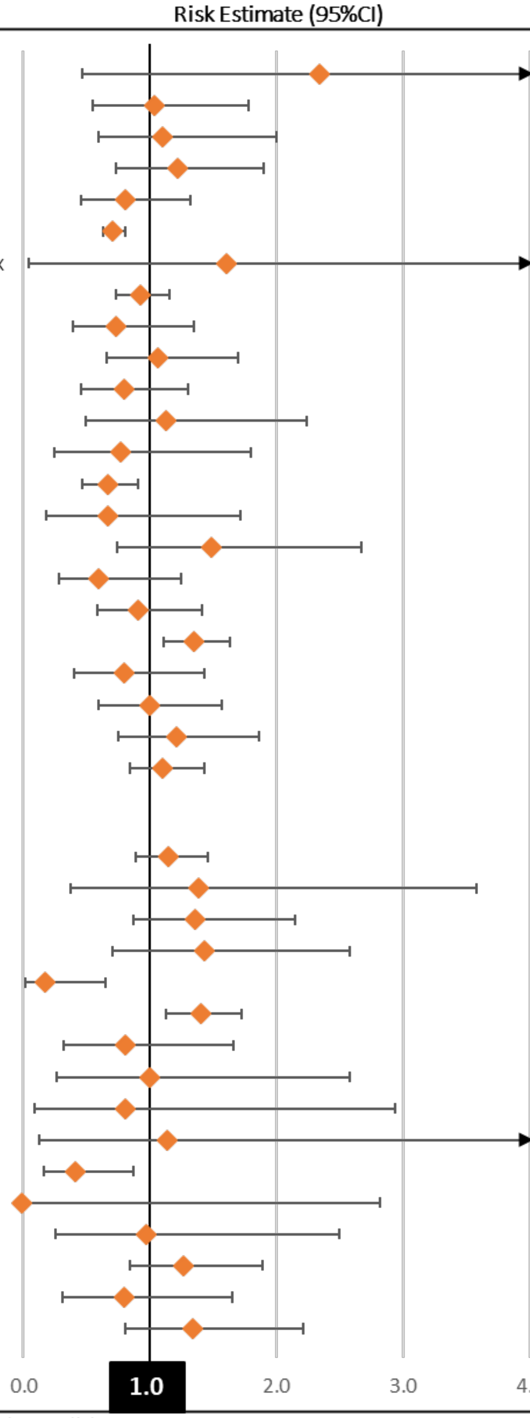
Among the seven case-control studies describing buccal and pharyngeal cancer in firefighters, two studies reported overall elevated odds of firefighter mortality from buccal and pharyngeal cancer (Table 13.). Elevated odds of malignant cancer of the buccal cavity and pharynx was reported in a study of Indiana firefighters (OR=2.15 95%CI: 1.19-3.79) (Muegge, 2018) and in oral cancer among

French firefighters (OR=10.2 95%CI: 3.1-34.0) (Paget-Bailly, 2013). In a large statewide study of cancer in Florida firefighters, researchers reported that firefighters, even when stratifying by race, stage of cancer, and age group, were not at an increased risk of developing cancer of the oral cavity or pharynx (Lee 2020).

Based on the peer-reviewed literature, there is little evidence to suggest that firefighters are at an increased risk of developing buccal and pharyngeal cancers. This is further supported by buccal cavity and pharyngeal cancer deaths among WA firefighters from 1950-2010, as described in Table 3 (WA DOH, 2011).   For men ages 20-64 in WA, the PMR for buccal and pharyngeal cancer in firefighters was lower than non-firefighters (PMR=23, p=0.01616) (WA DOH, 2011). The proportional mortality from buccal and pharyngeal cancer was elevated in firefighters aged 80 years and older, however this was not statistically significant (PMR=135, p=0.54821) (WA DOH, 2011). We did not identify any other databases or studies that reported PMRs for buccal and pharyngeal cancer for firefighters.

Table 2. Forest plot describing risk of buccal and related cancers in firefighters reported in cohort studies.

Study		Cancer Type	Point Estimate (95%CI)
Incidence Studies			
1*	Ahn, 2012	Parotid gland	SIR=2.34 (0.47-6.83)
8	Bigert, 2020	Pharynx	SIR=1.04 (0.55 -1.78)
12*	Demers, 1994	Oral & pharynx	SIR=1.1 (0.6-2.0)
14*	Demers, 1992b	Oral & Pharynx	SIR=1.22 (0.73-1.90)
17	Glass, 2019	Lip, oral cavity, & pharynx	SIR=0.81 (0.46-1.32)
18	Glass, 2017	Lip, oral cavity & Pharynx	SIR=0.71 (0.63-0.81)
19	Glass, 2016a	Lip, buccal cavity, & pharynx	SIR=1.61 (0.04-8.98)
20*	Glass, 2016b	Lip, oral cavity, & pharynx	SIR=0.93 (0.73-1.16)
21	Glass, 2009	Lip, head, and neck	SIR=0.73 (0.39-1.35)
23	Harris, 2018	Oral	HR=1.06 (0.66-1.70)
30	Li, 2016	Oral cavity and pharynx	SIR=0.80 (0.46-1.30)
31	Li, 2012[1]	Oral cavity and pharynx	SIR=1.13 (0.49-2.24)
31	Li, 2012[2]	Oral cavity and pharynx	SIR=0.77 (0.25-1.80)
32*	Ma, 2006	Buccal	SIR=0.67 (0.47-0.91)
35	Marjerrison, 2022	Oral cavity	SIR=0.67 (0.18-1.72)
35	Marjerrison, 2022	Pharynx	SIR=1.49 (0.74-2.67)
39*	Petersen, 2018b	Mouth	SIR=0.60 (0.28-1.25)
39*	Petersen, 2018b	Pharynx	SIR=0.91 (0.59-1.41)
40	Pinkerton, 2020	Buccal Cavity & pharynx	SIR=1.35 (1.11-1.63)
41*	Pukkala, 2014	Oral cavity	SIR=0.80 (0.40-1.43)
41*	Pukkala, 2014	Pharynx	SIR=1.00 (0.60-1.57)
44	Solan, 2013	Oral cavity & pharynx	SIR=1.21 (0.75-1.86)
45	Sritharan, 2022	Oral Cancer	HR=1.10 (0.84-1.43)
Mortality Studies			
2*	Amadeo, 2015	Lip, Oral Cavity, Pharynx	SMR=1.15 (0.89-1.46)
3*	Aronson, 1994	Pharynx	SMR=139 (38-357)
4*	Baris, 2001	Buccal cavity & pharynx	SMR=1.36 (0.87-2.14)
7*	Beaumont, 1991	Buccal cavity & pharynx	RR=1.43 (0.71-2.57)
9	Colbeth, 2020	Buccal & pharynx	SMR=0.18 (0.02-0.65)
11*	Daniels, 2014	Buccal & pharynx	SMR=1.40 (1.13-1.72)
13*	Demers, 1992a	Oral & pharynx	SMR=0.81 (0.33-1.66)
14*	Demers, 1992b	Oral & Pharynx	SMR=1.00 (0.27-2.57)
15*	Deschamps, 1995	Pharynx Cancer	SMR=0.81 (0.10-2.93)
22*	Guidotti, 1993	Oral	SMR=113.6 (13.7-410.4)
33*	Ma, 2005	Buccal & pharynx	SMR=0.42 (0.17-0.87)
35	Marjerrison, 2022	Oral cavity	SMR=0.00 (0.00-2.81)
35	Marjerrison, 2022	Pharynx	SMR=0.97 (0.26-2.49)
38	Petersen, 2018a	Oral cavity & oesophagus	SMR=1.27 (0.85-1.89)
42	Rosenstock, 1991	Buccal cavity & pharynx	SMR=0.80 (0.32-1.65)
51	Zhao, 2020	Mouth & Pharynx	MRR=1.34 (0.81-2.21)



*study was included in at least one meta analysis for this condition

1 Early period (through 2006)

2 Later period (2007-2008)

Table 3. WA-State specific buccal cavity and pharyngeal cancer deaths among firefighters

Source	Group	Firefighter Deaths	PMR (95% CI)	p-value or 95%CI
WA Occupational Mortality Database (males, 1950-2010) (WA DOH 2011)	All	14	PMR=0.65	p=0.10748
	Age Group:			
	50-59	2	PMR=0.54	p=0.59672
	60-69	1	PMR=0.14	p=0.01298
	70-79	7	PMR=1.16	p=0.6914
	80+	4	PMR=1.35	p=0.54821
	20-64	2	PMR=0.23	p=0.01616

Esophageal Cancer

Table 4. describes the risk of esophageal cancer in firefighters summarized in the six different meta-analyses studies we identified. Crawford (2017) reported that firefighters were at a statistically significantly elevated risk of esophageal cancer when using a fixed effect model (meta-RR=1.19, 95%CI: 1.05-1.35), but these results were no longer statistically significant when using a random effect model (meta-RR=1.03, 95%CI: 0.76-1.38). None of the other five meta-analyses reported that firefighters were at an increased risk of developing esophageal cancer.

Table 4. Meta-Analyses reporting Esophageal Cancer in Firefighters

First author, year	study pop	Analysis	# of studies	Studies included (by study ID)	Risk Estimate	95% CI
Casjens, 2020	male FFs	mSIR	8	1, 6, 11, 12, 20, 27, 32, 41	mSIR=1.06	0.76-1.36
		mSMR	7	2, 3, 4, 11, 13, 33, 49	mSMR=0.93	0.64-1.23
Crawford/IOM, 2017		Meta-RR (fixed effect model)	13	1, 3, 4, 5, 6, 7, 11[1], 12, 26, 32, 41, 49, 50	Meta-RR=1.19	1.05-1.35
		Meta-RR (random effect model)	13	1, 3, 4, 5, 6, 7, 11[1], 12, 26, 32, 41, 49, 50	RR=1.03	0.76-1.38
Jalilian, 2019	male FFs	SIRE	12	1, 6, 11, 12, 20, 26, 27, 32, 39, 41, 48, 50	SIRE=1.09	0.87-1.37
		SMRE	9	2, 3, 4, 7, 11, 13, 33, 34, 49	SMRE=1.01	0.76-1.34
Lee, 2023	FFs	SIRE		not reported	SIR=0.73	0.60-0.88
		SMRE		not reported	SMR=0.96	0.84-1.10

First author, year	study pop	Analysis	# of studies	Studies included (by study ID)	Risk Estimate	95% CI
LeMasters, 2006	FFs	Summary Risk Estimate	8	4, 6, 7, 13, 14, 34, 49, Feuer 1986[2]	mSMR=0.68	0.39-1.08
Soteriades, 2019	FFs	SIR- Good studies only	3	not reported	SIR=0.89	0.49-1.62
		SIR- Good & Adequate studies	5	5, 6[3], 12, 26, 32	SIR= 1.09	0.75-1.58
		SIR- All studies	5	5, 6[3], 12, 26, 32	SIR= 1.09	0.75-1.58
		MRE- Good studies only	5	3, 4, 7, 33, 49	SMR=0.9	0.47-1.71
		MRE-Good & Adequate studies	5	3, 4, 7, 33, 49	SMR=0.9	0.47-1.71
		MRE- All studies	10	NR	SMR= 1.02	0.8-1.31
		Combined SIR & MRE- Good studies only	8	NR	Risk Estimate= 0.93	0.06-1.43
		Combined SIR & MRE- Good & Adequate studies	10	3, 4, 5, 6[3], 7, 12, 26, 32, 33, 49	Risk Estimate= 1.02	0.74-1.40
		Combined SIR & MRE- All studies	15	NR	Risk Estimate= 1.06	0.87-1.29

NR: not reported

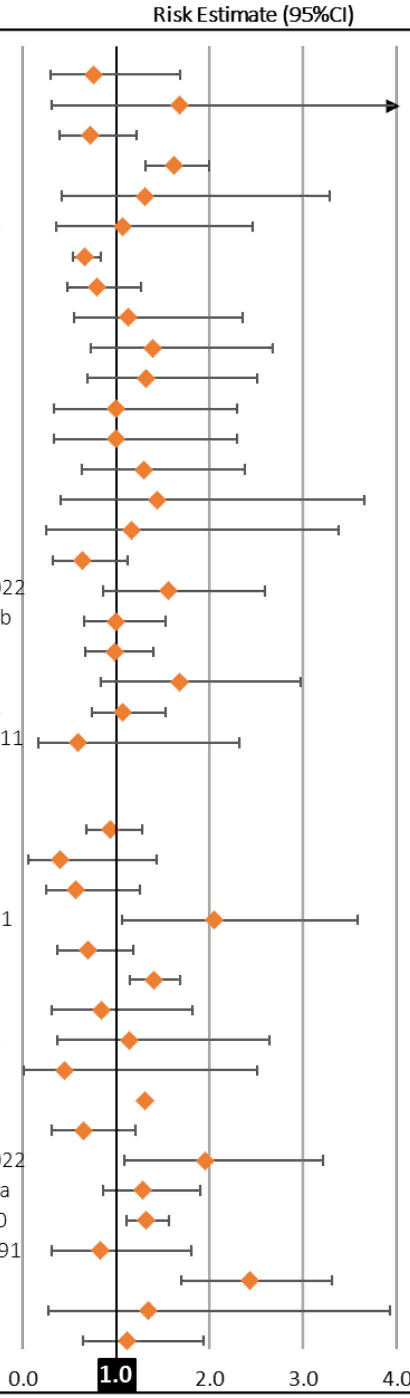
1. Author cited using Daniels' article "Mortality and cancer Incidence in a pooled cohort of US firefighters from SF, Chicago, and Philadelphia" published in Occ and Environmental Med as being from 2013. This was an error, as this article was published in 2014.
2. Feuer, 1986 is not included in the current tables as this study was not specific to esophageal cancer, but rather reported a PMR for all digestive cancers in firefighters
3. Author cited using results from a 2000 report by Bates titled "Retrospective cohort study of mortality and cancer incidence in New Zealand fire fighters," the results of which were published in a peer-reviewed journal by the same author in 2001.

We also identified 36 cohort studies and five case-control studies describing esophageal risk in firefighters, many of which were used in the meta-analyses found in Table 4. The main results of these cohort studies is summarized in Table 5. and detailed results for all of these studies can be found in Supplemental Table 13. Researchers in only three studies (Beaumont, 1991; Daniels, 2014; Pinkerton, 2020) reported a statistically significant elevated risk of esophageal cancer among firefighters. Beaumont (1991) reported the relative risk of esophageal mortality in firefighters as double that in the general population (n=12, RR=2.04, 95%CI: 1.05-3.57), but the risks were not significantly elevated when stratifying by years since first employment or length of employment. Similarly, Daniels (2014) reported elevated mortality of esophageal cancer among firefighters (SMR=1.39, 95%CI: 1.14-1.67) though when the results were stratified by employment duration, the SMRs did not increase as employment duration lengthened. Relative mortality was highest among firefighters with 10-20 years of experience (SMR=1.72 95%CI: 1.14-2.48) and firefighters with 20-30 years of experience (SMR=1.40 95%CI: 1.05-1.83), but was not significantly elevated among firefighters with 30 years of experience or more (SMR=1.19, 95%CI: 0.71-1.84). None of the five other cohort studies describing esophageal cancer risk in firefighters stratified by duration of employment reported statistically elevated rates among firefighters with the most experience (Ahn, 2012; Baris, 2001; Beaumont, 1991; Demers, 1994; Petersen, 2018a).

Few studies reported esophageal cancer risk in firefighters by age. In a study of firefighters in San Francisco, Chicago, and Philadelphia, firefighters aged 65 years and older had an elevated risk of esophageal cancer compared to the general public (SIR=1.35 95%CI: 1.07-1.68). Increased age, however, did not correspond to increased risk of esophageal cancer in a case-control study of cancer among Florida firefighters (Lee, 2020). Similarly, a case-control study of cancer mortality among Massachusetts firefighters did not find that esophageal cancer mortality changed when stratifying by age group (Kang, 2008).

Studies reporting PMRs of esophageal cancer in firefighters are described in Table 6. According to the WA Occupational Mortality Database, 43 male firefighters died from esophageal cancer between 1950 and 2010 (WA DOH, 2011), suggesting that a larger proportion of WA firefighters died of esophageal cancer compared to other workers (PMR=141, p=0.02553). In WA, the PMRs were highest in younger age groups, particularly men ages 30-39 (PMR=21.66, p=0.00397) and 40-49 (PMR= 3.46, p=0.02966). When stratified by time period, over half of the esophageal cancer deaths in WA from 1950-2010 occurred in the last decade. Between 2000 and 2010, WA recorded 23 esophageal cancer deaths among firefighters (PMR=1.88, p=0.00195). It is unclear why the proportion of esophageal cancer deaths in firefighters was elevated for that decade.

Table 5. Forest plot describing risk of esophageal cancer in firefighters reported in cohort studies



Study		Point Estimate (95%CI)
Incidence Studies		
1*	Ahn, 2012	SIR=0.75 (0.28-1.68)
6*	Bates, 2001	SIR=1.67 (0.3-4.9)
8	Bigert, 2020	SIR=0.71 (0.38 -1.21)
11*	Daniels, 2014	SIR-1.62 (1.31-2.00)
12*	Demers, 1994	SIR=1.3 (0.4-3.3)
14*	Demers, 1992b	SIR=1.06 (0.34-2.47)
18	Glass, 2017	SIR=0.65 (0.52-0.82)
20*	Glass, 2016b	SIR=0.78 (0.46-1.26)
21	Glass, 2009	SIR=1.12 (0.54-2.36)
23	Harris, 2018	HR=1.39 (0.72-2.68)
23	Harris, 2018	HR=1.31 (0.68-2.51)
25	Hrubec, 1992	SIR=0.99 (0.32-2.30)
27*	Kullberg, 2018	SIR=0.99 (0.32-2.30)
30	Li, 2016	SIR=1.29 (0.62-2.38)
31	Li, 2012[1]	SIR=1.43 (0.39-3.67)
31	Li, 2012[2]	SIR=1.16 (0.24-3.39)
32*	Ma, 2006	SIR=0.62 (0.31-1.11)
35	Marjerrison, 2022	SIR=1.55 (0.85-2.60)
39*	Petersen, 2018b	SIR=0.99 (0.65-1.53)
41*	Pukkala, 2014	SIR=0.98 (0.66-1.39)
44	Solan, 2013	SIR=1.67 (0.83-2.98)
45	Sritharan, 2022	HR=1.06 (0.73-1.53)
50*	Zeig Owens, 2011	SIR=0.58 (0.15-2.32)
Mortality Studies		
2*	Amadeo, 2015	SMR=0.93 (0.67-1.27)
3*	Aronson, 1994	SMR=40 (5-143)
4*	Baris, 2001	SMR=0.56 (0.25-1.24)
7*	Beaumont, 1991	RR=2.04 (1.05-3.57)
9	Colbeth, 2020	SMR=0.69 (0.36-1.17)
11*	Daniels, 2014	SMR=1.39 (1.14-1.67)
13*	Demers, 1992a	SMR=0.83 (0.30-1.80)
14*	Demers, 1992b	SMR=1.13 (0.37-2.63)
24	Heyer, 1990	SMR=44 (1-250)
25	Hrubec, 1992	RR=1.3 (NR)
33*	Ma, 2005	SMR=0.65 (0.31-1.20)
35	Marjerrison, 2022	SMR=1.94 (1.08-3.20)
38	Petersen, 2018a	SMR=1.27 (0.85-1.89)
40	Pinkerton, 2020	SMR=1.31 (1.10-1.55)
42	Rosenstock, 1991	SMR=0.82 (0.30-1.79)
46	Stec 2023	SMR=2.42 (1.69-3.29)
49*	Vena, 1987	SMR=1.34 (0.27-3.91)
51	Zhao, 2020	MRR=1.11 (0.64-1.92)

*study was included in at least one meta analysis for this condition

1 Early period (through 2006)

2 Later period (2007-2008)

Table 6. Canadian and WA-State specific esophageal cancer deaths among firefighters.

