Firefighters and Ischemic Heart Disease Risk

Report to the Legislature regarding expanding the current time restrictions for heart problems in RCW 51.32.185

Washington State Advisory Committee on Firefighter Presumption

SHARP Technical Report 101-04-2023

December 2023

Contents

Tables and Figures

ABBREVIATIONS

CDC	Centers for Disease Control and Prevention
CHD	Coronary heart disease
CI	Confidence Interval
CVD	Cardiovascular disease
FD	Fire Department or Fire District
IHD	Ischemic heart disease
L&I	Washington State Department of Labor and Industries
NIOSH	National Institute for Occupational Safety and Health
NOMS	National Occupational Mortality Surveillance
NR	Not reported
PMR	Proportionate mortality ratio
RR	Risk ratio
SHARP	Safety and Health Assessment and Research for Prevention
SIR	Standardized incidence ratio
WA	Washington State

KEYWORDS

SHARP, Ischemic heart disease, 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 1, 2023, the Washington State Legislature requested that the Firefighter Presumption Advisory Committee review the scientific literature related to heart problems in firefighters experienced beyond 72 hours from exposure to smoke, fumes, or toxic substances or experienced beyond 24 hours from strenuous physical exertion due to firefighting activities. 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 about burden of ischemic heart disease (IHD) in firefighters compared to other occupations and populations, and whether firefighter-related workplace exposures are associated with IHD. The purpose of this study was to (1) determine if firefighters are at a higher risk of developing IHD compared to other workers and (2) provide a recommendation about whether the IHD time limit should be expanded in the firefighter presumption law.

Key Findings

Ischemic heart disease by occupation

- We identified 32 published, peer-reviewed cohort studies quantifying the risk of IHD or heart disease in firefighters compared to other populations. The majority of these studies showed that firefighters are not at an increased risk of developing or dying from IHD 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 arteriosclerotic heart disease mortality compared to other workers. NIOSH's National Occupational Mortality databases did not show elevated PMRs for firefighters compared to other workers.
- To date, no studies have examined the time duration from firefighting activity to the onset of myocardial infarction (MI) or other IHD. Therefore, we were unable to determine if IHD risk in firefighters changes over time since they last engaged in firefighting activities or were last exposed to smoke, fumes, or toxic substances.

Occupational exposures associated with Ischemic Heart disease

- Firefighters have multiple occupational exposures that may increase their risk for cardiovascular disease (CVD). Shiftwork, which is common to the firefighting occupation, is associated with increased risk for CVD. Exposures to heat, chemicals and toxins during a fire response, exposure to infectious agents and infections, shift work with altered circadian rhythms, psychological stress, and strenuous physical activities may contribute to an acute and chronic inflammatory status which may contribute to the development of cardiovascular disease in firefighters.
- Shift work, inadequate and disrupted sleep, occupational injury, and occupational stress may contribute to poor health-related behaviors, and poor control of known cardiovascular risk factors in firefighters.

Advisory Committee Recommendation

This report and the subsequent recommendation only address the risk of IHD 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 IHD in individual firefighters with varying susceptibility and occupational exposures.

The current WA presumption law presumes that 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 are occupational diseases for firefighters. The committee evaluated whether there may be excess risk of IHD outside the current time periods of eligibility. Despite a thorough review of the existing literature, we were unable to identify a risk estimate specific to these time periods in published research. Research on the effects of shiftwork, chronic systemic inflammation, and other work factors suggest that it is biologically plausible that firefighters may be at an increased risk of IHD. While the currently available research provides scientific evidence suggesting biological plausibility, without evidence of increased morbidity of IHD in firefighters, there is not enough specific evidence to make a recommendation on whether the IHD presumption timeframe should be expanded.

Based on a review of the scientific literature, the committee cannot make a recommendation to modify Washington’s current presumption for ischemic heart disease in firefighters at this time. Scientific inquiry is not static, and additional research will broaden our understanding of environmental, occupational, and genetic risks for IHD. As more research evidence regarding these risks for IHD emerge, a subsequent request for a review of the presumption time limits can be considered.

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 posttraumatic 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 one dedicated SHARP epidemiologist, Ms. Claire LaSee, MPH/MSW, and is further assisted by other L&I staff members as needed.

Request for Review: Ischemic Heart Disease

On February 1, 2023, the Department of Labor and Industries (L&I) received a letter from two WA state legislators asking for an evaluation and recommendation related to "heart disease not related to exposure to toxic fumes or exertion" as a presumed occupational disease for firefighters (Appendix A – Legislative Request). This request resulted in the mobilization of the advisory committee on firefighter presumption.