Source	Group	Firefighter Deaths	PMR (95% CI)	p-value or 95%CI
WA Occupational Mortality Database (males, 1950-2010) (WA DOH 2011)	All	43	1.41	p=0.02553
	Age Group:			
	30-39	2	21.66	p=0.00397
	40-49	4	3.46	p=0.02966
	50-59	7	1.87	p=0.10872
	60-69	12	1.19	p=0.53381
	70-79	11	1.15	p=0.63235
	80+	6	1.13	p=0.75612
	20-64	20	2.07	p=0.00078
	By Time Period:			
	1950-1959	3	2.02	p=0.18720
	1960-1969	1	0.46	p=0.73036
	1970-1979	2	0.77	p=1.00000
	1980-1989	5	1.26	p=0.60742
	1990-1999	8	1.08	p=0.82951
	2000-2010	23	1.88	p=0.00195
British Columbia death records (Male Firefighters from 1950-1984) (Gallagher 1989)	All	1	0.57	95% CI: 0.01-3.21

Pancreatic Cancer

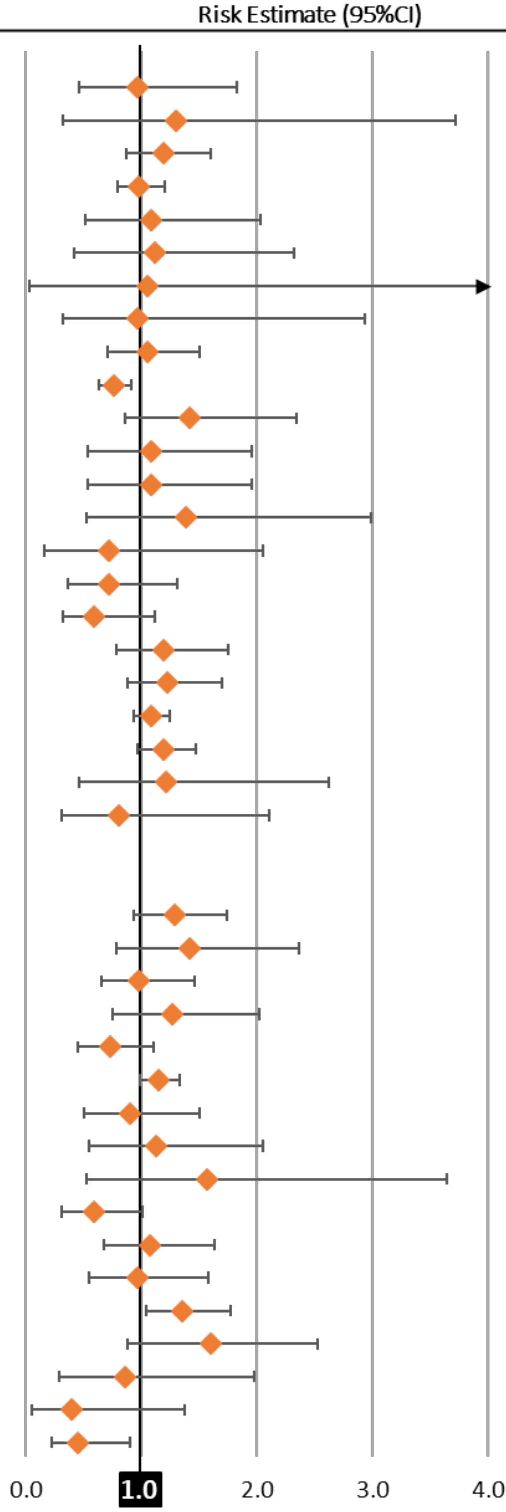
The six meta-analyses we identified describing pancreatic cancer in firefighters are summarized in Table 7. Five of these studies reported that firefighters were not at an increased risk of pancreatic cancer and one study reported a statistically significant risk of pancreatic cancer mortality in firefighters, but only when including low-quality studies in their analyses (Soteriades, 2019). Soteriades et al. (2019) found that firefighters were at an increased risk of pancreatic cancer mortality (mSMR=1.14, 95%CI: 1.01-1.28) when including all studies, however, they found no difference in pancreatic cancer risk between firefighters and non-firefighters when restricting their meta-analyses to good-quality studies (mSMR=0.99, 95%CI: 0.79-1.24) and when combining good- and adequate- quality studies (mSMR=0.99, 95%CI: 0.80-1.22).

Table 7. Meta Analyses reporting Pancreatic Cancer in Firefighters

First author, year	study pop	Analysis	# of studies	Studies included (by ID)	Risk Estimate	95% CI
Casjens, 2020	male FFs	mSIR	8	1, 6, 12, 20, 27, 32, 39, 41	mSIR=1.08	0.88-1.28
		mSMR	8	2, 3, 4, 13, 22, 33, 47, 49	mSMR=0.97	0.73-1.22
		mRR (incidence, overall)	8	1, 6, 12, 20, 27, 32, 39, 41	mRR=1.08	0.88–1.28
		mRR (incidence, US & Canada only)	2	12, 32	mRR=0.71	0.25–1.18
		mRR (mortality, overall)	8	2, 3, 4, 13, 22, 33, 47, 49	mRR=0.97	0.73–1.22
		mRR (mortality, US & Canada only)	6	3, 4, 13, 22, 33, 47	mRR=0.90	0.60–1.21
Crawford/IOM, 2017		Meta-RR (fixed effect model)	17	1, 3, 4, 5, 6, 7, 12, 16, 21, 22, 26, 32, 41, 43, 47, 49, 50	Meta-RR=1.02	0.90-1.15
Jalilian, 2019	male FFs	SIRE	14	1[1], 6, 12, 16, 20, 26, 27, 32, 39, 41, 43, 48, 50	SIRE=1.09	0.96-1.24
		SMRE	11	2, 3, 4[1],7, 13, 22, 33, 34, 47, 49	SMRE=1.13	0.99-1.29
Lee, 2023	FFs	SIRE		NR	SIR=0.88	0.76-1.02
		SMRE		NR	SMR=0.86	0.70-1.05
LeMasters, 2006	FFs	Summary Risk Estimate	13	3, 4, 6, 7, 13, 14, 16, 22, 34, 43, 47[1], 49	mSRM=0.98	0.75-1.26
Soteriades, 2019	FFs	SIR- Good studies only	7	5, 6[2], 12, 16, 26, 32, 47	mSIR=0.89	0.73-1.08
		SIR- Good & Adequate studies	7	5, 6[2], 12, 16, 26, 32, 47	mSIR=0.89	0.73-1.08
		SIR- All studies	7	5, 6[2], 12, 16, 26, 32, 47	mSIR=0.89	0.73-1.08
		MRE- Good studies only	8	NR	mSMR=0.99	0.79-1.24
		MRE-Good & adequate studies	9	3, 4, 7, 13, 22, 33, 43, 47, 49	mSMR=0.99	0.80-1.22
		MRE- All studies	15	NR	mSMR=1.14	1.01-1.28
		Combined SIR & MRE- Good studies only	12	NR	0.96	0.80-1.17
		Combined SIR & MRE- Good & adequate studies	15	3, 4, 5, 6[2], 7, 12, 13, 16, 22, 26, 32, 33, 43, 47, 49	0.93	0.81-1.08
		Combined SIR&MRE- All studies	21	NR	1.06	0.96-1.18

NR: not reported
1. included two different measures
2. Author cited using results from a 2000 report by Bates titled "Retrospective cohort study of mortality and cancer incidence in New Zealand fire fighters," the results of which were published in a peer-reviewed journal by the same author in 2001.

Table 8. Forest plot describing risk of pancreatic cancer in firefighters reported in cohort studies



	Study	Point Estimate (95%CI)
	Incidence Studies	
1*	Ahn, 2012	SIR=0.95 (0.44-1.81)
6*	Bates, 2001	SIR=1.28 (0.3-3.7)
8	Bigert, 2020	SIR=1.17 (0.85-1.58)
11	Daniels, 2015	SIR=0.96 (0.77-1.18)
14	Demers, 1992b	SIR=1.06 (0.49-2.01)
12*	Demers, 1994	SIR=1.1 (0.4-2.3)
16*	Giles, 1993	SIR=1.03 (0.01-5.75)
21*	Glass, 2009	SIR=0.94 (0.30-2.91)
20*	Glass, 2016b	SIR=1.03 (0.69-1.48)
18	Glass, 2017	SIR=0.74 (0.61-0.89)
23	Harris, 2018	HR=1.40 (0.84-2.32)
25	Hrubec, 1992	SIR=1.06 (0.51-1.94)
27*	Kullberg, 2018	SIR=1.06 (0.51-1.94)
31	Li, 2012[1]	SIR=1.37 (0.50-2.97)
31	Li, 2012[2]	SIR=0.70 (0.14-2.03)
30	Li, 2016	SIR=0.70 (0.34-1.29)
32*	Ma, 2006	SIR=0.57 (0.30-1.10)
35	Marjerrison, 2022	SIR=1.17 (0.76-1.73)
39*	Petersen, 2018b	SIR=1.20 (0.86-1.68)
40	Pinkerton, 2020	SIR=1.06 (0.91-1.22)
41*	Pukkala, 2014	SIR=1.17 (0.94-1.45)
47*	Tornling, 1995	SIR=119 (44-260)
50*	Zeig Owens, 2011	SIR=0.78 (0.29-2.09)
	Mortality Studies	
2*	Amadeo, 2015	SMR=1.27 (0.92-1.72)
3*	Aronson, 1994	SMR=140 (77-235)
4*	Baris, 2001	SMR=0.96 (0.64-1.44)
7*	Beaumont, 1991	RR=1.25 (0.73-2.00)
9	Colbeth, 2020	SMR=0.71 (0.43-1.09)
11	Daniels, 2014	SMR=1.13 (0.97-1.32)
13*	Demers, 1992a	SMR=0.89 (0.49-1.49)
14*	Demers, 1992b	SMR=1.11 (0.53-2.04)
22*	Guidotti, 1993	SMR=155.1 (50.4-362.0)
33*	Ma, 2005	SMR=0.57 (0.29-0.99)
35	Marjerrison, 2023	SMR=1.06 (0.66-1.62)
42	Rosenstock, 1991	SMR=0.95 (0.53-1.56)
45	Sritharan, 2022	HR=1.34 (1.02-1.76)
46	Stec 2023	SMR=1.58 (0.86-2.51)
47*	Tornling, 1994	SMR=84 (27-196)
49*	Vena, 1987	SMR=0.38 (.04-1.36)
51	Zhao, 2020	MRR=0.43 (0.21-0.88)

*study was included in at least one meta analysis for pancreatic cancer

1 Early period (through 2006)

2 Later period (2007-2008)

Table 8. and Supplemental Table 16. describe the results from the 35 cohort studies we identified assessing pancreatic cancer risk in firefighters. In a study of firefighters in Ontario, Canada, Sritharan et al. (2022) found that firefighters were at an increased risk of pancreatic cancer incidence (HR=1.34, 95%CI: 1.02-1.76). No other cohort study reported that firefighters overall had an increased risk of developing or dying from pancreatic cancer. We also identified seven case-control studies assessing pancreatic cancer in firefighters (Table 17.). Researchers studying cancer mortality in Indiana firefighters found that firefighters are 1.45 more likely to die from pancreatic cancer compared to non-firefighters (95%CI: 1.01-2.06) (Muegge, 2018). The remaining six case-control studies did not find that firefighters were an increased risk of pancreatic cancer incidence or mortality.

Studies stratifying results by years of experience or employment showed inconsistent findings. Two studies reported that firefighters with the fewest years of experience are at an increased risk of pancreatic cancer. In a cohort study of firefighters in Philadelphia, firefighters with less than 10 years of experience were at elevated risk of pancreatic cancer mortality compared to the general public (SMR=2.33, 95%CI: 1.36-4.02) (Baris, 2001). However, firefighters with less than 10 to 19 years of experience and firefighters with 20 or more years of experience were not at elevated risk of pancreatic cancer mortality (Baris, 2001). Similarly, Petersen et al. 2018b reported that firefighters with less than a year of experience were at an elevated risk of developing pancreatic cancer compared to non-firefighters (SIRE=1.79, 95%CI: 1.05-3.01) and firefighters with 1 year or more of experience, 10 years or more of experience, or 20 years or more of experience do not have an elevated risk of developing pancreatic cancer. Likewise, Ahn et al (2012) did not find that firefighters in South Korea with 10 or more years of firefighting experience were at a higher risk of developing pancreatic cancer compared to non-firefighters (SIR=0.93, 95%CI: 0.25-2.37). Years since first employed as a firefighters nor years of employment were not found to be associated with increased risk of pancreatic cancer mortality in studies among firefighters in Toronto, Canada (Aronson, 1994) and in San Francisco (Beaumont, 1991), indicating that length of employment as a firefighter may not affect pancreatic cancer mortality risk in firefighters.

Two cohort studies reported pancreatic cancer risk estimates in firefighters by employment status (Glass, 2016b; Petersen, 2018b), though it remains unclear how any of these factors impact pancreatic cancer risk in firefighters. Petersen et al. (2018b) found that full-time firefighters were at a higher risk of developing pancreatic cancer compared to the general public (SIR=1.54, 95%CI: 1.05-2.25), whereas part-time and volunteer firefighters were not at an elevated risk (SIR=0.65, 95%CI: 0.31-1.37). However, Glass et al. (2016b) found that neither full-time firefighters (SIR=1.07, 95%CI: 0.67-1.62) nor part-time firefighters (SIR=0.93, 95%CI: 0.37-1.91) were at an elevated risk of developing pancreatic cancer compared to non-firefighters. Peterson et al. (2018b) also reported elevated pancreatic risk among firefighters first employed before 1970 (SIR=1.63, 95%CI: 1.08-2.48) and in those under 25 years old at first employment (SIR=1.68, 95%CI: 1.12-2.53), but not in firefighters first employed in later eras or at more advanced ages.

Table 9. describes the PMR of pancreatic cancer in firefighters from WA-specific and Canadian mortality databases for adults of working ages. Between 1950 and 2010, there were 62 deaths from pancreatic cancer among male firefighters in WA, of which 26 were among male firefighters between the ages of 20 and 64 (WA DOH, 2011). When stratifying by age group, proportionally more deaths caused by pancreatic cancer occurred among firefighters ages 50-59 (n=13, PMR=190, p=0.01721) and ages 20-64 (PMR=151, p=0.03307) compared to non-firefighters. In contrast, only one pancreatic cancer death was reported among male firefighters in British Columbia, Canada from 1950-1984 (Gallagher, 1989).

Table 9. Canadian and WA-State specific pancreatic cancer deaths among firefighters

Source	Group	Firefighter Deaths	PMR (95% CI)	p-value or 95%CI
WA Occupational Mortality Database (males, 1950-2010) (WA DOH, 2011)	All	62	1.11	p=0.39691
	Age Group:			
	40-49	2	0.85	p=1.0
	50-59	13	1.90	p=0.01721
	60-69	18	1.06	p=0.81232
	70-79	23	1.23	p=0.3078
	80+	6	0.57	p=0.16376
	20-64	26	1.51	p=0.03307
British Columbia death records (Male Firefighters from 1950-1984) (Gallagher, 1989)	All	1	0.57	95%CI: 0.01-3.21

Exposure Studies[1]

Firefighters are exposed to a complex mixture of hazardous chemicals and toxins during their work. Whether on the fire ground or at the fire station, there is potential exposure to carcinogens. The IARC monograph *Occupational Exposure as a Firefighter, Volume 132*, (IARC, 2023) provides an authoritative summary of the research regarding firefighter exposure and biological uptake of carcinogens and mechanistic evidence for carcinogenesis in firefighters. We provide a brief rationale based on IARCs review supporting that firefighters work in an environment with exposures to carcinogens, and there are mechanistic pathways for carcinogenesis from the occupation of firefighting.

[1] This review was adapted from IARC (2023). Occupational exposure as a firefighter. *IARC Monogr Identif Carcinog Hazards Hum*. 132:1–730.

The combustion of most fuels, e.g. plastics, wood, etc., creates carcinogens. The composition of combustion products depends on the fuel burned, fire intensity, duration, and ventilation conditions. There is likely a high degree of variability in exposure based on the:

- employment type, such as being a career or volunteer firefighter,
- work location, such as being an urban, municipal, or rural firefighter, and
- activities performed, such as structural, wildland, vehicle, or hazardous materials response.

Firefighters wear personal protective equipment (PPE) which mostly prevents the ingestion, inhalation, and dermal uptake of carcinogens, however, even with PPE use exposures may occur – dermal exposure due to gaps in coverage of the skin (Sousa, 2022), inhalational exposures due to non-use of respiratory protection during specific phases of the fire response, e.g. overhaul, or ingestion of carcinogens from hand to mouth or secondary to upper airway exposure with subsequent ingestion of the carcinogens. There are also likely exposures to carcinogens through handling and use of soiled or contaminated gear.

Exposure monitoring of firefighters suggests most fires yield particulate matter, volatile organic compounds including benzene, toluene, ethylbenzene, xylene, carbon monoxide, and polycyclic aromatic hydrocarbons in breathable air. IARC suggests that firefighters are possibly exposed to a broad array of other designated carcinogens.[2] Assessments for potentially harmful chemicals have been performed on working and PPE surfaces and in the air, measuring firefighter exposures for asbestos, silica, per- and polyfluroalkyl substances, polybrominated diphenyl ethers, and other brominated flame retardants, diesel exhaust in the fire station, heavy metals, and dioxins.

Biomonitoring provides a means to assess exposure after biological uptake and distribution of the toxin within living persons. In multiple published studies, there are observed increases in urinary biomarkers for polycyclic aromatic hydrocarbons following fire suppression of structural and wildland fires and observed increases in benzene in exhaled breath following fire suppression. These observations suggest that in spite of PPE, significant PAH and VOC exposures are occurring; there is a strong suggestion that dermal uptake is the route of exposures and is of significant importance.

Finally, the organization of work as a firefighter may increase cancer risk. Shiftwork with disruption of circadian rhythms is recognized as probably carcinogenic to humans. The influence of work on health behaviors, specifically poor nutrition, increased tobacco use, and less leisure time physical activity which in part may promote obesity, are common in the fire service and may contribute to cancer risk (Sidossis, 2023).

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[2] The International Agency for Research on Cancer (IARC) classifies agents by strength of the evidence; Group 1 agents are designated as carcinogenic to humans. Group 1 agents that firefighters may potentially be exposed to (IARC, 2023) include: Arsenic and inorganic arsenic compounds; asbestos; benzene; benzo[a]pyrene, 1,3-butadiene; cadmium and cadmium compounds; chromium(VI) compounds; 1,2-dichloropropane; engine exhaust, diesel; ethylene oxide; formaldehyde; hepatitis B/c; nickel compounds; 2,3,4,7,8-Pentachlorodibenzofuran; 3,4,5,3',4'-pentachlorobiphenyl (PCB-126); pentachlorophenol; polychlorinated biphenyls; radioactivity – gamma activity; radionucleotides both alpha and beta emitters; crystalline silica; sulfuric acid; 2,3,7,8-Tetrachloro dibenzo-paradioxin (2,3,7,8-TCDD); trichloroethylene; UV radiation; vinyl chloride

The IARC review also addressed the mechanisms by which occupational exposure as a firefighter may lead to cancer – termed mechanistic pathways. Summaries of the research evidence supported that firefighting exhibits these five key characteristics of carcinogenesis – "*There is consistent and coherent evidence that occupational exposure as a firefighter exhibits five key characteristics of carcinogens: it is genotoxic; induces epigenetic alterations; induces oxidative stress; induces chronic inflammation; and modulates receptor-mediated effects"* (IARC, 2023, p.712).

Thus, there is sufficient biologic plausibility that occupational exposure as a firefighter creates a risk for cancer, and would support an association with firefighters and cancer if human epidemiologic studies consistently demonstrate significantly elevated risk of developing specified cancers in firefighters.

SUMMARY

This assessment summarizes the morbidity and mortality from buccal cavity cancer, pharyngeal cancer, esophageal cancer, and pancreatic cancer in firefighters compared to other workers and whether the biologically plausible association between firefighting as an occupation and cancer exists. A review of the epidemiologic evidence did not provide supportive evidence of an increased risk of buccal cavity cancer, pharyngeal cancer, esophageal cancer, or pancreatic cancer in firefighters. Firefighters have exposures to carcinogens during the course of their work which may contribute to mechanistic pathways to increase cancer risk, supporting biologic plausibility for a heightened risk of cancer. Reviews assessing the causal relationship between firefighting and specific cancer outcomes have known limitations, with poor characterization of exposure, absence of control for confounding factors, and insufficient outcomes to make a more precise estimate of the risk.

Advisory Committee Recommendation

This report and the subsequent recommendation only address the risk of buccal, pharyngeal, esophageal, and pancreatic cancer in firefighters as a collective group under the presumption law. The content of this report and the recommendation presented here are not intended to and should not be used for a causal determination of buccal, pharyngeal, esophageal, or pancreatic cancer in an individual firefighter with varying susceptibility and occupational exposures. Individual susceptibility and unique exposures during a firefighter's career may elevate an individual firefighter's risk for these malignancies, which would be obscured when analyzing data at the population level. Recent improvements in capturing work histories on death certificates, standardizing systems for linking datasets (including cancer registries, vital records, and hospital data), and future cohort studies or meta-analyses will further clarify the relationship between occupational exposures and cancer risk in firefighters over time.

Based on a review of the current scientific literature, the committee found sufficient evidence to support that firefighters are regularly exposed to carcinogenic agents at work, but did not find evidence that firefighters have an increased risk of buccal cavity, pharyngeal, esophageal, or pancreatic cancer incidence or mortality. Therefore, the committee has not found sufficient evidence for an association between firefighting and buccal cavity cancer, pharyngeal cancer, esophageal cancer, or pancreatic cancer to warrant inclusion of any of these cancer types into WA's presumption law. Subsequent requests for a review of these four types of cancer for inclusion into Washington presumption law may be necessary as more research evidence emerges.

Estimated Burden and Cost of Buccal, Pharyngeal, Esophageal, and Pancreatic Cancer in WA Firefighters

As defined in the firefighting presumption law (RCW 51.32.185), the advisory committee's recommendation must be accompanied by the estimated number of WA firefighters at risk of developing buccal, pharyngeal, esophageal, and pancreatic cancer, and estimates of medical treatment and disability costs. The advisory committee did not consider these estimates while developing their recommendation as to whether there is an association between firefighters and these four cancer types.

We estimated the number of oral cancer, esophageal cancer, and pancreatic cancer among WA firefighters by calculating state-wide cancer rates to the number of eligible firefighters. The number of firefighters is based on the total number of WA firefighters enrolled in WA's Law Enforcement Officer and Fire Fighter retirement plan. To emulate the eligibility criteria required for firefighter seeking coverage for cancers that are currently included in the presumption law, we restricted our analyses to WA firefighters who have worked for 10 years or more or who are currently working or are within five years of retirement or separation. Age- and sex- adjusted cancer rates were obtained from WA State's Cancer Registry (WSCR). Table 10. and Table 11. describe the total number of eligible firefighters, the state-wide cancer rates, and projected number of cancer cases among firefighters by age for males and females respectively.

Table 10. Estimated annual burden of Oral Cancer, Esophageal Cancer, and Pancreatic Cancer among Male WA Firefighters, by age

Age Group	Current and Former Male Firefighters[1]	Average Annual WA State Cancer Rates per 100,000, 2016-2020			Estimated annual cancer cases among male firefighter in WA		
		Oral	Esophageal	Pancreatic	Oral	Esophageal	Pancreatic
20-24	0	NR	NR	NR	NA	NA	NA
25-29	0	1.4	NR	NR	0	NA	NA
30-34	66	2.6	NR	0.7	0.001716	NA	0.000462
35-39	539	4	NR	1.6	0.02156	NA	0.008624

Age Group	Current and Former Male Firefighters[1]	Average Annual WA State Cancer Rates per 100,000, 2016-2020			Estimated annual cancer cases among male firefighter in WA		
		Oral	Esophageal	Pancreatic	Oral	Esophageal	Pancreatic
40-44	947	8.4	1.2	2.8	0.079548	0.011364	0.026516
45-49	1163	15.3	3.1	6	0.177939	0.036053	0.06978
50-54	1477	30.3	8.2	12.9	0.447531	0.121114	0.190533
55-59	1075	43.5	13.9	25.2	0.467625	0.149425	0.2709
60-64	671	60.2	24.2	36.1	0.403942	0.162382	0.242231
65-69	240	69.1	31.8	52.9	0.16584	0.07632	0.12696
70-74	38	78.4	43.3	76.1	0.029792	0.016454	0.028918
75-79	3	84.7	47.7	98.2	0.002541	0.001431	0.002946
80-84	0	86.2	55.5	118.7	0	0	0
85+	0	83.3	53.4	114	0	0	0
Total	6219				1.798034	0.574543	0.96787

1 Includes all living firefighters (current and former) as defined by enrollment in WA's Law Enforcement Officer and Fire Fighter Retirement program as of 2022.

Table 11. Estimated annual burden of Oral Cancer, Esophageal Cancer, and Pancreatic Cancer among Female WA Firefighters, by age

Age Group	Current and Former Female Firefighters[1]	Average Annual WA State Cancer Rates per 100,000, 2016-2020			Estimated annual cancer cases among male firefighter in WA		
		Oral	Esophageal	Pancreatic	Oral	Esophageal	Pancreatic
20-24	0	0.9	NR	NR	0	NA	NA
25-29	0	1.2	NR	NR	0	NA	NA
30-34	3	2.1	NR	1.1	0.000063	NA	0.000033
35-39	36	2.7	NR	1.2	0.000972	NA	0.000432
40-44	63	5	NR	2.7	0.00315	NA	0.001701
45-49	49	6.1	0.9	5.5	0.002989	0.000441	0.002695
50-54	71	11.1	2.6	9.9	0.007881	0.001846	0.007029
55-59	85	15.5	3.8	18.5	0.013175	0.00323	0.015725
60-64	41	21.8	5.1	27.1	0.008938	0.002091	0.011111
65-69	8	26.4	6.3	41	0.002112	0.000504	0.00328
70-74	0	27.5	8.6	61.2	0	0	0
75-79	1	38.7	11	72.8	0.000387	0.00011	0.000728
80-84	0	43.3	14.1	93.1	0	0	0
85+	0	42.6	13.5	102.2	0	0	0
Total	357				0.039667	0.008222	0.042734

1 Includes all living firefighters (current and former) as defined by enrollment in WA's Law Enforcement Officer and Fire Fighter Retirement program as of 2022.

The WA Department of Labor and Industries provides workers' compensation insurance coverage to all employers through the State Fund program, unless employers meet certain criteria and opt to self-insure. WA maintains data, including cost information, for all accepted claims in the state fund program. Between 2015 and 2023, we identified nine accepted cancer claims (four pharyngeal cancer cases and five pancreatic cancer cases) for which WA Department of Labor and Industries maintained cost information. These claims were medically complicated and most included coverage for serious comorbidities, and therefore are likely not representative of claims filed primarily for pharyngeal or pancreatic cancer. In a previous review, we identified 115 claims filed by firefighters between 2002 and 2017 for cancers that were included in the presumption law at the time the claim filing, half of which (n=58) were administered by the state fund. Of these claims, 90% (n=52) were accepted, and most (77%, n=40) of these claims were accepted for wage-replacement, which requires a medical certification that the worker is unable to perform normal work duties after a 3-calendar-day waiting period (LaSee, 2023). When adjusting to the 2017 consumer price index, median cost for a wage-replacement cancer claim in the state fund program accepted under the firefighter presumption law was $119,032 (range: $2,996-$2,780,634) . Median time-loss days for wage-replacement claims reporting at least one time loss day was 65 days (n=38, range: 1-3,044 days).

REFERENCES CITED

Ahn YS, Jeong KS, Kim KS. Cancer morbidity of professional emergency responders in Korea. Am J Ind Med. 2012 Sep;55(9):768-78. doi: 10.1002/ajim.22068. Epub 2012 May 24. PMID: 22628010.

Amadeo B, Marchand JL, Moisan F, Donnadieu S, Gaëlle C, Simone MP, Lembeye C, Imbernon E, Brochard P. French firefighter mortality: analysis over a 30-year period. Am J Ind Med. 2015 Apr;58(4):437-43. doi: 10.1002/ajim.22434. Epub 2015 Feb 23. PMID: 25708859.

Aronson KJ, Tomlinson GA, Smith L. Mortality among fire fighters in metropolitan Toronto. Am J Ind Med. 1994;26(1):89-101. Doi: 10.1002/ajim.4700260108. PMID: 8074127

Baris D, Garrity TJ, Telles JL, Heineman EF, Olshan A, Zahm SH. Cohort mortality study of Philadelphia firefighters. Am J Ind Med. 2001 May;39(5):463-76. doi: 10.1002/ajim.1040. PMID: 11333408.

Bates MN, Fawcett J, Garrett N, Arnold R, Pearce N, Woodward A (2001) Is testicular cancer an occupational disease of fire fighters? Am J Ind Med 40(3):263–270. doi: 10.1002/ajim.1097. PMID: 11598972.

Bates MN. Registry-based case-control study of cancer in California firefighters. Am J Ind Med. 2007 May;50(5):339-44. doi: 10.1002/ajim.20446. PMID: 17427202.

Beaumont JJ, Chu GS, Jones JR, Schenker MB, Singleton JA, Piantanida LG, Reiterman M. An epidemiologic study of cancer and other causes of mortality in San Francisco firefighters. Am J Ind Med. 1991;19(3):357-72. doi: 10.1002/ajim.4700190309. PMID: 2008922.

Bigert C, Martinsen JI, Gustavsson P, Sparén P. Cancer incidence among Swedish firefighters: an extended follow-up of the NOCCA study. Int Arch Occup Environ Health. 2020 Feb;93(2):197-204. doi: 10.1007/s00420-019-01472-x. Epub 2019 Aug 28. PMID: 31463517; PMCID: PMC7007886.

Casjens S, Brüning T, Taeger D. Cancer risks of firefighters: a systematic review and meta-analysis of secular trends and region-specific differences. Int Arch Occup Environ Health. 2020 Oct;93(7):839-852. doi: 10.1007/s00420-020-01539-0. Epub 2020 Apr 18. PMID: 32306177; PMCID: PMC7452930.

Colbeth HL, Zeig-Owens R, Hall CB, Webber MP, Schwartz TM, Prezant DJ. Mortality among Fire Department of the City of New York Rescue and Recovery Workers Exposed to the World Trade Center Disaster, 2001-2017. Int J Environ Res Public Health. 2020;17(17).

Crawford JO, Winski T, McElvenny D, Graveling R, Dixon K (2017) Firefighters and cancer: the epidemiological evidence. Research Report TM/17/01 (Research Avenue North, Riccarton, Edinburgh, EH14 4AP, Institute of Occupational Medicine 2017)

Daniels RD, Bertke S, Dahm MM, Yiin JH, Kubale TL, Hales TR, Baris D, Zahm SH, Beaumont JJ, Waters KM, Pinkerton LE. Exposure-response relationships for select cancer and non-cancer health outcomes in a cohort of U.S. firefighters from San Francisco, Chicago and Philadelphia (1950-2009). Occup Environ Med. 2015 Oct;72(10):699-706. doi: 10.1136/oemed-2014-102671. Epub 2015 Feb 11. PMID: 25673342; PMCID: PMC4558385.

Daniels RD, Kubale TL, Yiin JH, Dahm MM, Hales TR, Baris D, Zahm SH, Beaumont JJ, Waters KM, Pinkerton LE. Mortality and cancer incidence in a pooled cohort of US firefighters from San Francisco, Chicago and Philadelphia (1950-2009). Occup Environ Med. 2014 Jun;71(6):388-97. doi: 10.1136/oemed-2013-101662. Epub 2013 Oct 14. PMID: 24142974; PMCID: PMC4499779.

Demers PA, Checkoway H, Vaughan TL, Weiss NS, Heyer NJ, Rosenstock L. Cancer incidence among firefighters in Seattle and Tacoma, Washington (United States). Cancer Causes Control. 1994 Mar;5(2):129-35. doi: 10.1007/BF01830258. PMID: 8167259.

Demers PA, Heyer NJ, Rosenstock L. Mortality among firefighters from three northwestern United States cities. Br J Ind Med. 1992 Sep;49(9):664-70. doi: 10.1136/oem.49.9.664. PMID: 1390274; PMCID: PMC1039313.

Demers PA, Vanghan TL, Checkoway H, Weiss NS, Heyer NJ, Rosenstock L. Cancer identification using a tumor registry versus death certificates in occupational cohort studies in the United States. Am J Epidemiol. 1992;136(10):1232-40. DOI: 10.1093/oxfordjournals.aje.a116431. PMID:1476145.

Deschamps S, Momas I, Festy B. Mortality amongst Paris fire-fighters. Eur J Epidemiol. 1995 Dec;11(6):643-6. doi: 10.1007/BF01720297. PMID: 8861847.

Gallagher, R.P.; Cancer Control Agency of British Columbia;Workers' Compensation Board of British Columbia. Occupational mortality in British Columbia, 1950–1984; Cancer Control Agency of British Columbia: Vancouver, BC, Canada, 1989.

Giles G, Staples M, Berry J. Cancer incidence in Melbourne Metropolitan Fire Brigade members, 1980-1989. Health Rep. 1993;5(1):33-8. PMID: 8334236.

Glass DC, Del Monaco A, Pircher S, Vander Hoorn S, Sim MR. Mortality and cancer incidence among female Australian firefighters. Occup Environ Med. 2019 Apr;76(4):215-221. doi: 10.1136/oemed-2018-105336. PMID: 30674605.

Glass DC, Del Monaco A, Pircher S, Vander Hoorn S, Sim MR. Mortality and cancer incidence among male volunteer Australian firefighters. Occup Environ Med. 2017 Sep;74(9):628-638. doi: 10.1136/oemed-2016-104088. Epub 2017 Apr 8. PMID: 28391245.

Glass DC, Del Monaco A, Pircher S, Vander Hoorn S, Sim MR. Mortality and cancer incidence at a fire training college. Occup Med (Lond). 2016 Oct;66(7):536-42. doi: 10.1093/occmed/kqw079. Epub 2016 Jul 2. PMID: 27371948.

Glass DC, Pircher S, Del Monaco A, Hoorn SV, Sim MR. Mortality and cancer incidence in a cohort of male paid Australian firefighters. Occup Environ Med. 2016 Nov;73(11):761-771. doi: 10.1136/oemed-2015-103467. Epub 2016 Jul 25. PMID: 27456156.

Glass, D. Final Report on Queensland Fire Fighters' Cancer Incidence Study; Monash Centre for Occupational and Environmental Health: Melbourne, Australia, 2009.

Guidotti TL. Mortality of urban firefighters in Alberta, 1927-1987. Am J Ind Med. 1993 Jun;23(6):921-40. doi: 10.1002/ajim.4700230608. PMID: 8328477.

Harris MA, Kirkham TL, MacLeod JS, Tjepkema M, Peters PA, Demers PA. Surveillance of cancer risks for firefighters, police, and armed forces among men in a Canadian census cohort. Am J Ind Med. 2018 Oct;61(10):815-823. doi: 10.1002/ajim.22891. Epub 2018 Aug 2. PMID: 30073696.

Heyer N, Weiss NS, Demers P, Rosenstock L. Cohort mortality study of seattle fire fighters: 1945-1983. Am J Ind Med. 1990;17(4):493-504. DOI: 10.1002/ajim.4700170407. PMID: 2327416.

Hrubec, Z.; Blair, A.E.; Rogot, E.; Vaught, J. Mortality Risks by Occupation among U.S. Veterans of Known Smoking Status; NIH Publication No. 92–3407; National Institutes of Health: Bethesda, MD, USA, 1992.

IARC (2023). Occupational exposure as a firefighter. *IARC Monogr Identif Carcinog Hazards Hum*. 132:1–730.

Jalilian H, Ziaei M, Weiderpass E, Rueegg CS, Khosravi Y, Kjaerheim K. Cancer incidence and mortality among firefighters. Int J Cancer. 2019 Nov 15;145(10):2639-2646. doi: 10.1002/ijc.32199. PMID: 30737784.

Kang D, Davis LK, Hunt P, Kriebel D. Cancer incidence among male Massachusetts firefighters, 1987-2003. Am J Ind Med. 2008 May;51(5):329-35. doi: 10.1002/ajim.20549. PMID: 18306327.

Kullberg C, Andersson T, Gustavsson P, Selander J, Tornling G, Gustavsson A, Bigert C. Cancer incidence in Stockholm firefighters 1958-2012: an updated cohort study. Int Arch Occup Environ Health. 2018 Apr;91(3):285-291. doi: 10.1007/s00420-017-1276-1. Epub 2017 Nov 21. PMID: 29164319.

Langevin SM, Eliot M, Butler RA, McClean M, Kelsey KT. Firefighter occupation is associated with increased risk for laryngeal and hypopharyngeal squamous cell carcinoma among men from the Greater Boston area. Occ Env Med. 2020 Jun;77(6):381-385. doi: 10.1136/oemed-2019-106271. Epub 2020 Feb 27. PMID: 32107319.

LaSee CR, Bonauto DK, Marcum J. Workers' Compensation Claims for Conditions Presumed to Be Occupational Diseases Among Firefighters in Washington State, 2000–2017. Journal of Occupational and Environmental Medicine. 2023;65(2):e51-e6.

Lee DJ, Ahn S, McClure LA, Caban-Martinez AJ, Kobetz EN, Ukani H, Boga DJ, Hernandez D, Pinheiro PS. Cancer risk and mortality among firefighters: a meta-analytic review. Front Oncol. 2023;13:1130754. DOI: 10.3389/fonc.2023.1130754. PMID: 37251928

Lee DJ, Koru-Sengul T, Hernandez MN, Caban-Martinez AJ, McClure LA, Mackinnon JA, Kobetz EN. Cancer risk among career male and female Florida firefighters: Evidence from the Florida Firefighter Cancer Registry (1981-2014). Am J Ind Med. 2020 Apr;63(4):285-299. doi: 10.1002/ajim.23086. Epub 2020 Jan 12. PMID: 31930542.

LeMasters GK, Genaidy AM, Succop P, Deddens J, Sobeih T, Barriera-Viruet H, Dunning K, Lockey J. Cancer risk among firefighters: a review and meta-analysis of 32 studies. J Occ Env Med. 2006 Nov;48(11):1189-202. doi: 10.1097/01.jom.0000246229.68697.90. PMID: 17099456.

Li J, Brackbill RM, Liao TS, Qiao B, Cone JE, Farfel MR, Hadler JL, Kahn AR, Konty KJ, Stayner LT, Stellman SD. Ten- Year cancer incidence in rescue/recovery workers and civilians exposed to the September 11, 2001 terrorist attacks on the World Trade Center. Am J Ind Med 2016;59:709–21. doi: 10.1002/ajim.22638. PMID: 27582473

Li J, Cone JE, Kahn AR, Brackbill RM, Farfel MR, Greene CM, Hadler JM, Stayner LT, Stellman SD. Association between World Trade Center exposure and excess cancer risk. JAMA 2012;308:2479–88. doi: 10.1002/ajim.23278. PMID: 34288025.

Ma F, Fleming LE, Lee DJ, Trapido E, Gerace TA, Lai H, Lai S. Mortality in Florida professional firefighters, 1972 to 1999. Am J Ind Med. 2005 Jun;47(6):509-17. doi: 10.1002/ajim.20160. PMID: 15898094.