WA's current presumption law includes "any heart problems, experienced within seventy-two hours of exposure to smoke, fumes, or toxic substances, or experienced within twenty-four hours of strenuous physical exertion in the line of duty." Modifying this presumption involves assessing risk for "any heart problems" beyond the time limits specified in the current presumption. Doing a comprehensive review of "any heart problems" is beyond the committee's capacity and was deemed unrealistic by the committee chair. After informal consultation with a firefighter stakeholder, we chose to evaluate the risk of IHD in firefighters. If there is a significantly elevated risk for heart problems in firefighters, it is likely related to IHD outcomes – i.e. sudden cardiac death, acute myocardial infarction (MI), unstable angina.

Heart disease is the leading cause of death in the Unites States. IHD, also called coronary artery disease, is the most common type of heart disease. IHD results from an inadequate supply of blood to the heart due to obstruction of the coronary arteries. Inadequate blood supply to the heart can cause chest pain and discomfort, also called angina, and can result in death of the heart muscle, a myocardial infarction, if inadequate blood flow is significant and prolonged. Coronary arteries progressively narrow with age, and this process can be accelerated by unhealthy behaviors, such as smoking, or underlying medical conditions such as diabetes and hypertension.

Certain aspects of work can contribute to increased CVD risk. Shift work and occupational stress from the mismatch between work demands and the control the worker has over completing job tasks, may contribute to the development of IHD. In addition, work affects health-related behavior such as smoking, diet, and exercise which can influence IHD risk.

In evaluating whether firefighters have chronically elevated risks for IHD, the committee focused on the following mechanisms: 1) circadian rhythm disruption from shiftwork, 2) chronic systemic inflammation, and 3) how firefighting work may contribute through shift work and occupational stress to the worsening of known cardiovascular risk factors such as hypertension, dyslipidemia, and metabolic syndrome.

Criteria for causation

While the legislature did not specify which criteria to be used 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 for complete consideration of **experiment**.

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 of IHD compared to workers in other occupations. We searched publication databases to identify peer-reviewed, scientific publications that estimate risk by occupation for IHD, and specifically for firefighters. The second component of the evaluation considers whether there is a relationship between firefighting and increased IHD risk based on existing scientific information; such information demonstrating biologic plausibility, would support presumption if the epidemiologic studies demonstrate significantly elevated risk. Assessing whether the IHD presumption timeframe should be expanded requires consideration of both (1) increased IHD mortality in firefighters and (2) biologic plausibility for causation.

METHODS

Occupational Mortality Databases

We described the number of deaths and proportional mortality ratios (PMRs) of IHD 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 July 2023, we searched the PubMed Central online database for peer-reviewed research articles about IHD in firefighters using the following search terms:

> *((heart OR cardiovascular diseases[mh]) AND (Firefighter OR firefighting)) AND (case-control studies[mesh] OR cohort studies[mesh] OR meta-analysis[mh] OR review[pt] OR risk factors[mh] OR death certificates[mh]*

All relevant articles identified in the initial and secondary search were reviewed. When an article reported an estimate related to IHD 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. Articles solely describing on-duty heart events in firefighters were excluded as they did not have relevant information on whether the off-duty presumption time window for heart disease should be expanded.

Assessing Biologic Plausibility

When reviewing the existing scientific literature supporting an association between firefighter occupations and chronically elevated risk of IHD, we considered three contributors to IHD risk:

1) Circadian rhythm disruption from shiftwork,

2) Chronic systemic inflammation, and

3) How work may influence IHD risk factors in firefighters.

Recent research articles with open access were reviewed and summarized by the committee chair. Literature searches included connecting "*shiftwork*" and "*inflammation*" to "*cardiovascular disease*" or "*coronary artery disease*" risk and any assessments related to 'firefighting.'

The available research literature is voluminous in these subject areas and this review was focused on recent meta-analyses and review articles for above topics. This review was not intended to be comprehensive or authoritative due to time and resource constraints. This aim was to detect meaningful signals for shiftwork and inflammation as risk factors for the development of CVD and coronary artery disease in firefighters.

Finally, recently published papers providing hypotheses about/on how firefighting activities may contribute to known IHD risk factors, e.g. shiftwork, occupational stress, and poor musculoskeletal health were reviewed.