Ma F, Fleming LE, Lee DJ, Trapido E, Gerace TA. Cancer incidence in Florida professional firefighters, 1981 to 1999. J Occup Environ Med. 2006 Sep;48(9):883-8. doi: 10.1097/01.jom.0000235862.12518.04. PMID: 16966954.

Ma F, Lee DJ, Fleming LE, Dosemeci M. Race-specific cancer mortality in US firefighters: 1984-1993. J Occup Environ Med. 1998 Dec;40(12):1134-8. doi: 10.1097/00043764-199812000-00014. PMID: 9871891.

Marjerrison N., Jakobsen J., Demers P.A., Grimsrud T.K., Hansen J., Martinsen J.I., Nordby K-C., Veierød M.B., Kjaerheim K. Comparison of cancer incidence and mortality in the Norwegian Fire Departments Cohort, 1960-2018. Occup Environ Med 2022. doi:10.1136/oemed-2022-108331. PubMed PMID: 35589382.

Muegge CM, Zollinger TW, Song Y, Wessel J, Monahan PO, Moffatt SM. Excess mortality among Indiana firefighters, 1985-2013. Am J Ind Med. 2018 Dec;61(12):961-967. doi: 10.1002/ajim.22918. Epub 2018 Nov 13. PMID: 30421827.

Paget-Bailly S, Guida F, Carton M, Menvielle G, Radoï L, Cyr D, Schmaus A, Cénée S, Papadopoulos A, Févotte J, Pilorget C, Velten M, Guizard AV, Stücker I, Luce D. Occupation and head and neck cancer risk in men: results from the ICARE study, a French population-based case-control study. J Occup Environ Med. 2013 Sep;55(9):1065-73. doi: 10.1097/JOM.0b013e318298fae4. PMID: 23969505.

Petersen KKU, Pedersen JE, Bonde JP, Ebbehoej NE, Hansen J. Long-term follow-up for cancer incidence in a cohort of Danish firefighters. Occ Env Med 2018 Apr;75(4):263–9. https://doi.org/10.1136/ oemed-2017-104660.

Petersen KU, Pedersen JE, Bonde JP, Ebbehøj NE, Hansen J. Mortality in a cohort of Danish firefighters; 1970-2014. Int Arch Occup Environ Health. 2018 Aug;91(6):759-766. doi: 10.1007/s00420-018-1323-6. Epub 2018 May 28. PMID: 29808435.

Pinkerton L, Bertke SJ, Yiin J, Dahm M, Kubale T, Hales T, Purdue M, Beaumont JJ, Daniels R. Mortality in a cohort of US firefighters from San Francisco, Chicago and Philadelphia: an update. Occup Environ Med. 2020 Feb;77(2):84-93. doi: 10.1136/oemed-2019-105962. Epub 2020 Jan 2. PMID: 31896615; PMCID: PMC10165610.

Pukkala E, Martinsen JI, Weiderpass E, Kjaerheim K, Lynge E, Tryggvadottir L, Sparén P, Demers PA. Cancer incidence among firefighters: 45 years of follow- up in five Nordic countries. Occup Environ Med. 2014 Jun;71(6):398-404. doi: 10.1136/oemed-2013-101803. Epub 2014 Feb 6. PMID: 24510539.

Rosenstock L, Demers P, Heyer N. Northwest Firefighters Mortality Study: 1945–1989. Occupational Medicine Program, University of Washington, Seattle. 1991. Available at https://www.hsdl.org/?view&did=776446.

Sama SR, Martin TR, Davis LK, Kriebel D. Cancer incidence among Massachusetts firefighters, 1982-1986. Am J Ind Med. 1990;18(1):47-54. doi: 10.1002/ajim.4700180106. PMID: 2378369.

Sidossis A, Lan FY, Hershey MS, Hadkhale K, Kales SN. Cancer and Potential Prevention with Lifestyle among Career Firefighters: A Narrative Review. Cancers (Basel). 2023 Apr 24;15(9):2442. doi: 10.3390/cancers15092442. PMID: 37173909; PMCID: PMC10177420.

Solan S, Wallenstein S, Shapiro M, Teitelbaum SL, Stevenson L, Kochman A, et al. Cancer incidence in World Trade Center rescue and recovery workers, 2001-2008. Environ Health Perspect 2013;121:699–704. DOI: 10.1289/ehp.1205894. PMID: 23613120

Soteriades ES, Kim J, Christophi CA, Kales SN. Cancer Incidence and Mortality in Firefighters: A State-of-the-Art Review and Meta-Analysis. Asian Pac J Cancer Prev. 2019 Nov 1;20(11):3221-3231. doi: 10.31557/APJCP.2019.20.11.3221. PMID: 31759344.

Sousa G, Teixeira J, Delerue-Matos C, Sarmento B, Morais S, Wang X, Rodrigues F, Oliveira M. Exposure to PAHs during Firefighting Activities: A Review of Skin Levels, In Vitro/In Vivo

Bioavailability and Health Risks. Int J Environ Res Public Health. 2022; 19(19): 12677. doi: 10.3390/ijerph191912677. PMID: 36231977.

Sritharan J, Kirkham TL, MacLeod J, Marjerrison N, Lau A, Dakouo M, Logar- Henderson C, Norzin T, DeBono NL, Demers PA. Cancer risk among firefighters and police in the Ontario workforce. Occup Environ Med. 2022 Aug;79(8):533-539. doi: 10.1136/oemed-2021-108146. Epub 2022 Mar 30. PMID: 35354650; PMCID: PMC9304109.

Stec AA, Robinson A, Wolffe TAM, Bagkeris E. Scottish Firefighters Occupational Cancer and Disease Mortality Rates: 2000-2020. Occup Med (Lond). 2023 Feb 14;73(1):42-48. doi: 10.1093/occmed/kqac138. PMID: 36624617.

Tornling G, Gustavsson P, Hogstedt C. Mortality and cancer incidence in Stockholm fire fighters. Am J Ind Med. 1994;25(2):219-28. DOI: 10.1002/ajim.4700250208. PMID: 8147394.

Tsai RJ, Luckhaupt SE, Schumacher P, Cress RD, Deapen DM, Calvert GM. Risk of cancer among firefighters in California, 1988-2007. Am J Ind Med. 2015 Jul;58(7):715-29. doi: 10.1002/ajim.22466. Epub 2015 May 6. PMID: 25943908; PMCID: PMC4527530.

Vena JE, Fiedler RC. Mortality of a municipal-worker cohort: IV. Fire fighters. Am J Ind Med. 1987;11(6):671-84. doi: 10.1002/ajim.4700110608. PMID: 3605104.

Zeig-Owens R, Webber MP, Hall CB, Schwartz T, Jaber N, Weakley J, Rohan TE, Cohen HW, Derman O, Aldrich TK, Kelly K, Prezant DJ. Early assessment of cancer outcomes in New York City firefighters after the 9/11 attacks: an observational cohort study. Lancet. 2011 Sep 3;378(9794):898-905. doi: 10.1016/S0140-6736(11)60989-6. PMID: 21890054.

Zhao G, Erazo B, Ronda E, Brocal F, Regidor E. Mortality Among Firefighters in Spain: 10 Years of Follow-up. Ann Work Expo Health. 2020 Jul 1;64(6):614-621. doi: 10.1093/annweh/wxaa036. PMID: 32253442.

SUPPLEMENTAL TABLES

Table 12. Characteristics of cohort and case-control studies of buccal, pharynx, esophageal, and pancreatic cancer risk in firefighters

ID	First Author, year	Region	Years(s)		Study Design	Outcome	Study Pop	n	Data Source		Reference Population	Covariates/Cofactors
			Enrollment	Follow-up					Occ	Disease		
1	Ahn, 2012	South Korea	1980-2007	1996-2007	Cohort	Incidence	Male FFs	29,438	ER	CR	general Korean pop	age, calendar year
2	Amadeo, 2015	France	1979	1979-2008	Cohort	Mortality	Male FFs	10829	ER	DC	National general pop.	age, calendar period
3	Aronson, 1994	Toronto, Canada	1950-1989	1950-1989	Cohort	Mortality	Male FFs	5,373	ER	DC	Ontario male pop	age, year
4	Baris, 2001	Philadelphia	1925-1986	1925-1986	Cohort	Mortality	Male FFs	7789	ER	DC	US white male pop.	age, year
5	Bates, 2007	California	1988-2003		Case Control	Incidence	Male FF	3,659	CR	CR	males in CR between ages 21-80 at date of diagnosis	age, year of diagnosis, race, SES
6	Bates, 2001	New Zealand	1977-1995	1977-1996	Cohort	Incidence	Paid male FFs	3,657	AR	DC, CR	New Zealand pop	age, year
7	Beaumont, 1991	San Francisco	1940-1970	1940-1982	Cohort	Mortality	White male FF employed by the SFFD for at least 3 years and worked at least one day between 1/1/49 and 12/31/70	3066	ER	DC	US White Male pop.	age, year
8	Bigert, 2020	Sweden	1960, 1970, 1980, 1990 censuses	1961-2009	Cohort	Incidence	Male FFs (working as FF for more than 1/2 of the regular working hours that year)	8136	CD	CR	Swedish male pop.	age, year

ID	First Author, year	Region	Years(s)		Study Design	Outcome	Study Pop	n	Data Source		Reference Population	Covariates/Cofactors
			Enrollment	Follow-up					Occ	Disease		
9	Colbeth, 2020	New York City	9/11/2001 - 7/25/2002	9/12/2001-12/31/2017	Cohort	Mortality	FDNY FFs and EMS who arrived at the WTC-site between 9/11/01 and 7/25/2002; and were employed for 18-months or more	15,431	ER	DC	US general pop	sex, race, age, calendar period
10	Daniels, 2015	SF, Chicago, and Philadelphia	1950-2009	1950-2009	Cohort	Incidence and Mortality	FFs	19,309	ER	CR	Exposed-days (2500 runs reference, calculated for all three fire departments, Fire runs (2100 runs reference, calculated for only firefighters in Chicago and Philadelphia), Fire-hours (600 hours reference, calculated for Chicago only)	race, fire department, age
11	Daniels, 2014	SF, Chicago, and Philadelphia	1950-2009	1950-2009 (mortality), 1985-2009 (incidence)	Cohort	Incidence and Mortality	FFs who worked for at least 1 day	29,993	ER	DC, ER	US pop	gender, age, race, calendar year
12	Demers, 1994	Seattle & Tacoma (WA)	1944-1979	1974-1989	Cohort	Incidence	Male FFs employed for at least on year from	2,447	ER	CSS	Local county rates	age, time period

ID	First Author, year	Region	Years(s)		Study Design	Outcome	Study Pop	n	Data Source		Reference Population	Covariates/Cofactors
			Enrollment	Follow-up					Occ	Disease		
							1944-1979, alive as of 1/1/74, and a resident of 13 northwestern counties in WA state					
13	Demers,1992 a (Mortality among g FFs from 3 NW US cities)	Seattle & Tacoma (WA), Portland (OR)	1944-1979	1945-1989	Cohort	Mortality	Male FF employed by Seattle, Tacoma or Portland (OR) for at least one year btwn 1944-1979	4401	ER	DC	US white male pop	age, time period
14	Demers, 1992b (Cancer ID using a tumor registry)	Seattle and Tacoma, WA	1944-1979	1974-1989	Cohort	Incidence and Mortality	Male FFs and Police Officers, employed for at least 1 year by Seattle or Tacoma (WA)	4528	ER	CR, DC	White males in WA state	
15	Deschamps, 1995	Paris, France	1977	1977-1991	Cohort	Mortality	Male FFs who worked for at least 5 years	830	ER	Pension records linked to non-nominal mortality card index on 5 variables (gender, DOB, DOD, birth place, death place)	general French male pop	age, person-years at risk

ID	First Author, year	Region	Years(s)		Study Design	Outcome	Study Pop	n	Data Source		Reference Population	Covariates/Cofactors
			Enrollment	Follow-up					Occ	Disease		
16	Giles, 1993	Melbourne, Australia	1917-1989	1980-1989	Cohort	Incidence	Male Firefighters employed by the Melbourne Fire Brigade	2,856	ER and union records	CR	General	age
17	Glass, 2019	Australia	1982-1998/2000	1982-2010	Cohort	Incidence	Female volunteer FFs from 9 agencies throughout Australia	37,973	ER	CR	general Australian pop	age, calendar year
18	Glass, 2017	Australia	1998 to 2000-2010	1998 to 2000-2010	Cohort	Incidence	Male volunteer FFs from five fire agencies. Each agency had a different start date, which ranged from 1998-2000	157,931	ER	DC, CR	Australian general pop.	age, year
19	Glass, 2016a (Firetraining college)	Victoria, Australia	1971-1999	1982-2012	Cohort	Incidence	male employed and volunteer FF trainers at a fire training college and a group of paid FF who trained at the college	611	ER and volunteer records	CR	general pop of Victoria Australia	age, calendar period
20	Glass, 2016b	Australia	1976 to 2003-??	1982-2019/2010	Cohort	Incidence	FFs (records from 8 of 10 Australian fire agencies	29041	ER	DC, CR	Australian general pop.	age, sex

ID	First Author, year	Region	Years(s)		Study Design	Outcome	Study Pop	n	Data Source		Reference Population	Covariates/Cofactors
			Enrollment	Follow-up					Occ	Disease		
							on or after the commencement date, which ranged from 1976-2003 depending on the department					
21	Glass, 2009	Queensland, Australia	1995-2006	1995-2006	Cohort	Incidence	Male FF	694	ER	CR	general Queensland pop	age group, period-specific
22	Guidotti, 1993	Alberta, Canada	1927-1987	1927-1987	Cohort	Mortality	Calgary and Edmonton FFs	3328	ER	DC	male residents of Alberta	age, time periods
23	Harris, 2018	Canada	1992-2010	1992-2010	Cohort	Incidence	Male FFs	4,535	CD	CR	Male Canadian workers	age, region, education
24	Heyer, 1990	Seattle	1945-1980	1945-1983	Cohort	Mortality	Male FFs	2,289	ER	DC	US white males	
25	Hrubec, 1992	US	1917-1940	1954-1980	Cohort	Mortality	White males who had served in the US Armed Forces between 1917-1940 and subsequently served as a fireman or in fire protection	902	Census	Beneficiary records locator subsystem	All other occupations	age at observation, calendar time, type of smoking and amount of cigarettes smoked
26	Kang, 2008	Massachusetts		1987-2003	Case Control	Mortality	White male FFs	2,125	CR	CR	(1) white police officers; (2)	age, smoking status

ID	First Author, year	Region	Years(s)		Study Design	Outcome	Study Pop	n	Data Source		Reference Population	Covariates/Cofactors
			Enrollment	Follow-up					Occ	Disease		
											All white adults (18+) with any occupational information	
27	Kullberg, 2018	Stockholm, Sweden	1931-1983	1958-2012	Cohort	Incidence	Male FFs	1,080	ER	CR	Stockholm county male pop	age, year
28	Langevin, 2020	Greater Boston area		Phase I: 1999-2003; Phase II: 2006-2011	Case Control	Incidence	Male FF	11	PI	CR	male non-FFs	adjusted for age, race, education, smoking and alcohol consumption
29	Lee, 2020	Florida		1981-2014	Case Control	Incidence	FFs	3,928	FC	CR	all other cancer	age at dx, calendar year
30	Li, 2016	New York	2001	2007-2011	Cohort	Incidence	rescue/recovery workers enrolled in the WTC Health Registry cohort in 2003-2004	24,863	WTCHR	CR	NY state pop	age, race/ethnicity, sex, calendar period
31	Li, 2012	New York	2001	2003/2004-2008	Cohort	Incidence	rescue/recovery workers enrolled in the WTC Health Registry cohort in 2003-2004 who were NY state residents	21,820	WTCHR	CR	NY state pop	age, race/ethnicity, sex
32	Ma, 2006	Florida	1972-1999	1981-1999	Cohort	Incidence	FFs	36,813	FC	CR	Florida general pop	age, gender, year

ID	First Author, year	Region	Years(s)		Study Design	Outcome	Study Pop	n	Data Source		Reference Population	Covariates/Cofactors
			Enrollment	Follow-up					Occ	Disease		
33	Ma, 2005	Florida	1972-1999	1972-1999	Cohort	Mortality	FFs	36,813	FC	DC	Florida general pop	age, year, gender
34	Ma, 1998	24 US states		1984-1993	Case Control	Incidence	Male Firefighters	6,607	DC	DC	All causes of death (except cancer) of DC coded for occupation	age, time of death
35	Marjerrison 2022	Norway	1950-2018	1960-2018	Cohort	Incidence and Mortality	Male Firefighters	4,295 (includes 414 chimney sweeps, fire inspectors, and office personnel)	ER	CR	Norwegian male pop	age, calendar period
36	Muegge, 2018	Indiana		1985-2013	Case Control	Mortality	FFs	2818	DC	DC	non-FFs matched on age at death, sex, race, ethnicity, and year	
37	Paget-Bailly, 2013	France		2001-2007	Case Control	Incidence	Male FFs	13	in-person intervie w	CR	general pop matched by sex, age, and geographic location	age, geographic location, alcohol consumption, tobacco consumption, smoking status
38	Peterson, 2018a	Denmark	1928-2004	1970-2014	Cohort	Mortality	Male FFs	11,775	ER	CR	males in the military	5 year age and calendar intervals
39	Petersen, 2018b (long term)	Denmark	1928-2004	1968-2014	Cohort	Incidence	Male FFs	9,061	ER	CR	National pop, sample of national employed pop, males in the military	Age, Calendar time

ID	First Author, year	Region	Years(s)		Study Design	Outcome	Study Pop	n	Data Source		Reference Population	Covariates/Cofactors
			Enrollment	Follow-up					Occ	Disease		
40	Pinkerton, 2020	SF, Chicago, and Philadelphia	1950-2009	1950-2016	Cohort	Mortality	FFs	29,992	ER	DC	US general pop	age group, gender, race, calendar period
41	Pukkala, 2014	Denmark, Finland, Iceland, Norway, and Sweden	Denmark (1970 census), Finland (1970, 1980, and 1990 censuses), Iceland (1981 census), Norway (1960, 1970, 1980 censuses), Sweden (1960, 1970, 1980, and 1990 censuses)	1961-2005	Cohort	Incidence	Male FFs	16,422	CD	CR	national male pop	age, calendar period
42	Rosenstock, 1991	Seattle, Tacoma, Bellevue, and Kent (WA), and Portland (OR)	1944-1979	1945-1983	Cohort	Mortality	Male FF employed for at least one year	4546	ER	DC	US white males	age group, time period
43	Sama, 1990	Massachusetts		1982-1986	Case Control	Mortality	Male FFs	321	CR	CR	1) all other cancer patients in MA 2) Police	age
44	Solan, 2013	New York City area	2001	7/16/2002-12/31/2008	Cohort	Incidence	employees and volunteers in the rescue,	20,984	cohort intake	CR	NY, CT, PA, NJ residents	Sex, age, race, smoking history, occupation, year of registration in