RESULTS

Epidemiological Studies

Literature search

We found 391 articles in our initial PubMed literature search. After reviewing the title and abstracts of these articles, we identified 67 articles that were highly relevant to our research question (Appendix A). In our secondary search, we identified 78 additional articles (Appendix B). We were able to obtain full text for all articles except for five articles - two articles that were 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 (Table 3). Risk estimates from individual papers were reported by study design or type: five studies reporting proportional mortality ratios (PMR), 32 cohort studies, and five studies about World Trade Center cohorts. One cohort study also analyzed the data using case-control methodology (Sardinas, 1986). We did not find any meta-analyses related to IHD or heart disease among firefighters.

Ischemic Heart Disease in Firefighters

Table 1. describes the PMR of IHD in firefighters from WA-specific, New Jersey-specific, and national mortality databases for adults of working ages. From 1950–2011, there is little evidence showing male firefighters of any age have a proportionally higher risk of mortality from arteriosclerotic heart disease (WA DOH, 2011). In two cohort studies stratifying IHD mortality risk in firefighters by age group, age did not significantly change the IHD risk in firefighters (Pinkerton, 2020; Tornling, 1994). Few studies analyzed IHD risk by race. In a national mortality sample, the PMR was elevated in black firefighters

(PMR=1.69, 95%CI: 1.10-2.47), but was not elevated in white firefighters (PMR=1.04, 95%CI: 0.94-1.14) (Calvert 1999). In contrast, in a recent cohort analysis of 29,992 firefighters in San Francisco, Chicago, and Philadelphia, non-white firefighters had a statistically significantly lower risk of IHD mortality (SMR=0.79, 95% CI: 0.65-0.95) compared to US general population, while white firefighters did not have a lower risk of IHD mortality (SMR=0.99, 95%CI: 0.96-1.02) (Pinkerton, 2020). It remains unclear how age and race are related to the risk of IHD or other heart diseases in firefighters.

Table 1. National and WA-State specific Ischemic Heart Disease and related deaths among firefighters.

Source	Disease	Group	Firefighter Deaths	PMR (95% CI)	p-value
WA Occupational Mortality Database (males, 1950-2010) (WA DOH 2011)	Arteriosclerotic Heart Disease, including coronary disease	Age Group: 20-29	0	0*	NA
		30-39	9	1.18*	0.58682
		40-49	55	1.17*	0.1682
		50-59	130	1.09*	0.25447
		60-69	264	0.96*	0.37362
		70-79	367	1.03(NR)	0.53318
		80+	315	0.99 (NR)	0.79235
		20-64	306	1.05 (NR)	0.34126
NOMS (white males in 27 states, 1984-1990) (Burnett 1994)	Ischemic Heart Disease	Age Group: All	1608	1.01 (0.97-1.05)	NR
		Under age 65	555	1.04 (0.95-1.13)	NR
NOMS (Males ages 16-60 in 27 states, 1982-1992) (Calvert 1999)	Ischemic Heart Disease	Race: White	434	1.04 (0.94-1.14)	NR
		Black	26	1.69 (1.10-2.47)	NR
New Jersey's Police and Firemen Retirement System (White males, with 10+ years of experience), 1974-1988 (Feuer 1986)	Arteriosclerotic Heart Disease	All	115	1.15* 1.22**	p>0.05* p<0.05**
		Duration of Employment: ≤20 years	30	1.24	not reported
		22-25 years	39	1.28	not reported
		>25 years	46	0.94	not reported
		Time between first employment and death: ≤22 years	38	1.43	not reported
		22-27	36	1.11	not reported
		>27 years	41	0.91	not reported
		Employment status: Employed	73	1.2* 1.15**	p>0.05* p<.05**
		Retired	42	0.98* 0.98**	p>0.05* p>0.05**

NR: Not reported
*rates compared to rates compared to NJ PMRs for white males
**rates compared to US PMRs for white males

Table 4. summarizes 32 cohort studies assessing the cardiac risk in firefighters compared to the cardiac risk in the general population. Among cohort studies reporting risk estimates for IHD in firefighters, nine studies reported risk estimates that showed firefighters' risk of developing IHD were not statistically different from the comparison population. Four studies reported statistically significant increased risk of IHD in firefighters, and four studies reported a statistically significant decreased risk of IHD. One study (Stec et al, 2023) reported a statistically significant increase or risk of acute IHD in firefighters, but not chronic IHD. Finally, Ide (1998) reported an SMR for IHD in firefighters, but did not indicate if the result was statistically significant. The remaining studies reported risk estimates for heart conditions other than IHD.

IHD risk estimates stratified by duration of employment and number of runs showed inconsistent findings. In a cohort study of firefighters in Philadelphia, PA, firefighters with 10-19 years of experience were at elevated risk of IHD mortality compared to the general public (SMR=1.35, 95%CI: 1.21-1.49) (Baris, 2001). However, firefighters with less than 10 years of experience and firefighters with 20 or more years of experience were not at elevated risk of IHD mortality (Baris, 2001), indicating that length of employment as a firefighter may not affect IHD mortality risk in firefighters. Risk estimates stratified by length of employment from cohort studies in South Korea, Denmark, and Sweden did not show dose-response relationship between length of employment and IHD risk (Ahn, 2015; Pederson, 2018; Peterson, 2018; Tornling, 1994).

Three cohort studies reported IHD risk estimates in firefighters by number of runs or fires attended (Baris, 2001; Glass, 2017; Tornling, 1994), though it remains unclear how number of runs and fires attended impacts IHD risk. Baris et al (2001) reported firefighters with the most lifetime runs (5,099 runs or more) had a lower IHD mortality risk compared to the general population (SMR=0.77, 95% CI: 0.62-0.95). Firefighters with fewer cumulative runs did not have a statistically significant decreased risk of IHD. In a study of firefighters in Stockholm, Sweden, there were no differences in IHD mortality when firefighters stratified by the number of fires attended were compared to the general public (Tornling, 1994). Volunteer firefighters in Australia who attended more than 576 fires had nearly two times higher risk of IHD mortality compared to volunteer firefighters who attended fewer than 221 fires (RR=1.86, 95% CI: 1.07-3.23) (Glass, 2017).

None of the studies reported the timing of the heart-related event from the last exposure to smoke, fumes, or toxic substances, or timing from the last strenuous physical exertion due to firefighting activities. Inclusion criteria for firefighters varied by studies, but commonly required the subjects to be either current or former firefighters. As a result, it is unclear if the firefighters in these studies experienced IHD or other heart-related events during a current shift, off-duty between firefighting shifts, or after retirement from firefighting work. Studies of World Trade Center workers and cohorts were reviewed as a potential source to provide better understanding of the IHD risk over time from last firefighting event.

Table 5. describes five studies of heart disease risk in World Trade Center rescue workers and others in lower Manhattan, however none of these studies reported IHD risk estimates by time from the firefighting exposure. To summarize, the epidemiological studies report inconsistent findings and it remains unclear if IHD risk is elevated among firefighters outside of the 72-hour exposure window specified in the current presumption law.

Exposure Studies

Firefighters are known to have workplace exposures that can adversely impact their health. These exposures may be short-term which would present acute risks for IHD or long-term, chronic exposures with underlying, persistently elevated risk for IHD. We considered three chronic exposures that may contribute to elevated IHD risk in firefighters:

1) Circadian rhythm disruption from shiftwork,

2) Systemic inflammation, and

3) How work may influence IHD risk factors in firefighters.

Exposures associated with Ischemic Heart Disease

Circadian rhythm disruption from shift work

Firefighters are shift workers, often on duty for a period of 24 hours or more with a subsequent period off duty. Shift work alters circadian rhythms, which disrupts usual behavioral, psychosocial and physiologic function, likely contributing to poor health outcomes (e.g. neurologic, psychiatric, metabolic, and immunologic disorders) and further influencing health behaviors through sleep disruption, and poor quality sleep (Fishbein, 2021). Shorter sleep duration and poor sleep quality, poor nutrition, physical inactivity and weight gain from shift work likely increasing CVD risk; shift workers have a 25% excess risk of being overweight (Boini, 2022). Disruption of circadian rhythms leads to alterations in glucose and lipid metabolism, systemic inflammation, autonomic nervous system dysregulation and increased blood pressure and these changes lead to an increased risk of developing atherosclerosis, dyslipidemia and insulin resistance. (Morris, 2016; Torquati, 2018). Consequently, shift workers have a 10% excess risk of diabetes, and a 30% excess risk of hypertension (Boini, 2022).

There is a substantial body of research published in the peer-reviewed literature evaluating and reporting an elevated risk for cardiovascular outcomes related to shift work. Although this literature mostly includes shiftwork consisting of evening, night, or rotating shifts of 12 hours which are common among nursing and law enforcement work and are different from the 24- and 48-hour shifts common to firefighters, these studies can inform cardiovascular risk for firefighters in relationship to shift work.