ID	First Author, year	Region	Years(s)		Study Design	Outcome	Study Pop	n	Data Source		Reference Population	Covariates/Cofactors
			Enrollment	Follow-up					Occ	Disease		
							recovery, and cleanup efforts at Ground Zero, enrolled in the World Trade Center Health Program (WTCHP)					cohort, center of first clinical visit
45	Sritharan, 2022	Ontario, Canada	1983-2020	1983-2020	Cohort	Incidence	FFs	13,642	Occupational Disease Surv system	CR	all other workers, police	age at start of follow-up, birth year, sex
46	Stec, 2023	Scotland	2000-2020	2000-2020	Cohort	Mortality	Male FFs (full-time) between the ages of 30-74	not reported	National Records of Scotland	National Records of Scotland	Scottish male pop between 30-74 years old	age, calendar year
47	Tornling, 1994	Stockholm, Sweden	1931-1983	1951-1986	Cohort	Incidence and Mortality	Male FFs employed 1+ year	1,116	ER	DC	regional rates	age, time periods, sex
48	Tsai, 2015	California		1988-2007	Case Control	Incidence	Male FFs	3,996	CR	CR	All adult males (18-97) in the cancer registry with I&O information (see note)	age of diagnosis, race, and year of diagnosis
49	Vena, 1987	Buffalo, NY	1950-1979	1961-2005	Cohort	Mortality	White male FFs	1,867	ER	DC	US white males	age, year
50	Zeig Owens, 2011	New York City	1996	2001-2008	Cohort	Incidence	male FFs (excluding Asian and Native	9,853	ER, HM, PI	CR, HM	US National cancer rates	age, race, ethnic origin, calendar year

ID	First Author, year	Region	Years(s)		Study Design	Outcome	Study Pop	n	Data Source		Reference Population	Covariates/Cofactors
			Enrollment	Follow-up					Occ	Disease		
							American FFs)					
51	Zhao, 2020	Spain	2001-2011	2001-2011	Cohort	Mortality	Male FFs	27365	CD	DC	men between the ages of 20 and 64 who were employed at enrollment in 2001	age

AR: Association records CD: Census data CR: Cancer registry CSS: Cancer Surveillance System DC: Death certificates, records, & registers DX: Diagnosis ER: Employment records FC: Firefighter certification records FF: Firefighter HM: Departmental health monitoring examination records PI: Personal interview via phone or mail WTC: World Trade Center WTCHR: World Trade Center Health Registry

Table 13. Extract estimates of buccal and pharyngeal cancer risk and mortality in firefighters from cohort studies

ID	First Author, year	Cancer type (ICD)	Category	Cancer estimates		
				obs	point estimate	95% CI
1	Ahn, 2012	Parotid gland (C07)	Full cohort	3	SIR=2.34	0.47-6.83
			≥10 years of FF experience	2	SIR=2.38	0.27-8.58
2	Amadeo, 2015	Lip, Oral Cavity, Pharynx	Full cohort	69	SMR=1.15	0.89-1.46
3	Aronson, 1994	Pharynx (146-149)	Full cohort	4	SMR=139	38-357
			Years since first employment/exposure:			
			<20 years	0	SMR=0	0-946
			20-29 Years	1	SMR=122	3-680
			≥30 Years	3	SMR=181	37-528
			Years of employment:			
			<15	1	SMR=233	6-1296
			15-29	0	SMR=0	0-326
			≥30 Years	3	SMR=233	48-680
			Age:			
			<60 years	1	SMR=62	2-344
			≥60 years	3	SMR=240	49-701
4	Baris, 2001	Buccal cavity & pharynx (140-149)	Full cohort	19	SMR=1.36	0.87-2.14
			Duration of employment:			
			≤ 9 years	4	SMR=1.15	0.43-3.07
			10-19 years	9	SMR=1.83	0.95-3.51
			≥ 20 years	6	SMR=1.09	0.50-2.43
			Company type:			
			Engine company only	11	SMR=2.00	1.11-3.63
			Ladder only companies	1	SMR=0.91	0.13-6.44
			Engine and Ladder companies	5	SMR=0.72	0.30-1.73
			Cumulative runs:			
			Low runs (<3323 runs)	7	SMR=1.72	0.82-3.61
			Medium runs (3323-5098 runs)	0	NA	NA
			High runs (5099 runs or more)	2	SMR=0.77	0.19-3.09
			Hire date:			
			hired before 1935	10	SMR=2.11	1.13-3.91
			Hired 1935-1944	4	SMR=0.87	0.33-2.32
			Hired after 1944	5	SMR=1.10	0.46-2.64
			Rate Ratios (n=6,477)			
			Cumulative Runs			
			Low (≤ 3,191runs)	7	RR=1.0	REF
			High (>3,191 runs)	2	RR=0.19	0.04-0.96
			Runs during first 5 years as a FF			
			Low (≤729 runs)	5	RR=1.0	REF
			High (>729 runs)	4	RR=0.77	0.20-2.98
			Number of Lifetime runs			
			Non-exposed	4	RR=1.00	REF
			Low Exposed (1-259 runs)	2	RR=2.76	0.50-15.34

ID	First Author, year	Cancer type (ICD)	Category	Cancer estimates		
				obs	point estimate	95% CI
			Medium runs (260-1,423 runs)	3	RR=2.59	0.49-13.76
			High (>1,423 runs)	NA	NA	NA
7	Beaumont, 1991	Buccal cavity & pharynx	Full cohort	11	RR=1.43	0.71-2.57
		Lip		2	RR=6.17	0.75-22.29
		Tongue		2	RR=1.06	0.13-3.86
		Pharynx		4	RR=1.17	0.32-3.00
8	Bigert, 2020	Pharynx (C09-14)	Full cohort	13	SIR=1.04	0.55 -1.78
9	Colbeth, 2020	Buccal & pharynx	Full Cohort	≤5	SMR=0.18	0.02-0.65
			Race:			
			Non-Hispanic White	≤5	SMR=0.20	0.02-0.74
			Non-White	0	SMR=0.00	0.00-2.93
			Profession:			
			Firefighters	≤5	SMR=0.20	0.02-0.71
			EMS providers	0	SMR=0.00	0.00-3.86
			Exposure:			
			High Exposure	0	SMR=0.00	0.00-2.45
			Moderate/Low Exposure	≤5	SMR=0.21	0.03-0.76
11	Daniels, 2014	Buccal & pharynx (C00-C14)	Full cohort (mortality, 1950-2009)	94	SMR=1.40	1.13-1.72
		Lip (C00)	Full cohort (mortality, 1950-2009)	<5	SMR=0.80	0.02-4.44
		Tongue (C01, C02)	Full cohort (mortality, 1950-2009)	25	SMR=1.61	1.04-2.68
		Other Buccal (C03-C08)	Full cohort (mortality, 1950-2009)	25	SMR=1.43	0.93-2.12
		Pharynx (C09-C14)	Full cohort (mortality, 1950-2009)	43	SMR=1.31	0.95-1.77
		Buccal & Pharynx (C00-C14)	Full cohort (incidence, 1985-2009)	174	SIR=1.39	1.19-1.62
		Lip (C00)*	Full cohort (incidence, 1985-2009)	<20	SIR=1.11	0.65-1.78
		Tongue (C01, C02)*	Full cohort (incidence, 1985-2009)	52	SIR=1.74	1.30-2.28
		Other Buccal (C03-C08)*	Full cohort (incidence, 1985-2009)	46	SIR=1.24	0.91-1.65
		Pharynx (C09-C14)*	Full cohort (incidence, 1985-2009)	5	SIR=1.39	1.06-1.79
12	Demers, 1994	Oral & pharynx (140-149)	Full cohort	11	SIR=1.1	0.6-2.0
			Duration of employment:			
			<10 years	2	SIR=1.4	0.2-5.1
			10-19 years	4	SIR=2.5	0.7-6.4
			20-29 years	2	SIR=0.3	0.0-1.2
			30+ years	3	SIR=3.9	0.8-11
			Years since first employment:			
			<20 years	1	SIR=1.5	0.0-8.2
			20-29 years	1	SIR=0.5	0.0-2.7
			30+ years	9	SIR=1.3	0.6-2.4
13	Demers, 1992a	Oral & pharynx (140-149)	Full cohort	7	SMR=0.81	0.33-1.66
14	Demers, 1992b	Oral & Pharynx (ICD-9 140-149)	Full Cohort (incidence)	19	SIR=1.22	0.73-1.90
			Full cohort (mortality)	4	SMR=1.00	0.27-2.57

ID	First Author, year	Cancer type (ICD)	Category	Cancer estimates		
				obs	point estimate	95% CI
15	Deschamps, 1995	Pharynx Cancer (140-149)	Full cohort	2	SMR=0.81	0.10-2.93
17	Glass, 2019	Lip, oral cavity, & pharynx (C00-C14)	Full cohort	16	SIR=0.81	0.46-1.32
			Volunteers who attended incidents	7	SIR=0.87	0.35-1.79
18	Glass, 2017	Lip, oral cavity & Pharynx (C00-C14)	Full cohort	245	SIR=0.71	0.63-0.81
			Volunteers who attended incidents	159	SIR=0.70	0.60-0.82
		Lip (C00)	Full cohort	125	SIR=1.15	0.96-1.37
			Volunteers who attended incidents	87	SIR=1.20	0.96-1.48
19	Glass, 2016a	Lip, buccal cavity, & pharynx	Low risk of chronic exposure	0	NA	NA
			Medium risk of chronic exposures	1	SIR=0.65	0.02-3.62
			High risk of chronic exposures	1	SIR=1.61	0.04-8.98
20	Glass, 2016b	Lip, oral cavity, & pharynx (C00-C14)	Full Cohort	76	SIR=0.93	0.73-1.16
			Full time FF	55	SIR=0.95	0.71-1.23
			Part-time FF	21	SIR=0.89	0.55-1.36
21	Glass, 2009	Lip, head, and neck (C00-C14)	Full cohort (men who ever held an active FF job)	10	SIR=0.73	0.39-1.35
			Men who served 12+ months as an active FF	10	SIR=0.74	0.40-1.38
			Men ever employed as a full time FF	6	SIR=0.72	0.32-1.60
22	Guidotti, 1993	Oral (140-149)	Full cohort	2	SMR=113.6	13.7-410.4
23	Harris, 2018	Oral	Model 1 (adjusted for age & region)	20	HR=1.06	0.66-1.70
			Model 2 (adjusted for age, region, & edu)	20	HR=1.01	0.63-1.62
		Lip	Model 1 (adjusted for age & region)	5	HR=2.22	0.92-5.36
			Model 2 (adjusted for age, region, & edu)	5	HR=2.09	0.87-5.06
25	Hrubec, 1992	Buccal cavity	Total Adjusted	2	RR=2.0	NR (95% CIs including 1.0 were NR when <5 cases)
			Non-Smokers	0	NA	
			Current cigarettes	2	RR=3.6	1.11-11.60
		Lip (140)	Full cohort (1958-2012)	2	SIR=1.45	0.18-5.26
			Former follow-up only (1958-1986)	1	SIR=1.42	0.04-7.91
			Extended follow-up only (1987-2012)	1	SIR=1.49	0.38-8.32
27	Kullberg, 2018	Lip (140)	Full cohort (1958-2012)	2	SIR=1.45	0.18-5.26
			Former follow-up only (1958-1986)	1	SIR=1.42	0.04-7.91
			Extended follow-up only (1987-2012)	1	SIR=1.49	0.38-8.32
30	Li, 2016	Oral cavity and pharynx*	Full cohort	16	SIR=0.80	0.46-1.30
31	Li, 2012	Oral cavity and pharynx*	Early period (through 2006)	8	SIR=1.13	0.49-2.24
			Later period (2007-2008)	≤5	SIR=0.77	0.25-1.80
32	Ma, 2006	Buccal (C00-C14)	By Sex:			
			Male	39	SIR=0.67	0.47-0.91
			Female FF	0	NA	NA
33	Ma, 2005	Buccal & pharynx	By Sex:			
			Male	7	SMR=0.42	0.17-0.87

ID	First Author, year	Cancer type (ICD)	Category	Cancer estimates		
				obs	point estimate	95% CI
			Female	0	NA	NA
			Males certified from 1972-1976	5	SMR=0.38	0.12-0.89
35	Marjerrison, 2022	Lip (C00)	Incidence	<5	SIR=0.51	0.11-1.50
			Mortality	0	SMR=0.00	0.00-12.3
		Oral cavity (C02-C06)	Incidence	<5	SIR=0.67	0.18-1.72
			Mortality	0	SMR=0.00	0.00-2.81
		Pharynx (C09-C14, C01)	Incidence	11	SIR=1.49	0.74-2.67
			Mortality	<5	SMR=0.97	0.26-2.49
38	Petersen, 2018a	Oral cavity & oesophagus (C00-15)	Employment status:			
			Full time	24	SMR=1.27	0.85-1.89
			Part time/volunteer	8	SMR=0.63	0.32-1.27
			Duration of employment			
			<1 year	11	SMR=1.39	0.77-2.51
			≥1 year	13	SMR=1.18	0.68-2.03
			>10 years	11	SMR=1.13	0.63-2.05
			>20 years	10	SMR=1.21	0.65-2.25
39	Petersen, 2018b	Lip (C00)	Compared to the general population	4	SIR=1.04	0.39-2.78
			Compared to a general sample of employees	4	SIR=1.13	0.42-3.01
			Compared to the military sample	4	SIR=1.60	0.60-4.28
		Tongue (C01-C02)	Compared to the general population	12	SIR=1.52	0.86-2.68
			Compared to a general sample of employees	12	SIR=1.62	0.92-2.85
			Compared to the military sample	12	SIR=1.46	0.83-2.57
		Mouth (C03-C06, C462)	Compared to the general population	7	SIR=0.60	0.28-1.25
			Compared to a general sample of employees	7	SIR=0.57	0.27-1.19
			Compared to the military sample	7	SIR=0.61	0.29-1.27
		Salivary glands (C07-C08)	Compared to the general population	4	SIR=1.79	0.67-4.77
			Compared to a general sample of employees	4	SIR=1.90	0.71-5.07
			Compared to the military sample	4	SIR=1.59	0.60-4.24
		Pharynx (C09-C14)	Compared to the general population	20	SIR=0.91	0.59-1.41
			Compared to a general sample of employees	20	SIR=0.94	0.60-1.45
			Compared to the military sample	20	SIR=0.87	0.56-1.35
40	Pinkerton, 2020	Buccal Cavity & pharynx	Full cohort	NR	SIR=1.35	1.11-1.63
		Lip	Full cohort	<5	SIR=0.67	0.02-3.71
		Tongue	Full cohort	26	SIR=1.42	0.93-2.08
		Other buccal	Full cohort	30	SIR=1.50	1.01-2.14
		Pharynx	Full cohort	29	SIR=1.27	0.94-1.68
41	Pukkala, 2014	Oral cavity (C03-C06)	Full cohort	11	SIR=0.80	0.40-1.43
		Pharynx (C09-14)	Full cohort	19	SIR=1.00	0.60-1.57
42	Rosenstock, 1991	Buccal cavity & pharynx	Full cohort	7	SMR=0.80	0.32-1.65
44	Solan, 2013	Oral cavity & pharynx	Diagnosed between 9/11/01 and 12/31/08	21	SIR=1.21	0.75-1.86
			Diagnosed at least 6 month after registering in the WTCHP cohort	10	SIR=1.00	0.48-1.84
45		Oral Cancer (C01-C14)	Compared to all other workers	56	HR=1.10	0.84-1.43

ID	First Author, year	Cancer type (ICD)	Category	Cancer estimates		
				obs	point estimate	95% CI
	Sritharan, 2022		FF compared to police	56	HR=1.03	0.72-1.46
51	Zhao, 2020	Mouth & Pharynx (C00-C14)	Full cohort	18	MRR=1.34	0.81-2.21
		Hypopharynx (C12 &C13)	Full cohort	6	MRR=2.96	1.31-6.69

NA: Not applicable NR: Not reported NS: not statistically significant
* Where this is the first cancer diagnosis

Table 14. Extract estimates of buccal and pharyngeal cancer risk and mortality in firefighters from case control studies

ID	First Author, year	Cancer type/Definition (ICD)	Category	Cancer estimates		
				Cases	point estimate	95% CI
26	Kang, 2008	Buccal Cavity	Compared to police	21	SMOR=0.72	0.37-1.41
			Stratified by age at DX:			
			18-54 year olds		SMOR=1.07	0.27-4.28
			55-74 year olds		SMOR=0.59	0.25-1.40
			75+ year olds		SMOR=0.69	0 .12-3.84
			Compared to all other occupations	21	SMOR=0.66	0.41-1.06
		Nasopharynx	Compared to police	3	SMOR=1.17	0.19-7.17
			Stratified by age at DX:			
			18-54 year olds		NA	NA
			55-74 year olds		SMOR=0.88	0.12-6.46
			75+ year olds		NA	NA
			Compared to all other occupations	3	SMOR=1.31	0.32-5.31
28	Langevin, 2020	Oral Cavity Squamous Cell Carcinoma	Ever Firefighter (REF=never firefighter)	2	OR=0.44	0.09-2.04
			Per decade as FF		OR=0.76	0.41-1.40
		Oropharyngeal Squamous Cell Carcinoma	Ever Firefighter (REF=never firefighter)	4	OR=0.84	0.27-2.67
			per decade as FF		OR=0.88	0.55-1.40
		Hypopharyngeal Squamous Cell Carcinoma	Ever Firefighter (REF=never firefighter)	2	OR=3.11	0.63-15.39
			per decade as FF		OR=1.34	0.84-2.14
29	Lee, 2020	Oral cavity and Pharynx	By Sex:			
			Male Firefighters	159	aOR=0.85	0.72-0.99
			Female Firefighters	<10	aOR=1.26	0.47-3.40
			By Stage of Cancer:			
			Early stage	43	aOR=0.75	0.55-1.01
			Late stage	107	aOR=1.07	0.88-1.30
			By Age Group:			
			<50 years old	42	aOR=0.75	0.55-1.02
			≥50 years old	117	aOR=0.85	0.71-1.02
34	Ma, 1998	Nasopharynx	By race:			
			White male FF	0	NA	NA
			Black male FF	1	MOR=7.6	1.3-46.4
36	Muegge, 2018	Malignant cancer of buccal cavity and pharynx		21	OR=2.15	1.19-3.79
		Malignant cancer of other parts of the buccal cavity		6	OR=4.00	1.07-14.96
		Malignant cancer of pharynx		13	OR=2.26	1.05-4.65
37	Paget-Bailly, 2013	Oral		6	OR=10.2	3.1-34.0
		Oropharynx		2	OR=1.9	0.4-9.9

ID	First Author, year	Cancer type/Definition (ICD)	Category	Cancer estimates		
				Cases	point estimate	95% CI
		Oral cavity and pharynx not otherwise specified or overlapping		2	OR=11.3	2.0-63.9
		Hypopharynx		2	OR=3.1	0.6-17.1
		Larynx		1	OR=1.2	0.1-9.9
48	Tsai, 2015	Gum and other mouth	All Subjects	14	OR=1.07	0.62-1.85
			All subjects by race:			
			White firefighters	13	OR=1.06	0.60-1.87
			other races	1	OR=1.50	0.20-11.15
		Pharyngeal	All subjects	43	OR=1.06	0.75-1.50
			All subjects by race:			
			White firefighters	38	OR=1.03	0.71-1.48
			other races	4	OR=1.35	0.45-4.05

DX: Diagnosis **NA:** not applicable

Table 15. Extract estimates of esophageal cancer risk and mortality in firefighters from cohort studies