In a meta-analysis of 21 studies with 173,010 participants, the risk for any CVD event was 17% higher (95% CI: 1.09-1.25) and the risk of coronary heart disease (CHD) morbidity was 26% higher (95% CI: 1.10-1.43) among shift workers compared to day workers. Risk for CVD outcomes increased with duration of shift work, and after the first five years of employment, every additional five years increased risk by 7.1% (95% CI: 1.05-1.10) (Torquati, 2018). In a 2022 population-based prospective cohort study of

238,661 UK persons, shift workers had an 11% (95% CI: 1.06–1.19) increased risk of CVD incident and a 25% (95% CI: 1.08–1.44) increased risk of fatal CVD compared with non-shift workers, after adjusting for socio-economic and work-related factors (Ho, 2022).

Systemic inflammation

Exposures to heat, chemicals and toxins during a fire response, exposure to infectious agents and infections, shift work with altered circadian rhythms, psychological stress, and strenuous physical activities may induce an acute and chronic inflammatory status in firefighters (Orysiak, 2022). Given time limits of the current presumption, our focus is to assess if exposures during firefighting induce chronic systemic inflammation, rather than an acute inflammatory response from a short-term exposure linked to an acute cardiovascular outcome.

There is growing evidence that systemic inflammation is a risk factor for CVD (Furman, 2019). Repetitive and long-term exposures to particulate matter may induce systemic inflammation which leads to impaired vascular function, endothelial damage, and modulation of the autonomic nervous system with potential increases in blood pressure and hypertension, all contributing to elevated risk of CVD outcomes (US EPA, 2019; US EPA, 2022). As a biologic mechanism, the inhalation of air pollution (or particulates during a fire response) leads to respiratory inflammation and oxidative stress. Inflammatory mediators from the respiratory tract then enter the circulatory system and impact other organ systems by inducing vascular damage and altering cardiac function (US EPA, 2019; US EPA, 2022).

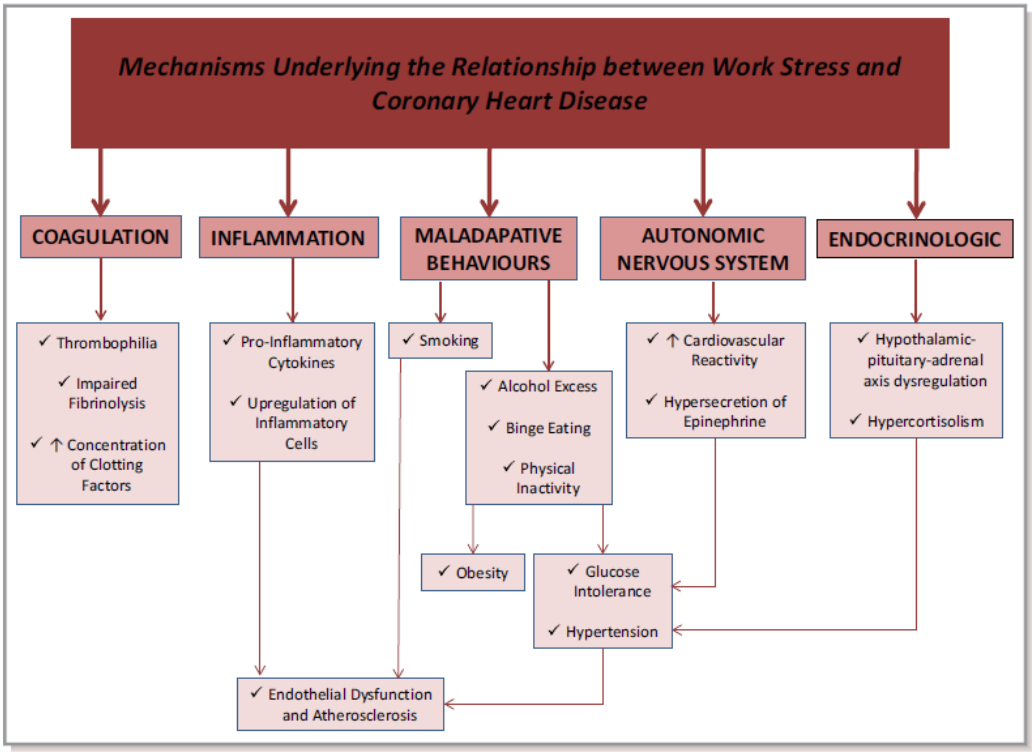
Acute and chronic systemic inflammation are indicated by higher levels of circulating inflammatory biomarkers, e.g. cytokines, chemokines, and acute phase proteins. These biomarkers have been used to evaluate risk for cardiovascular events. For example, elevated circulating Il-6 and C-reactive protein levels indicates a higher risk for atherosclerosis and increased cardiovascular morbidity (Ridker, 2000; Ridker, 2003). Multiple research studies have demonstrated elevated levels of circulating inflammatory biomarkers in firefighters following smoke exposure (Richardson, 2023; Orysiak, 2023). When compared to non-firefighter controls and firefighter trainees, professional firefighters have significantly elevated levels of inflammatory biomarkers (Gianniou, 2016). Furthermore, there is a positive correlation between years of service as a firefighter and levels of inflammatory biomarkers (Gianniou, 2016), and increased levels of biomarkers with greater exposure to fires (Watkins, 2021). Greven (2011) reported elevated inflammatory biomarkers three months after smoke exposure in firefighters, which suggest development of chronic inflammation from a single smoke exposure.

Other cardiovascular risk factors

Firefighters have a physically and mentally demanding job. As such, newly hired firefighters are likely to be significantly healthier than their peer group in other occupations. However, several CVD risk factors increase with age in firefighters, e.g. increased blood pressure, dyslipidemia and metabolic syndrome (Bode, 2021) placing firefighters at risk for IHD. The increase in CVD risk with firefighter career progression is likely multifactorial, with contributions from shift work and occupational stress.

Occupational stress likely plays a significant role in exacerbating known cardiovascular risk factors. A generally accepted framework for the development of occupational stress is when there are high psychological demands associated with work, i.e. time-sensitive work outcomes associated with low control in decision-making in how the work is completed (Karasek, 1990). Other models for the development of occupational stress include the effort-reward imbalance model (Siegrist, 1996) and an organizational justice model (Kivimäki, 2005). There are multiple biological pathways linking occupational stress to/with CVD risk – through coagulopathy, inflammation, maladaptive behaviors, autonomic dysregulation, and disruption of the endocrine system (See Figure 1).

Figure 1. Mechanisms underlying the relationship between work stress and coronary heart disease.



Source: Sara J., et al. J Am Heart Assoc. 2018;7:e008073. DOI: 10.1161/JAHA.117.008073.

Figure 1. describes a general framework for occupational stress and its relationship to CHD risk. Firefighting as an occupation may further exacerbate underlying medical conditions due to its work organization, specifically shift work of long duration, non-predictable sleep times and durations, which contribute to poor health behaviors. Indeed firefighting "*inherently promotes obesogenic behaviours, including increased food portion sizes, night-time snacking and sleep interruption*" (Beckett, 2023). Additionally, the physical demands of work and emergency response, and work scheduling may increase fatigue and lessen interest in and time for leisure time physical activity contributing to diminished physical fitness and increased risk for metabolic syndrome – which is an aggregate of multiple CVD risk factors (Saklayen, 2018).

Furthermore, Ras et al. (2022) explored the interrelationships between CVD risk factors, physical fitness, musculoskeletal health, and occupational performance. These relationships are likely complex and elucidating causality may be difficult. However, it is reasonable to suggest that poor musculoskeletal health is associated with diminished physical activity, poor occupational performance and a poor cardiovascular risk profile (Ras, 2022). The high risk of work-related musculoskeletal disorders in firefighters (Anderson, 2023) may contribute to less physical activity, poor physical fitness and in part increased cardiovascular risk. In conclusion, there is scientific evidence to support the biologic plausibility of shiftwork, psychological stress and other exposures related in firefighting increasing the risk for cardiovascular disease among firefighters.

SUMMARY

This assessment summarizes the morbidity of IHD in firefighters compared to other workers and whether the biologically plausible association between firefighting as an occupation and IHD exists. The epidemiologic evidence does not support an association between firefighting and IHD. The literature did not consistently show that firefighters are at a higher risk of developing IHD compared to other workers. Furthermore, none of the reviewed studies reported IHD risk from time of last firefighting activity or from time of last firefighting shift. Studies of heart disease risk in an analogous population of World Trade Center cohorts did not provide further information to allow a better understanding of how IHD risk changes over time from last firefighting activity. While the epidemiologic evidence does not suggest IHD morbidity is higher in firefighters compared to other workers, there is reasonable biologic plausibility for firefighters to be at a heightened risk of IHD due to their chemical, biologic and physical occupational exposures. Such information demonstrating biologic plausibility would support presumption if the epidemiologic studies identified significantly elevated risk.