ID	First Author, year	Category	Cancer estimates		
			obs	point estimate	95% CI
1	Ahn, 2012	Full cohort	6	SIR=0.75	0.28-1.68
		≥10 years of FF experience	6	SIR=0.94	0.34-2.05
2	Amadeo, 2015	Full cohort	40	SMR=0.93	0.67-1.27
3	Aronson, 1994	Full Cohort	2	SMR=40	5-143
4	Baris, 2001	Full cohort	6	SMR=0.56	0.25-1.24
		By duration of employment:			
		≤9 years	0	NA	NA
		10-19 years	3	SMR=0.82	0.26-2.52
		≥20 years	3	SMR=0.65	0.21-2.02
		By Company type:			
		Engine company only	3	SMR=0.70	0.23-2.19
		Ladder only companies	0	NA	NA
		Engine and Ladder companies	3	SMR=0.56	0.18-1.72
		By Cumulative runs:			
		Low runs (<3323 runs)	2	SMR=0.66	0.17-2.64
		Medium runs (3323-5098 runs)	1	SMR=0.50	0.07-3.54
		High runs (5099 runs or more)	3	SMR=1.40	0.45-4.33
		Hire date:			
		hired before 1935	0	NA	NA
		Hired 1935-1944	2	SMR=0.55	0.14-2.20
		Hired after 1944	4	SMR=1.12	0.42-2.99
6	Bates, 2001	Full Cohort (1977-1996)	3	SIR=1.67	0.3-4.9
		From 1990-1996	2	SIR=1.80	0.2-6.5
7	Beaumont, 1991	Full cohort	12	RR=2.04	1.05-3.57
		Years since first employment:			
		3-19	2	RR=5.22	p≥0.05
		20-29	2	RR=1.41	p≥0.05
		30-39	5	RR=2.34	p≥0.05
		40+	3	RR=1.55	p≥0.05
		Length of Employment:			
		3-9 years	0	NA	NA
		10-19 years	2	RR=3.47	p≥0.05
		20-29 years	6	RR=2.10	p≥0.05
		30+ years	4	RR=1.82	p≥0.05
8	Bigert, 2020	Full cohort	13	SIR=0.71	0.38 -1.21
9	Colbeth, 2020	Full Cohort	13	SMR=0.69	0.36-1.17
10	Daniels, 2015	Mortality			
		Exposed-days at 8,700 days	61	HR=0.61	NC-1.10
		Fire-runs at 8,800 runs	54	HR=1.24	0.91-1.88
		Fire-hours at 2,300 hours	34	HR=1.18	0.80-1.98
		Incidence			
		Exposed-days at 8,700 days	54	HR=0.66	0.42-1.18
		Fire-runs at 8,800 runs	48	HR=1.22	0.89-1.88

ID	First Author, year	Category	Cancer estimates		
			obs	point estimate	95% CI
		Fire-hours at 2,300 hours	29	HR=0.57	NC-1.95
11	Daniels, 2014	Mortality (1950-2009): Full cohort	113	SMR=1.39	1.14-1.67
		By Race:			
		White males	110	SMR=1.46	1.20-1.75
		non-white males	<5	SMR=0.51	0.11-1.49
		By employment duration:			
		0-10 years	13	SMR=1.17	0.62-2.00
		10-20 years of experience	28	SMR=1.72	1.14-2.48
		20-30 years	53	SMR=1.40	1.05-1.83
		30+ years of experience	19	SMR=1.19	0.71-1.84
		By employment duration (SRR)			
		0-10 years		REF	
		10-20 years of experience		SRR=2.43	1.07-5.50
		20-30 years		SRR=1.17	0.56-2.41
		30+ years of experience		SRR=0.60	0.27-1.35
		Incidence (1985-2009)			
		Full cohort	90	SIR=1.62	1.31-2.00
		Where this is the first cancer dx	80	SIR=1.71	1.36-2.13
		By Race:			
		White males	87	SIR=1.70	1.36-2.09
		non-white males	<5	SIR=0.73	0.15-2.15
12	Demers, 1994	Full cohort	4	SIR=1.3	0.4-3.3
		By duration of employment:			
		<10 years	0	SIR=0.0	0.0-9.3
		10-19 years	2	SIR=4.8	0.6-17.2
		20-29 years	2	SIR=1.0	0.1-36.1
		30+ years	0	SIR=0.0	0.0-12
		Years since first employment:			
		<20 years	0	SIR=0.0	0.0-36.5
		20-29 years	2	SIR=4.3	0.5-15.4
		30+ years	2	SIR=0.8	0.1-2.8
13	Demers, 1992a	Full cohort	6	SMR=0.83	0.30-1.80
14	Demers, 1992b	Full Cohort (incidence)	5	SIR=1.06	0.34-2.47
		Full cohort (mortality)	5	SMR=1.13	0.37-2.63
18	Glass, 2017	Full cohort (n=157,931)	77	SIR=0.65	0.52-0.82
		Volunteer FF who attended incidents (n=100,126)	57	SIR=0.76	0.57-0.98
20	Glass, 2016b	Full Cohort (n=29,014)	17	SIR=0.78	0.46-1.26
		Full time FF (n=17,002)	12	SIR=0.76	0.39-1.33
		Part-time FF (n=12,012)	5	SIR=0.85	0.28-1.98
21	Glass, 2009	Full cohort (men who ever who ever held an active firefighting job; n=6,964) (esophageal and stomach cancer)	7	SIR=1.12	0.54-2.36
		Men who served more than 12 months as an active Firefighter (n=6,297) (esophageal and stomach cancer)	7	SIR=1.15	0.55-2.41

ID	First Author, year	Category	Cancer estimates		
			obs	point estimate	95% CI
		Men ever employed as a full time fire fighter (n=3,531)	3	SIR=0.75	0.24-2.33
23	Harris, 2018	Model 1 (adjusted for age & region)	5	HR=1.39	0.72-2.68
		Model 2 (adjusted for age, region, & edu)	5	HR=1.31	0.68-2.51
24	Heyer, 1990	Full cohort	1	SMR=44	1-250
25	Hrubec, 1992	Total Adjusted (N=902)	2	RR=1.3	NR[1]
		Non-Smoker (N=158)	0	NA	
		Current cigarettes (N=420)	2	RR=2.1	NR[1]
27	Kullberg, 2018	Full cohort (1958-2012)	5	SIR=0.99	0.32-2.30
		Former follow-up only (1958-1986)	1	SIR=0.43	0.01-2.38
		Extended follow-up only (1987-2012)	4	SIR=1.46	0.4-3.75
30	Li, 2016	Full cohort (first primary cancer diagnosis)	10	SIR=1.29	0.62-2.38
31	Li, 2012	Early period (enrollment in cohort through 2006) (first primary cancer diagnosis)	≤5	SIR=1.43	0.39-3.67
		Later period (2007-2008) (first primary cancer diagnosis)	≤5	SIR=1.16	0.24-3.39
32	Ma, 2006	By Sex:			
		Male	11	SIR=0.62	0.31-1.11
		Female FF	0	NA	NA
33	Ma, 2005	By Sex:			
		Male	10	SMR=0.65	0.31-1.20
		Female FF	0	NA	NA
		Males certified from 1972-1976	7	SMR=0.55	0.22-1.14
35	Marjerrison, 2022	Incidence	14	SIR=1.55	0.85-2.60
		Mortality	15	SMR=1.94	1.08-3.20
		Mortality (corrected to be in line with morphologically confirmed diagnoses)	14	SMR=1.81	0.99-3.04
38	Petersen, 2018a	Full Cohort (includes cancers of oral cavity and esophagus)			
		Full time	24	SMR=1.27	0.85-1.89
		Part time/volunteer	8	SMR=0.63	0.32-1.27
		By duration of employment			
		<1 year	11	SMR=1.39	0.77-2.51
		≥1 year	13	SMR=1.18	0.68-2.03
		>10 years	11	SMR=1.13	0.63-2.05
		>20 years	10	SMR=1.21	0.65-2.25
39	Petersen, 2018b	Compared to the general population	21	SIR=0.99	0.65-1.53
		Compared to a general sample of employees	21	SIR=1.05	0.68-1.61
		Compared to the military sample	21	SIR=1.18	0.77-1.81
40	Pinkerton, 2020	Full cohort	133	SMR=1.31	1.10-1.55
		By Race:			
		White	>128	SIR=1.38	1.15-1.64
		Other	<5	SIR=0.50	0.14-1.28
		By age:			
		<65 years	54	SIR=1.26	0.94-1.64
		65+ years old	79	SIR=1.35	1.07-1.68

ID	First Author, year	Category	Cancer estimates		
			obs	point estimate	95% CI
41	Pukkala, 2014	Full cohort	31	SIR=0.98	0.66-1.39
42	Rosenstock, 1991		6	SMR=0.82	0.30-1.79
44	Solan, 2013	Diagnosed between 9/11/01 and 31/12/2008	11	SIR=1.67	0.83-2.98
45	Sritharan, 2022	Compared to all other workers	29	HR=1.06	0.73-1.53
		FF compared to Police	29	HR=0.93	0.57-1.50
46	Stec 2023		14	SMR=2.42	1.69-3.29
49	Vena, 1987		3	SMR=1.34	0.27-3.91
50	Zeig Owens, 2011	By WTC exposure status:			
		Exposed	5	SIR=0.58	0.15-2.32
		Non-exposed	5	SIR=0.44	0.06-3.13
51	Zhao, 2020		13	MRR=1.11	0.64-1.92

DX: diagnosis **NA:** not applicable **NR:** not reported

1. confidence intervals including 1 were not reported when fewer than 5 cases

Table 16. Extract estimates of esophageal cancer risk and mortality in firefighters from case control studies

ID	First Author, year	Category	Cancer estimates		
			Cases	point estimate	95% CI
5	Bates, 2007	All subjects	62	OR=1.37	1.06-1.76
		Subjects aged 21-60 by period of diagnosis:			
		1988-1995	8	OR=1.36	0.67-2.78
		1996-2003	15	OR=1.86	1.10-3.14
26	Kang, 2008	Compared to police	57	SMOR=0.93	0.61-1.41
		Stratified by age at dx:			
		18-54 year olds		SMOR=1.30	0.52-3.24
		55-74 year olds		SMOR=0.70	0.41-1.20
		75+ year olds		SMOR=1.58	0 .56-4.42
		Compared to all other occupations	57	SMOR=0.64	0.47-0.87
29	Lee, 2020	By Sex:			
		Male Firefighters	53	aOR=0.91	0.69-1.19
		Female Firefighters	<10	NR	NR
		By Stage of Cancer:			
		Early stage	<10	aOR=0.48	0.22-1.08
		Late stage	37	aOR=1.16	0.84-1.61
		By Age Group:			
		<50 years old	<10	aOR=0.49	0.20-1.18
		≥50 years old	<10	aOR=0.99	0.74-1.32
34	Ma, 1998	By race:			
		White male FF	37	MOR=0.9	0.7-1.3
		Black male FF	4	MOR=1.4	NR
48	Tsai, 2015	All Subjects	68	OR=1.59	1.20-2.09
		By race:			
		White firefighters	63	OR=1.59	1.19-2.12
		Non-white firefighters	5	OR=2.14	0.81-5.65
		Esophageal-adenocarcinoma	46	OR=1.85	1.34-2.55
		White firefighters	44	OR=1.84	1.32-2.56
		Non-white firefighters	2	OR=2.79	0.66-11.87
		Esophagus-squamous carcinoma	12	OR=0.96	0.53-1.73
		White firefighters	10	OR=0.94	0.49-1.78
		non-white firefighters	2	OR=1.44	0.34-6.14

DX: diagnosis **NR:** not reported

Table 17. Extract estimates of pancreatic cancer risk and mortality in firefighters from cohort studies

ID	First Author, year	Category	Cancer estimates		
			obs	point estimate	95% CI
1	Ahn, 2012	Full cohort	9	SIR=0.95	0.44-1.81
		≥10 years of FF experience	5	SIR=0.93	0.25-2.37
		Compared to non-firefighters	9	SRR=0.58	0.07-4.58
2	Amadeo, 2015	Full cohort	42	SMR=1.27	0.92-1.72
3	Aronson, 1994	Full Cohort	14	SMR=140	77-235
		By years since first employment/exposure:			
		<20 years	1	SMR=103	3-574
		20-29 Years	2	SMR=95	12-344
		≥30 Years	11	SMR=159	80-285
		By years of employment:			
		<15	2	SMR=175	21-634
		15-29	3	SMR=96	20-279
		≥30 Years	9	SMR=161	74-305
		By age:			
		<60 years	4	SMR=97	27-249
		≥60 years	10	SMR=170	81-313
4	Baris, 2001	Full cohort	23	SMR=0.96	0.64-1.44
		By duration of employment:			
		≤ 9 years	13	SMR=2.33	1.36-4.02
		10-19 years	5	SMR=0.60	0.25-1.45
		≥20 years	5	SMR=0.49	0.21-1.19
		By Company type:			
		Engine company only	8	SMR=0.84	0.42-1.68
		Ladder only companies	3	SMR=1.57	0.51-4.88
		Engine and Ladder companies	11	SMR=0.92	0.51-1.66
		By Cumulative runs:			
		Low runs (<3323 runs)	7	SMR=1.02	0.48-2.13
		Medium runs (3323-5098 runs)	5	SMR=1.17	0.49-2.80
		High runs (5099 runs or more)	7	SMR=1.61	0.77-5.74
		Hire date:			
		Hired before 1935	4	SMR=0.47	0.18-1.26
		Hired 1935-1944	12	SMR=1.48	0.84-2.61
		Hired after 1944	7	SMR=0.94	0.45-1.97
		Rate Ratios (n=6,477)			
		By Cumulative Runs:			
		Low (≤ 3,191runs)	7	RR=1.00	REF
		High (>3,191 runs)	12	RR=1.42	0.52-3.88
		Runs during first 5 years as a FF:			
		Low (≤729 runs)	9	RR=1.00	REF
		High (>729 runs)	10	RR=1.17	0.47-2.95
		Number of Lifetime runs:			
		Non-exposed	13	RR=1.00	REF
		Low Exposed (1-259 runs)	3	RR=1.38	0.39-4.86

ID	First Author, year	Category	Cancer estimates		
			obs	point estimate	95% CI
		Medium runs (260-1,423 runs)	1	RR=0.36	0.04-2.86
		High (>1,423 runs)	2	RR=0.80	0.14-0.54
6	Bates, 2001	Full Cohort (1977-1996)	3	SIR=1.28	0.3-3.7
		From 1990-1996	3	SIR=2.17	0.4-6.4
7	Beaumont, 1991	Full cohort	17	RR=1.25	0.73-2.00
		Years since first employment:			
		3-19	3	RR=2.85	p≥0.05
		20-29	5	RR=1.74	p≥0.05
		30-39	7	RR=1.56	p≥0.05
		40+	2	RR=0.38	p≥0.05
		Length of Employment:			
		3-9 years	1	RR=1.64	p≥0.05
		10-19 years	4	RR=2.78	p≥0.05
		20-29 years	7	RR=1.11	p≥0.05
		30+ years	5	RR=0.96	p≥0.05
8	Bigert, 2020	Full cohort	43	SIR=1.17	0.85-1.58
9	Colbeth, 2020	Full Cohort	20	SMR=0.71	0.43-1.09
11	Daniels, 2014	Mortality: Full cohort	168	SMR=1.13	0.97-1.32
		Incidence: Full cohort	90	SIR=0.96	0.77-1.18
12	Demers, 1994	Full cohort	6	SIR=1.1	0.4-2.3
13	Demers, 1992a	Full cohort	14	SMR=0.89	0.49-1.49
14	Demers, 1992b	Full Cohort (incidence)	9	SIR=1.06	0.49-2.01
		Full cohort (mortality)	10	SMR=1.11	0.53-2.04
16	Giles, 1993	Full cohort	1	SIR=1.03	0.01-5.75
18	Glass, 2017	Full cohort (n=157,931)	116	SIR=0.74	0.61-0.89
		Volunteer FF who attended incidents (n=100,126)	77	SIR=0.77	0.61-0.97
20	Glass, 2016b	Full Cohort (n=29,014)	29	SIR=1.03	0.69-1.48
		Full time FF (n=17,002)	22	SIR=1.07	0.67-1.62
		Part-time FF (n=12,012)	7	SIR=0.93	0.37-1.91
21	Glass, 2009	Full cohort (men who ever who ever held an active firefighting job; n=6,964)	3	SIR=0.94	0.30-2.91
		Men who served more than 12 months as an active Firefighter (n=6,297)	3	SIR=0.95	0.31-2.96
		Men ever employed as a full time fire fighter (n=3,531)	3	SIR=1.45	0.47-4.49
22	Guidotti, 1993	Full cohort	5	SMR=155.1	50.4-362.0
		By latency (yrs.)			
		<20	0	NA	NA
		20-29	1	SMR=112.9	NR
		30-39	1	SMR=96.7	NR
		40-49	0	NA	NA
		50+	3	SMR=761.4	NR (p<0.05)
23	Harris, 2018	Model 1 (adjusted for age & region)	15	HR=1.40	0.84-2.32
		Model 2 (adjusted for age, region, & edu)	15	HR=1.38	0.83-2.29

ID	First Author, year	Category	Cancer estimates		
			obs	point estimate	95% CI
25	Hrubec, 1992	Full cohort (1958-2012)	10	SIR=1.06	0.51-1.94
		Former follow-up only (1958-1986)	6	SIR=1.23	0.45-2.68
		Extended follow-up only (1987-2012)	4	SIR=0.87	0.24-2.23
27	Kullberg, 2018	Full cohort (1958-2012)	10	SIR=1.06	0.51-1.94
		Former follow-up only (1958-1986)	6	SIR=1.23	0.45-2.68
		Extended follow-up only (1987-2012)	4	SIR=0.87	0.24-2.23
30	Li, 2016(first primary cancer diagnosis)		10	SIR=0.70	0.34-1.29
31	Li, 2012(first primary cancer diagnosis)	Early period (enrollment in cohort through 2006)	6	SIR=1.37	0.50-2.97
		Later period (2007-2008)	≤5	SIR=0.70	0.14-2.03
32	Ma, 2006	By Sex:			
		Male	12	SIR=0.57	0.30-1.10
		Female FF	0	NA	NA
33	Ma, 2005	By Sex:			
		Male	12	SMR=0.57	0.29-0.99
		Female FF	0	NA	NA
		Males certified from 1972-1976	12	SMR=0.7	0.36-1.22
35	Marjerrison, 2022	Incidence	25	SIR=1.17	0.76-1.73
		Mortality	21	SMR=1.06	0.66-1.62
39	Petersen, 2018b	Compared to the general population	34	SIR=1.20	0.86-1.68
		Compared to a general sample of employees	34	SIR=1.27	0.91-1.78
		Compared to the military sample	34	SIR=1.28	0.92-1.80
		By employment type			
		Full time (n=4,243)	27	SIR=1.54	1.05-2.25
		Part time/volunteer (4,818)	7	SIR=0.65	0.31-1.37
		By era of first employment			
		<1970 (n=1,362)	22	SIR=1.63	1.08-2.48
		1970-1994 (n=4,521)	10	SIR=0.78	0.42=1.45
		≥1995 (n=3,178)	2	SIR=1.02	0.26-4.08
		By age at first employment			
		<25 years (n=4,016)	23	SIR=1.68	1.12-2.53
		25-34 years (n=3,426)	3	SIR=0.36	0.12-1.13
		≥35 years (n=1,619)	8	SIR=1.27	0.63-2.53
		By duration of employment			
		<1 year (n=1,423)	14	SIR=1.79	1.05-3.01
		≥1 year (n=7,638)	20	SIR=0.98	0.63-1.52
		≥10 years (n=5,553)	13	SIR=0.74	0.43-1.27
		≥20 year (n=3,022)	10	SIR=0.74	0.40-1.37
40	Pinkerton, 2020		194	SIR=1.06	0.91-1.22
41	Pukkala, 2014	Full cohort	87	SIR=1.17	0.94-1.45
42	Rosenstock, 1991		15	SMR=0.95	0.53-1.56
45	Sritharan, 2022	Compared to all other workers	53	HR=1.34	1.02-1.76
		FF compared to Police	53	HR=1.09	0.75-1.59
46	Stec 2023		9	SMR=1.58	0.86-2.51

ID	First Author, year	Category	Cancer estimates		
			obs	point estimate	95% CI
47	Tornling, 1994	Mortality	5	SMR=84	27-196
		Incidence	6	SIR=119	44-260
49	Vena, 1987		2	SMR=0.38	.04-1.36
50	Zeig Owens, 2011	By WTC exposure status:			
		Exposed	5	SIR=0.78	0.29-2.09
		Non-exposed	5	SIR=0.31	0.04-2.20
51	Zhao, 2020		8	MRR=0.43	0.21-0.88

NA: not applicable NR: not reported

Table 18. Extract estimates of pancreatic cancer risk and mortality in firefighters from case control studies

ID	First Author, year	Category	Cancer estimates		
			Cases	point estimate	95% CI
5	Bates, 2007	All subjects	63	OR=0.85	0.66-1.09
		Subjects aged 21-60 by period of diagnosis:			
		1988-1995	11	OR=1.16	0.63-2.13
		1996-2003	9	OR=0.74	0.38-1.45
26	Kang, 2008	Compared to police	38	SMOR=0.86	0.53-1.40
		Stratified by age at dx:			
		18-54 year olds		SMOR=0.70	0.22-2.16
		55-74 year olds		SMOR=0.88	0.47-1.65
		75+ year olds		SMOR=1.12	0.37-3.34
		Compared to all other occupations		SMOR=0.84	0.58-1.22
29	Lee, 2020	By Sex:			
		Male Firefighters	71	aOR=0.85	0.68-1.08
		Female Firefighters	<10	aOR=0.47	0.07-3.29
		By Stage of Cancer:			
		Early stage	<10	aOR=0.84	0.38-1.87
		Late stage	53	aOR=0.91	0.69-1.20
		By Age Group:			
		<50 years old	<10	aOR=0.65	0.35-1.22
		≥50 years old	<10	aOR=0.89	0.69-1.15
34	Ma, 1998	By race:			
		White male FF	88	MOR=1.2	1.0-1.5
		Black male FF	5	MOR=2.0	0.9-4.6
36	Muegge, 2018		46	OR=1.45	1.01-2.06
43	Sama, 1990	Compared to state population	6	OR=98	42-226
		Compared to police population	6	OR=319	72-1415
48	Tsai, 2015	All subjects	79	OR=1.10	0.83-1.46
		All subjects by race:			
		White firefighters	74	OR=1.14	0.85-1.54
		other races	5	OR=0.90	0.33-2.45

DX: diagnosis

APPENDIX A

Legislative Request

Legislative Building **Washington State Legislature** Olympia, WA 98504-0600

February 1, 2023

Mr. Joel Sacks
Director
Department of Labor & Industries
7273 Linderson Way SW
Tumwater, WA 98501

Dear Director Sacks,

In 2019, the Washington State Legislature passed HB 1913 which expanded the occupational disease statute and required you, as the Director of the Department of Labor & Industries, to create an advisory committee on occupational disease presumptions.

As the Chairs of the Senate Labor and Commerce Committee and the House Labor and Workplace Standards Committee, we would like to formally request that the advisory committee on occupational disease presumptions to review the scientific evidence and make recommendations to the legislature for the following diseases: adenocarcinoma, esophageal cancer, buccal cancer, pancreatic cancer, pharynx cancer, heart disease not related to exposure to toxic fumes or exertion and Parkinson's disease. Regarding pancreatic cancer, we would like the committee to also look at a link between PFAS (per- and polyfluoroalkyl) exposure and the occurrence of pancreatic cancer in firefighters.

Thank you for your consideration of this request.

Sincerely,

Karen Keiser
State Senator
33rd Legislative District

Liz Berry
State Representative
36th Legislative District

APPENDIX B

Epidemiologic Studies Reviewed

No.	Reference	Notes
1	Ahn YS, Jeong KS, Kim KS. Cancer morbidity of professional emergency responders in Korea. Am J Ind Med. 2012 Sep;55(9):768-78. doi: 10.1002/ajim.22068. Epub 2012 May 24. PMID: 22628010.	initial search
2	Ahn YS, Jeong KS. Mortality due to malignant and non-malignant diseases in Korean professional emergency responders. PLoS One. 2015 Mar 10;10(3):e0120305. doi: 10.1371/journal.pone.0120305. Erratum in: PLoS One. 2015;10(9):e0139255. PMID: 25756281; PMCID: PMC4355623.	initial search
3	Amadeo B, Marchand JL, Moisan F, Donnadieu S, Gaëlle C, Simone MP, Lembeye C, Imbernon E, Brochard P. French firefighter mortality: analysis over a 30-year period. Am J Ind Med. 2015 Apr;58(4):437-43. doi: 10.1002/ajim.22434. Epub 2015 Feb 23. PMID: 25708859.	initial search
4	Aronson (1994) Mortality among fire fighters in metropolitan Toronto	secondary search
5	Balanof, T. (1976) Fire Fighter Mortality report. International Association of Fire Fighters, Washington DC.	secondary search
6	Baris D, Garrity TJ, Telles JL, Heineman EF, Olshan A, Zahm SH. Cohort mortality study of Philadelphia firefighters. Am J Ind Med. 2001 May;39(5):463-76. doi: 10.1002/ajim.1040. PMID: 11333408.	initial search
7	Bates M. Retrospective cohort study of mortality and cancer incidence in New Zealand fire fighters: Institute of Environmental Science and Research Limited; 2000.	secondary search
8	Bates MN, Fawcett J, Garrett N, Arnold R, Pearce N, Woodward A (2001) Is testicular cancer an occupational disease of fire fighters? Am J Ind Med 40(3):263–270	secondary search
9	Bates MN. Registry-based case-control study of cancer in California firefighters. Am J Ind Med. 2007 May;50(5):339-44. doi: 10.1002/ajim.20446. PMID: 17427202.	initial search
10	Beaumont JJ, Chu GS, Jones JR, Schenker MB, Singleton JA, Piantanida LG, Reiterman M. An epidemiologic study of cancer and other causes of mortality in San Francisco firefighters. Am J Ind Med. 1991;19(3):357-72. doi: 10.1002/ajim.4700190309. PMID: 2008922.	initial search
11	Bigert C, Martinsen JI, Gustavsson P, Sparén P. Cancer incidence among Swedish firefighters: an extended follow-up of the NOCCA study. Int Arch Occup Environ Health. 2020 Feb;93(2):197-204. doi: 10.1007/s00420-019-01472-x. Epub 2019 Aug 28. PMID: 31463517; PMCID: PMC7007886.	initial search
12	Blair A, Walrath J, Rogot E. Mortality Patterns Among U.S. Veterans by Occupation. I. Cancer. JNCI: Journal of the National Cancer Institute. 1985;75(6):1039-47.	secondary search
13	Brantom PG, Brown I, Baril M, McNamee R. Epidemiological literature review on the risk of cancer among firefighters; Corrected Version. 2021.	secondary search
14	Brant-RaufPW, Fallon Jr. LF, Tarantini T, Idema, C, Andrews, L. 1988. Health hazards of Freighters: Exposure assessment. Br J Ind Med 45:606±612.	secondary search

15	Burnett C, Maurer JD, Dosemeci M. Mortality by occupation, industry, and cause of death; 24 reporting states, 1984-1988. 1997.	secondary search
16	Burnett CA, Halperin WE, Lalich NR, Sestito JP. 1994. Mortality among Fire Fighters: a 27 state survey. Am J Ind Med 26:831±883.	secondary search
17	Casjens S, Brüning T, Taeger D. Cancer risks of firefighters: a systematic review and meta-analysis of secular trends and region-specific differences. Int Arch Occup Environ Health. 2020 Oct;93(7):839-852. doi: 10.1007/s00420-020-01539-0. Epub 2020 Apr 18. PMID: 32306177; PMCID: PMC7452930.	initial search
18	Centers for Disease Control and Prevention, HHS. World Trade Center Health Program; addition of certain types of cancer to the list of WTC-related health conditions. Final rule. Fed Regist. 2012 Sep 12;77(177):56138-68. PMID: 22970452.	initial search
19	Chaudhry R, Marrett L, Kreiger N, Sullivan T. The Occupation of Firefighting and Cancer Risk: Assessment of the Literature. Report to the Workers Compensation Board of British Columbia. British Columbia, Canada: Workers Compensation Board; 2004.	secondary search
20	Colbeth HL, Zeig-Owens R, Hall CB, Webber MP, Schwartz TM, Prezant DJ. Mortality among Fire Department of the City of New York Rescue and Recovery Workers Exposed to the World Trade Center Disaster, 2001-2017. Int J Environ Res Public Health. 2020;17(17).	secondary search
21	Covering Those Who Risk All. State Legis. 2018 Sep-Oct;44(8):20. PMID: 30272891.	initial search
22	Crawford JO, Winski T, McElvenny D, Graveling R, Dixon K (2017) Firefighters and cancer: the epidemiological evidence. Research Report TM/17/01 (Research Avenue North, Riccarton, Edinburgh, EH14 4AP, Institute of Occupational Medicine 2017)	secondary search
23	Cronin KA, Scott S, Firth AU, Sung H, Henley SJ, Sherman RL, Siegel RL, Anderson RN, Kohler BA, Benard VB, Negoita S, Wiggins C, Cance WG, Jemal A. Annual report to the nation on the status of cancer, part 1: National cancer statistics. Cancer. 2022 Dec 15;128(24):4251-4284. doi: 10.1002/cncr.34479. Epub 2022 Oct 27. PMID: 36301149; PMCID: PMC10092838.	initial search
24	Crosignani P, Amendola P, Scaburri A, Chiappino G, Marinaccio A. Confounders and confusion: dealing with cancer cases of occupational origin. Am J Ind Med. 2010;53(10):1002-1005.	secondary search
25	Daniels RD, Bertke S, Dahm MM, Yiin JH, Kubale TL, Hales TR, Baris D, Zahm SH, Beaumont JJ, Waters KM, Pinkerton LE. Exposure-response relationships for select cancer and non-cancer health outcomes in a cohort of U.S. firefighters from San Francisco, Chicago and Philadelphia (1950-2009). Occup Environ Med. 2015 Oct;72(10):699-706. doi: 10.1136/oemed-2014-102671. Epub 2015 Feb 11. PMID: 25673342; PMCID: PMC4558385.	initial search
26	Daniels RD, Kubale TL, Yiin JH, Dahm MM, Hales TR, Baris D, Zahm SH, Beaumont JJ, Waters KM, Pinkerton LE. Mortality and cancer incidence in a pooled cohort of US firefighters from San Francisco, Chicago and Philadelphia (1950-2009). Occup Environ Med. 2014 Jun;71(6):388-97. doi: 10.1136/oemed-2013-101662. Epub 2013 Oct 14. PMID: 24142974; PMCID: PMC4499779.	initial search
27	DeBono NL, Daniels RD, Beane Freeman LE, Graber JM, Hansen J, Teras LR, Driscoll T, Kjaerheim K, Demers PA, Glass DC, Kriebel D, Kirkham TL, Wedekind R, Filho AM, Stayner L, Schubauer-Berigan MK. Firefighting and Cancer: A Meta- analysis	initial search

	of Cohort Studies in the Context of Cancer Hazard Identification. Saf Health Work. 2023 Jun;14(2):141-152. doi: 10.1016/j.shaw.2023.02.003. Epub 2023 Mar 7. PMID: 37389311; PMCID: PMC10300491.	
28	Demers PA, Checkoway H, Vaughan TL, Weiss NS, Heyer NJ, Rosenstock L. Cancer incidence among firefighters in Seattle and Tacoma, Washington (United States). Cancer Causes Control. 1994 Mar;5(2):129-35. doi: 10.1007/BF01830258. PMID: 8167259.	initial search
29	Demers PA, Heyer NJ, Rosenstock L. Mortality among firefighters from three northwestern United States cities. Br J Ind Med. 1992 Sep;49(9):664-70. doi: 10.1136/oem.49.9.664. PMID: 1390274; PMCID: PMC1039313.	initial search
30	Demers PA, Martinsen JI, Kjaerheim K, et al. Cancer incidence among Nordic firefighters [abstract]. Am J Epidemiol 2011;173:S191.	secondary search
31	Demers PA, Vanghan TL, Checkoway H, Weiss NS, Heyer NJ, Rosenstock L. Cancer identification using a tumor registry versus death certificates in occupational cohort studies in the United States. American journal of epidemiology. 1992;136(10):1232-40.	secondary search
32	Deschamps S, Momas I, Festy B. Mortality amongst Paris fire-fighters. Eur J Epidemiol. 1995 Dec;11(6):643-6. doi: 10.1007/BF01720297. PMID: 8861847.	initial search
33	Donnan, S.P.B. Study of Mortality and Cancer Incidence in Firefighters in Britain: A Third Report, 1965–1993; Home Office Scientific Research and Development Branch: London, UK, 1996.	secondary search
34	Drever F. Occupational Health: Decennial Supplement: the Registrar General's Decennial Supplement for England and Wales: HM Stationery Office; 1995.	secondary search
35	Dubrow R, Wegman DH. Setting priorities for occupational cancer research and control: synthesis of the results of occupational disease surveillance studies. Journal of the National Cancer Institute. 1983;71(6):1123-42.	secondary search
36	Eliopulos E, Armstrong BK, Spickett JT, Heyworth F. Mortality of fire fighters in Western Australia. Br J Ind Med. 1984;41(2):183-7.	secondary search
37	Fahy R F., LeBlanc PR, Molis JL. Firefighter fatalities in the United States 2008. Quincy: National Fire Protection Association; 2009.	secondary search
38	Feuer E, Rosenman K. Mortality in police and firefighters in New Jersey. Am J Ind Med. 1986;9(6):517-27. doi: 10.1002/ajim.4700090603. PMID: 3488681.	initial search
39	Firth HM, Cooke KR, Herbison GP. Male cancer incidence by occupation: New Zealand, 1972-1984. Int J Epidemiol. 1996 Feb;25(1):14-21. doi: 10.1093/ije/25.1.14. PMID: 8666482.	initial search
40	Gallagher, R.P.; Cancer Control Agency of British Columbia;Workers' Compensation Board of British Columbia. Occupational mortality in British Columbia, 1950–1984; Cancer Control Agency of British Columbia: Vancouver, BC, Canada, 1989.	secondary search
41	Giles G, Staples M, Berry J. Cancer incidence in Melbourne Metropolitan Fire Brigade members, 1980-1989. Health reports. 1993;5(1):33-8.	secondary search
42	Glass DC, Del Monaco A, Pircher S, Vander Hoorn S, Sim MR. Mortality and cancer incidence among female Australian firefighters. Occup Environ Med. 2019 Apr;76(4):215-221. doi: 10.1136/oemed-2018-105336. Epub 2019 Jan 23. PMID: 30674605.	initial search

43	Glass DC, Del Monaco A, Pircher S, Vander Hoorn S, Sim MR. Mortality and cancer incidence among male volunteer Australian firefighters. Occup Environ Med. 2017 Sep;74(9):628-638. doi: 10.1136/oemed-2016-104088. Epub 2017 Apr 8. PMID: 28391245.	initial search
44	Glass DC, Del Monaco A, Pircher S, Vander Hoorn S, Sim MR. Mortality and cancer incidence at a fire training college. Occup Med (Lond). 2016 Oct;66(7):536-42. doi: 10.1093/occmed/kqw079. Epub 2016 Jul 2. PMID: 27371948.	initial search
45	Glass DC, Pircher S, Del Monaco A, Hoorn SV, Sim MR. Mortality and cancer incidence in a cohort of male paid Australian firefighters. Occup Environ Med. 2016 Nov;73(11):761-771. doi: 10.1136/oemed-2015-103467. Epub 2016 Jul 25. PMID: 27456156.	initial search
46	Glass, D. Final Report on Queensland Fire Fighters’ Cancer Incidence Study; Monash Centre for Occupational and Environmental Health: Melbourne, Australia, 2009.	secondary search
47	Golden A, Markowitz S, Landrigan P. Occupational cancer in New York City firefighters. A report by the Department of Community Medicine, Division of Environmental an Occupational Medicine, Mount Sinai School of Medicine. City University of New York. 1995.	secondary search
48	Golden AL, Markowitz SB, Landrigan PJ. The risk of cancer in firefighters. Occup Med. 1995 Oct-Dec;10(4):803-20. PMID: 8903750.	initial search
49	Gourd E. Firefighters at increased risk of cancer diagnosis. Lancet Oncol. 2023 Feb;24(2):e73. doi: 10.1016/S1470-2045(23)00021-9. Epub 2023 Jan 19. PMID: 36682369.	initial search
50	Grimes G, Hirsch D, Borgeson D. Risk of death among Honolulu fire fighters. Hawaii Med J. 1991;50(3):82-5.	secondary search
51	Guidotti TL, Clough VM (1992) Occupational health concerns of firefighting. Annu Rev Public Health 13:151–171	secondary search
52	Guidotti TL. Evaluating causality for occupational cancers: the example of firefighters. Occup Med (Lond). 2007 Oct;57(7):466-71. doi: 10.1093/occmed/kqm031. Epub 2007 Jun 4. PMID: 17548868.	initial search
53	Guidotti TL. Mortality of urban firefighters in Alberta, 1927-1987. Am J Ind Med. 1993 Jun;23(6):921-40. doi: 10.1002/ajim.4700230608. PMID: 8328477.	initial search
54	Guidotti TL. Occupational mortality among firefighters: assessing the association. J Occup Environ Med. 1995 Dec;37(12):1348-56. doi: 10.1097/00043764-199512000-00004. PMID: 8749740.	initial search
55	Gustavsson P, Evanoff B, Hogstedt C. Increased risk of esophageal cancer among workers exposed to combustion products. Arch Environ Health. 1993;48(4):243-5.	secondary search
56	Haas NS, Gochfeld M, Robson MG, Wartenberg D. Latent health effects in firefighters. Int J Occup Environ Health. 2003 Apr-Jun;9(2):95-103. doi: 10.1179/oeh.2003.9.2.95. PMID: 12848236.	initial search
57	Han M, Park S, Park JH, Hwang SS, Kim I. Do police officers and firefighters have a higher risk of disease than other public officers? A 13-year nationwide cohort study in South Korea. BMJ Open. 2018;8(1):e019987.	secondary search
58	Hansen ES. A cohort study on the mortality of firefighters. Br J Ind Med. 1990 Dec;47(12):805-9. doi: 10.1136/oem.47.12.805. PMID: 2271386; PMCID: PMC1035284.	initial search
59	Hardy T. Firefighter Occupational Cancer Risk: Starting the Conversation. J Cancer Educ. 2022 Aug;37(4):1019-1025. doi: 10.1007/s13187-020-01914-y. Epub 2020 Nov 16. PMID: 33196950.	initial search