Advisory Committee Recommendation

This report and the subsequent recommendation only address the risk of IHD 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 IHD in an individual firefighter with varying susceptibility and occupational exposures.

The current WA presumption law presumes that 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 are occupational diseases for firefighters. The committee evaluated whether there may be excess risk of IHD outside the current time periods of eligibility. Despite a thorough review of the existing literature, we were unable to identify a risk estimate specific to these time periods in published research. Research on the effects of shiftwork, chronic systemic inflammation, and other work factors suggest that it is biologically plausible that firefighters may be at an increased risk of IHD. While the currently available research provides scientific evidence suggesting biological plausibility, without evidence of increased morbidity of IHD in firefighters, there is not enough specific epidemiological evidence to recommend expanding the current the IHD presumption timeframe.

Based on a review of the scientific literature, the committee recommends no modification to Washington's current presumption for ischemic heart disease in firefighters at this time. Scientific inquiry is not static, and additional research will broaden our understanding of environmental, occupational, and genetic risks for IHD. As more research evidence regarding these risks for IHD emerge, a subsequent request for a review of the presumption time limits can be considered.

Estimated Burden and Cost of Ischemic Heart Disease 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 IHD, 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 IHD.

Heart disease events, including number of IHD cases and myocardial infarctions (MIs), are not reportable conditions in WA or nationally, so heart disease incidence data is sparse. In a study of hospitalizations among 35–54 year old men and women in four US communities, incidence of acute MI was reported as 3.9 cases per 1,000 hospitalizations for men and 2.3 cases per 1,000 for women in 2013 (Arora, 2019). Table 2. describes number of current and former WA firefighters and acute MI case estimates by age and sex. 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 presumptive coverage for other conditions, we also described the number WA firefighters who are currently working or within five years of separation or retirement. Over two thirds of all current firefighters in WA are at ages between 35 and 54, and based on acute MI incidence rates for this age group, we estimate about 21 acute MI cases in firefighters per year. Previously, WA firefighters filed 40 worker compensation claims for MI over a 19-year period between 2002 and 2017, averaging two MI claims per year (LaSee, 2023). In total, 141 firefighters filed claims for all heart problems covered by WA's presumption law between 2000 and 2017 (LaSee, 2023).

Table 2: Estimated annual burden of Acute MI among WA Firefighters by age and sex

Age Group	All Current and Former Firefighters[1] by Sex (N)		Estimated Cases of Acute MI by Sex (N)	
	M	F	M	F
0 to 34	1314	139	unknown	
35 to 54	5125	316	19.99	0.73
55+	989	63	unknown	
Total	**7428**	**518**		

[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. Of the 40 MI claims filed by firefighters between 2002 and 2017, 63% (n=25) were administered by the state fund and 60% (n=15) of these state fund MI claims were accepted. Most (n=14) 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. When adjusting to the 2017 consumer price index, median cost for a MI wage replacement claim was $49,785.25. Median time-loss days for wage-replacement claims reporting at least one time loss day was 97 days.

REFERENCES CITED

Ahn YS, Jeong KS. Mortality due to malignant and non-malignant diseases in Korean professional emergency responders. PLoS One. 2015;10(3):e0120305.

Amadeo B, Marchand JL, Moisan F, Donnadieu S, Gaëlle C, Simone MP, et al. French firefighter mortality: analysis over a 30-year period. Am J Ind Med. 2015;58(4):437-43.

Anderson NJ, Marcum JL, Bonauto DK, Siegel MR, LaSee CR. The relative burden of occupational injuries and illnesses in Firefighters: an analysis of Washington workers' compensation claims, 2006-2020. 2023. In Press.

Arora S, Stouffer GA, Kucharska-Newton AM, Qamar A, Vaduganathan M, Pandey A, et al. Twenty year trends and sex differences in young adults hospitalized with acute myocardial infarction: the ARIC Community Surveillance Study. Circulation. 2019;139(8):1047-56.

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

Bates JT. Coronary Artery Disease Deaths in the Toronto Fire Department. Journal of Occupational Medicine. 1987;29(2):132-5.

Beaumont JJ, Chu GS, Jones JR, Schenker MB, Singleton JA, Piantanida LG, et al. An epidemiologic study of cancer and other causes of mortality in San Francisco firefighters. Am J Ind Med. 1991;19(3):357-72.

Bode ED, Mathias KC, Steward DF, Moffatt SM, Jack K, Smith DL. Cardiovascular disease risk factors by BMI and age in United State firefighters. Obesity. 2021;29(7):1186-1194.