60	Harris MA, Kirkham TL, MacLeod JS, Tjepkema M, Peters PA, Demers PA. Surveillance of cancer risks for firefighters, police, and armed forces among men in a Canadian census cohort. Am J Ind Med. 2018 Oct;61(10):815-823. doi: 10.1002/ajim.22891. Epub 2018 Aug 2. PMID: 30073696.	initial search
61	Heyer N, Weiss NS, Demers P, Rosenstock L. Cohort mortality study of seattle fire fighters: 1945-1983. American journal of industrial medicine. 1990;17(4):493-504.	secondary search
62	Howe GR, Burch JD. 1990. Fire fighters and risk of cancer: An assessment and overview of the epidemiologic evidence. Am J Epidemiol 132:1039–1050.	secondary search
63	Howe GR, Lindsay JP. A Follow-up Study of a Ten-Percent Sample of the Canadian Labor Force. I. Cancer Mortality in Males, 1965–732. JNCI: Journal of the National Cancer Institute. 1983;70(1):37-44.	secondary search
64	Hrubec, Z.; Blair, A.E.; Rogot, E.; Vaught, J. Mortality Risks by Occupation among U.S. Veterans of Known Smoking Status; NIH Publication No. 92–3407; National Institutes of Health: Bethesda, MD, USA, 1992.	secondary search
65	IARC Working Group on the Evaluation of Carcinogenic Risks to Humans. Painting, firefighting, and shiftwork. IARC Monogr Eval Carcinog Risks Hum. 2010;98:9-764. PMID: 21381544; PMCID: PMC4781497.	initial search
66	Ide CW. Cancer incidence and mortality in serving whole-time Scottish firefighters 1984-2005. Occup Med (Lond). 2014 Sep;64(6):421-7. doi: 10.1093/occmed/kqu080. Epub 2014 Jul 7. PMID: 25006097.	initial search
67	Ide CW. Failing firefighters: a survey of causes of death and ill-health retirement in serving firefighters in Strathclyde, Scotland from 1985-94. Occup Med (Lond). 1998 Sep;48(6):381-8. doi: 10.1093/occmed/48.6.381. PMID: 10024734.	initial search
68	Industrial Disease Standards Panel. 1994. IDSP Report No:13. Report to Workers' Compensation Board on Cardiovascular Disease and Cancer Among Fire®ghters. Toronto, Ont.	secondary search
69	Jahnke SA, PostonWSC, Haddock CK, Jitnarin N. Injury among a population based sample of career firefighters in the central USA. Inj Prev. (2013) 19:393–8. doi: 10.1136/injuryprev-2012-040662	secondary search
70	Jalilian H, Ziaei M, Weiderpass E, Rueegg CS, Khosravi Y, Kjaerheim K. Cancer incidence and mortality among firefighters. Int J Cancer. 2019 Nov 15;145(10):2639-2646. doi: 10.1002/ijc.32199. Epub 2019 Mar 1. PMID: 30737784.	initial search
71	Kang D, Davis LK, Hunt P, Kriebel D. Cancer incidence among male Massachusetts firefighters, 1987-2003. Am J Ind Med. 2008 May;51(5):329-35. doi: 10.1002/ajim.20549. PMID: 18306327.	initial search
72	Kang H-J, Byun S-H, Mun C-H, Choi Y-J, Choi J-W, A. study on the relationship between firefighters disease and health status. Fire Sci Eng. (2020) 34:86– 92. doi: 10.7731/KIFSE.66a0ec57	secondary search
73	Kullberg C, Andersson T, Gustavsson P, Selander J, Tornling G, Gustavsson A, Bigert C. Cancer incidence in Stockholm firefighters 1958-2012: an updated cohort study. Int Arch Occup Environ Health. 2018 Apr;91(3):285-291. doi: 10.1007/s00420-017-1276-1. Epub 2017 Nov 21. PMID: 29164319; PMCID: PMC5845066.	initial search
74	Kunz KR, Turcotte K, Pawer S, Zheng A, Purewal A, Wellar A, Karmali S, Garis L, Thomas LS, Pike I. Cancer in female firefighters: The clinicobiological, psychological, and social perspectives. Front Public Health. 2023 Apr 12;11:1126066. doi: 10.3389/fpubh.2023.1126066. PMID: 37124817; PMCID: PMC10130581.	initial search
75	Landrigan PJ, Golden AL, Markowitz SB. 1995. Occupational cancer in New York City Firefighters. A report by the Department of	secondary search

76	Langevin SM, Eliot M, Butler RA, McClean M, Kelsey KT. Firefighter occupation is associated with increased risk for laryngeal and hypopharyngeal squamous cell carcinoma among men from the Greater Boston area. Occup Environ Med. 2020 Jun;77(6):381-385. doi: 10.1136/oemed-2019-106271. Epub 2020 Feb 27. PMID: 32107319; PMCID: PMC8704482.	initial search
77	Laroche E, L'Espérance S. Cancer Incidence and Mortality among Firefighters: An Overview of Epidemiologic Systematic Reviews. Int J Environ Res Public Health. 2021 Mar 3;18(5):2519. doi: 10.3390/ijerph18052519. PMID: 33802629; PMCID: PMC7967542.	initial search
78	Lee DJ, Ahn S, McClure LA, Caban-Martinez AJ, Kobetz EN, Ukani H, et al. Cancer risk and mortality among firefighters: a meta-analytic review. Front Oncol. 2023;13:1130754.	secondary search
79	Lee DJ, Koru-Sengul T, Hernandez MN, Caban-Martinez AJ, McClure LA, Mackinnon JA, Kobetz EN. Cancer risk among career male and female Florida firefighters: Evidence from the Florida Firefighter Cancer Registry (1981-2014). Am J Ind Med. 2020 Apr;63(4):285-299. doi: 10.1002/ajim.23086. Epub 2020 Jan 12. PMID: 31930542.	initial search
80	Lee WR, Lee H, Nam EW, Noh JW, Yoon JH, Yoo KB. Comparison of the risks of occupational diseases, avoidable hospitalization, and all-cause deaths between firefighters and non-firefighters: A cohort study using national health insurance claims data. Front Public Health. 2023 Jan 16;10:1070023. doi: 10.3389/fpubh.2022.1070023. PMID: 36726614; PMCID: PMC9884821.	initial search
81	LeMasters GK, Genaidy AM, Succop P, Deddens J, Sobeih T, Barriera-Viruet H, Dunning K, Lockey J. Cancer risk among firefighters: a review and meta-analysis of 32 studies. J Occup Environ Med. 2006 Nov;48(11):1189-202. doi: 10.1097/01.jom.0000246229.68697.90. PMID: 17099456.	initial search
82	Lewis S, Bierman H, Faith M. Cancer Mortality among Los Angeles City Fire Fighters; Report to the city of Los Angeles Fire Department. Institute for Cancer and Blood Research: Beverly Hills, CA, USA. 1982.	secondary search
83	Li J, Brackbill RM, Liao TS, et al. Ten- Year cancer incidence in rescue/recovery workers and civilians exposed to the September 11, 2001 terrorist attacks on the World Trade Center. Am J Ind Med 2016;59:709–21.	secondary search
84	Li J, Cone JE, Kahn AR, et al. Association between World Trade Center exposure and excess cancer risk. JAMA 2012;308:2479–88.	secondary search
85	Ma F, Fleming LE, Lee DJ, Trapido E, Gerace TA, Lai H, Lai S. Mortality in Florida professional firefighters, 1972 to 1999. Am J Ind Med. 2005 Jun;47(6):509-17. doi: 10.1002/ajim.20160. PMID: 15898094.	initial search
86	Ma F, Fleming LE, Lee DJ, Trapido E, Gerace TA. Cancer incidence in Florida professional firefighters, 1981 to 1999. J Occup Environ Med. 2006 Sep;48(9):883-8. doi: 10.1097/01.jom.0000235862.12518.04. PMID: 16966954.	initial search
87	Ma F, Lee DJ, Fleming LE, Dosemeci M. Race-specific cancer mortality in US firefighters: 1984-1993. J Occup Environ Med. 1998 Dec;40(12):1134-8. doi: 10.1097/00043764-199812000-00014. PMID: 9871891.	initial search
88	Marjerrison N, Jakobsen J, Grimsrud TK, Hansen J, Martinsen JI, Nordby KC, Veierød MB, Kjærheim K. Cancer incidence in sites potentially related to occupational exposures: 58 years of follow-up of firefighters in the Norwegian Fire Departments Cohort. Scand J Work Environ Health. 2022 Apr 1;48(3):210-219. doi: 10.5271/sjweh.4009. Epub 2022 Jan 11. PMID: 35015085; PMCID: PMC9523464.	initial search

89	Marjerrison N., Jakobsen J., Demers P.A., Grimsrud T.K., Hansen J., Martinsen J.I., Nordby K-C., Veierød M.B., Kjaerheim K. Comparison of cancer incidence and mortality in the Norwegian Fire Departments Cohort, 1960-2018. Occup Environ Med 2022. doi:10.1136/oemed-2022-108331. PubMed PMID: 35589382.	secondary search
90	Mastromatteo E. Mortality in city firemen. 2. A study of mortality in firemen of a city fire department. Arch Indust Health. 1959;20:227-33.	secondary search
91	McClure LA, Koru-Sengul T, Hernandez MN, Caban-Martinez AJ, Kobetz EN, Lee DJ. Comparing cancer risk estimates using occupational record linkage approaches in male Florida firefighters. Am J Ind Med. 2021 Feb;64(2):78-83. doi: 10.1002/ajim.23205. Epub 2020 Dec 1. PMID: 33283309.	initial search
92	Melius J (2001). Occupational health for firefighters. Occup Med, 16, 101-8.	secondary search
93	Milham S. Occupational mortality in Washington State, 1950-1989: US Department of Health and Human Services, Public Health Service, Centers …; 1997.	secondary search
94	Moir W, Zeig- Owens R, Daniels RD, et al. Post-9/11 cancer incidence in World Trade Center- exposed New York City firefighters as compared to a pooled cohort of firefighters from San Francisco, Chicago and Philadelphia (9/11/2001-2009). Am J Ind Med 2016;59:722–30.	secondary search
95	Moir W, Zeig-Owens R, Daniels RD, Hall CB, Webber MP, Jaber N, Yiin JH, Schwartz T, Liu X, Vossbrinck M, Kelly K, Prezant DJ. Post-9/11 cancer incidence in World Trade Center-exposed New York City firefighters as compared to a pooled cohort of firefighters from San Francisco, Chicago and Philadelphia (9/11/2001-2009). Am J Ind Med. 2016 Sep;59(9):722-30. doi: 10.1002/ajim.22635. PMID: 27582474; PMCID: PMC5010035.	initial search
96	Muegge CM, Zollinger TW, Song Y, Wessel J, Monahan PO, Moffatt SM. Excess mortality among Indiana firefighters, 1985-2013. Am J Ind Med. 2018 Dec;61(12):961-967. doi: 10.1002/ajim.22918. Epub 2018 Nov 13. PMID: 30421827.	initial search
97	Musk AW, Monson RR, Peters JM, Peters RK. Mortality among Boston firefighters, 1915--1975. Br J Ind Med. 1978 May;35(2):104-8. doi: 10.1136/oem.35.2.104. PMID: 656333; PMCID: PMC1008362.	initial search
98	Paget-Bailly S, Cyr D, Luce D. Occupational exposures to asbestos, polycyclic aromatic hydrocarbons and solvents, and cancers of the oral cavity and pharynx: a quantitative literature review. Int Arch Occup Environ Health 2012;85:341–51.	secondary search
99	Paget-Bailly S, Guida F, Carton M, Menvielle G, Radoï L, Cyr D, Schmaus A, Cénée S, Papadopoulos A, Févotte J, Pilorget C, Velten M, Guizard AV, Stücker I, Luce D. Occupation and head and neck cancer risk in men: results from the ICARE study, a French population-based case-control study. J Occup Environ Med. 2013 Sep;55(9):1065-73. doi: 10.1097/JOM.0b013e318298fae4. PMID: 23969505.	initial search
100	Pawer S, Turcotte K, Desapriya E, Zheng A, Purewal A, Wellar A, Kunz K, Garis L, Thomas LS, Pike I. Female Firefighter Work-Related Injuries in the United States and Canada: An Overview of Survey Responses. Front Public Health. 2022 May 9;10:861762. doi: 10.3389/fpubh.2022.861762. PMID: 35615035; PMCID: PMC9124893.	initial search
101	Petersen KKU, Pedersen JE, Bonde JP, Ebbehoej NE, Hansen J. Long-term follow-up for cancer incidence in a cohort of Danish firefighters. Occup Environ Med 2018 Apr;75(4):263–9. https://doi.org/10.1136/ oemed-2017-104660.	initial search
102	Petersen KU, Pedersen JE, Bonde JP, Ebbehøj NE, Hansen J. Mortality in a cohort of Danish firefighters; 1970-2014. Int Arch Occup Environ Health. 2018 Aug;91(6):759-766. doi: 10.1007/s00420-018-1323-6. Epub 2018 May 28. PMID: 29808435.	initial search

103	Petersen, G.R.; Milham, S. Occupational Mortality in the State of California, 1959–1961; National Institute for Occupational Safety and Health: Cincinnati, OH, USA, 1980.	secondary search
104	Pinkerton L, Bertke SJ, Yiin J, Dahm M, Kubale T, Hales T, Purdue M, Beaumont JJ, Daniels R. Mortality in a cohort of US firefighters from San Francisco, Chicago and Philadelphia: an update. Occup Environ Med. 2020 Feb;77(2):84-93. doi: 10.1136/oemed-2019-105962. Epub 2020 Jan 2. PMID: 31896615; PMCID: PMC10165610.	initial search
105	Pukkala E, Martinsen JI, Lynge E, Gunnarsdottir HK, Sparén P, Tryggvadottir L, et al. Occupation and cancer – follow-up of 15 million people in five Nordic countries. Acta Oncologica. 2009;48(5):646-790.	secondary search
106	Pukkala E, Martinsen JI, Weiderpass E, Kjaerheim K, Lynge E, Tryggvadottir L, Sparén P, Demers PA. Cancer incidence among firefighters: 45 years of follow- up in five Nordic countries. Occup Environ Med. 2014 Jun;71(6):398-404. doi: 10.1136/oemed-2013-101803. Epub 2014 Feb 6. PMID: 24510539.	initial search
107	Rosenstock, L.; Demers, P.; Heyer, N. Northwest fire fighter mortality 1945–1989; 1991	secondary search
108	Sama SR, Martin TR, Davis LK, Kriebel D. Cancer incidence among Massachusetts firefighters, 1982-1986. Am J Ind Med. 1990;18(1):47-54. doi: 10.1002/ajim.4700180106. PMID: 2378369.	initial search
109	Samet JaB, N. An Occupational Health Investigation of Cancer Among Fire Fighters in Anne Arundel County, Maryland. 2005.	secondary search
110	Saywell RM, Zollinger TW, Moffatt SM, Galloway C, Muegge CM, Kochhar K. A cohort mortality study of Indianapolis firefighters 1970– 2006: what are our firefighters dying from? Fire Chief. February 2011.	secondary search
111	Schaefer Solle N, Legros A, Jackson R, Rangan A, Beaver CC, Kling H, Khan F, Koru-Sengul T, Penedo FJ, Caban-Martinez AJ, Kobetz EN. Understanding Cancer Survivorship among Firefighters: A Mixed-Method Study. Int J Environ Res Public Health. 2022 Dec 24;20(1):257. doi: 10.3390/ijerph20010257. PMID: 36612579; PMCID: PMC9819887.	initial search
112	Sidossis A, Lan FY, Hershey MS, Hadkhale K, Kales SN. Cancer and Potential Prevention with Lifestyle among Career Firefighters: A Narrative Review. Cancers (Basel). 2023 Apr 24;15(9):2442. doi: 10.3390/cancers15092442. PMID: 37173909; PMCID: PMC10177420.	initial search
113	Sim M, Pircher MS, Del Monaco MA, Vander Hoorn MS. Fiskville Firefighters' Health Study. 2014.	secondary search
114	Solan S, Wallenstein S, Shapiro M, et al. Cancer incidence in World Trade Center rescue and recovery workers, 2001-2008. Environ Health Perspect 2013;121:699–704.	secondary search
115	Soteriades ES, Kim J, Christophi CA, Kales SN. Cancer Incidence and Mortality in Firefighters: A State-of-the-Art Review and Meta-Analysis. Asian Pac J Cancer Prev. 2019 Nov 1;20(11):3221-3231. doi: 10.31557/APJCP.2019.20.11.3221. PMID: 31759344; PMCID: PMC7063017.	initial search
116	Sritharan J, Kirkham TL, MacLeod J, Marjerrison N, Lau A, Dakouo M, Logar- Henderson C, Norzin T, DeBono NL, Demers PA. Cancer risk among firefighters and police in the Ontario workforce. Occup Environ Med. 2022 Aug;79(8):533-539. doi: 10.1136/oemed-2021-108146. Epub 2022 Mar 30. PMID: 35354650; PMCID: PMC9304109.	initial search
117	Stec AA, Robinson A, Wolffe TAM, Bagkeris E. Scottish Firefighters Occupational Cancer and Disease Mortality Rates: 2000-2020. Occup Med (Lond). 2023 Feb 14;73(1):42-48. doi: 10.1093/occmed/kqac138. PMID: 36624617; PMCID: PMC9927825.	initial search

118	Straif K, Baan R, Grosse Y, Secretan B, El Ghissassi F, Bouvard V, Altieri A, Benbrahim-Tallaa L, Cogliano V; WHO International Agency For Research on Cancer Monograph Working Group. Carcinogenicity of shift-work, painting, and fire-fighting. Lancet Oncol. 2007 Dec;8(12):1065-6. doi: 10.1016/S1470-2045(07)70373-X. PMID: 19271347.	initial search
119	Stroup AM, Harris G, Wilson M, Black TM, Graber JM. New Jersey's Response to the Call for Firefighter Cancer Data: Creating a Retrospective Cohort to Study Cancer Mortality among New Jersey Firefighters through Data Linkages and an Honest Broker. J Registry Manag. 2022 Spring;49(1):39-40. PMID: 37260627; PMCID: PMC10198388.	initial search
120	Tornling G, Gustavsson P, Hogstedt C. Mortality and cancer incidence in Stockholm fire fighters. Am J Ind Med. 1994;25(2):219-28.	secondary search
121	Tsai RJ, Luckhaupt SE, Schumacher P, Cress RD, Deapen DM, Calvert GM. Risk of cancer among firefighters in California, 1988-2007. Am J Ind Med. 2015 Jul;58(7):715-29. doi: 10.1002/ajim.22466. Epub 2015 May 6. PMID: 25943908; PMCID: PMC4527530.	initial search
122	Vena JE, Fiedler RC. Mortality of a municipal-worker cohort: IV. Fire fighters. Am J Ind Med. 1987;11(6):671-84.	secondary search
123	Wagner NL, Berger J, Flesch-Janys D, Koch P, Kochel A, Peschke M, Ossenbach T (2006) Mortality and life expectancy of professional fire fighters in Hamburg, Germany: a cohort study 1950–2000. Environ Health 5:27	secondary search
124	Webber MP, Singh A, Zeig-Owens R, Salako J, Skerker M, Hall CB, Goldfarb DG, Jaber N, Daniels RD, Prezant DJ. Cancer incidence in World Trade Center- exposed and non-exposed male firefighters, as compared with the US adult male population: 2001-2016. Occup Environ Med. 2021 Oct;78(10):707-714. doi: 10.1136/oemed-2021-107570. Epub 2021 Sep 10. PMID: 34507965; PMCID: PMC8458058.	initial search
125	Williams RR, Stegens NL, Goldsmith JR. Associations of cancer site and type with occupation and industry from the Third National Cancer Survey Interview. Journal of the National Cancer Institute. 1977;59(4):1147-85.	secondary search
126	Wolffe TAM, Robinson A, Dickens K, Turrell L, Clinton A, Maritan-Thomson D, Joshi M, Stec AA. Cancer incidence amongst UK firefighters. Sci Rep. 2023 Jan 10;12(1):22072. doi: 10.1038/s41598-022-24410-3. PMID: 36627291; PMCID: PMC9831995.	initial search
127	World Health Organization, International Agency for Research on Cancer. IARC Monographs on the Evaluation of Carcinogenic Risks to Humans; WHO: Geneva, Switzerland, 2010; Volume 88: Formaldehyde, 2-Butoxyethanol and 1-tert-Butoxypropan-2-ol.	secondary search
128	Youakim S. Risk of cancer among firefighters: a quantitative review of selected malignancies. Arch Environ Occup Health. 2006 Sep-Oct;61(5):223-31. doi: 10.3200/AEOH.61.5.223-231. PMID: 17891891.	initial search
129	Zeig-Owens R, Webber MP, Hall CB, Schwartz T, Jaber N, Weakley J, Rohan TE, Cohen HW, Derman O, Aldrich TK, Kelly K, Prezant DJ. Early assessment of cancer outcomes in New York City firefighters after the 9/11 attacks: an observational cohort study. Lancet. 2011 Sep 3;378(9794):898-905. doi: 10.1016/S0140-6736(11)60989-6. PMID: 21890054; PMCID: PMC5525140.	initial search
130	Zhao G, Erazo B, Ronda E, Brocal F, Regidor E. Mortality Among Firefighters in Spain: 10 Years of Follow-up. Ann Work Expo Health. 2020 Jul 1;64(6):614-621. doi: 10.1093/annweh/wxaa036. PMID: 32253442.	initial search