Boini S, Bourgkard E, Ferrières J, Esquirol Y. What do we know about the effect of night-shift work on cardiovascular risk factors? An umbrella review. Frontiers in Public Health. 2022 Nov 23;10:1034195.

Burnett CA, Halperin WE, Lalich NR, Sestito JP. Mortality among fire fighters: a 27 state survey. American journal of industrial medicine. 1994;26(6):831-3.

Calvert GM, Merling JW, Burnett CA. Ischemic heart disease mortality and occupation among 16- to 60-year-old males. J Occup Environ Med. 1999;41(11):960-6.

Cohen HW, Zeig-Owens R, Joe C, Hall CB, Webber MP, Weiden MD, et al. Long-term Cardiovascular Disease Risk Among Firefighters After the World Trade Center Disaster. JAMA Netw Open. 2019;2(9):e199775.

Demers PA, Heyer NJ, Rosenstock L. Mortality among firefighters from three northwestern United States cities. Br J Ind Med. 1992;49(9):664-70.

Deschamps S, Momas I, Festy B. Mortality amongst Paris fire-fighters. Eur J Epidemiol. 1995;11(6):643-6.

Dibbs E, JrU TH, Weiss ST, Sparrow D. Fire fighting and coronary heart disease. Circulation. 1982;65(5):943-6.

Eliopulos E, Armstrong BK, Spickett JT, Heyworth F. Mortality of fire fighters in Western Australia. Br J Ind Med. 1984;41(2):183-7.

Feuer E, Rosenman K. Mortality in police and firefighters in New Jersey. Am J Ind Med. 1986;9(6):517-27.

Fishbein AB, Knutson KL, Zee PC. Circadian disruption and human health. The Journal of clinical investigation. 2021 Oct 7;131(19).

Furman D, Campisi J, Verdin E, Carrera-Bastos P, Targ S, Franceschi C, Ferrucci L, Gilroy DW, Fasano A, Miller GW, Miller AH. Chronic inflammation in the etiology of disease across the life span. Nature medicine. 2019 Dec;25(12):1822-32.

Gianniou N, Katsaounou P, Dima E, Giannakopoulou CE, Kardara M, Saltagianni V, Trigidou R, Kokkini A, Bakakos P, Markozannes E, Litsiou E. Prolonged occupational exposure leads to allergic airway sensitization and chronic airway and systemic inflammation in professional firefighters. Respiratory Medicine. 2016 Sep 1;118:7-14.

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;74(9):628-38.

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;73(11):761-71.

Greven FE, Krop EJ, Spithoven JJ, Burger N, Rooyackers JM, Kerstjens HA, et al. Acute respiratory effects in firefighters. American journal of industrial medicine. 2012;55(1):54-62.

Grimes G, Hirsch D, Borgeson D. Risk of death among Honolulu fire fighters. Hawaii Med J. 1991;50(3):82-5.

Guidotti TL. Mortality of urban firefighters in Alberta, 1927-1987. Am J Ind Med. 1993;23(6):921-40.

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.

Hansen ES. A cohort study on the mortality of firefighters. Br J Ind Med. 1990;47(12):805-9.

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.

Ho FK, Celis-Morales C, Gray SR, Demou E, Mackay D, Welsh P, Katikireddi SV, Sattar N, Pell JP. Association and pathways between shift work and cardiovascular disease: a prospective cohort study of 238 661 participants from UK Biobank. International journal of epidemiology. 2022 Apr 1;51(2):579-90.

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;48(6):381-8.

Jeung DY, Hyun DS, Kim I, Chang SJ. Effects of Emergency Duties on Cardiovascular Diseases in Firefighters: A 13-Year Retrospective Cohort Study. J Occup Environ Med. 2022;64(6):510-4.

Jordan HT, Miller-Archie SA, Cone JE, Morabia A, Stellman SD. Heart disease among adults exposed to the September 11, 2001 World Trade Center disaster: results from the World Trade Center Health Registry. Preventive medicine. 2011a;53(6):370-6.

Jordan HT, Brackbill RM, Cone JE, Debchoudhury I, Farfel MR, Greene CM, et al. Mortality among survivors of the sept 11, 2001, world trade center disaster: results from the world trade center health registry cohort. The Lancet. 2011b;378(9794):879-87.

Jordan HT, Stein CR, Li J, Cone JE, Stayner L, Hadler JL, et al. Mortality among rescue and recovery workers and community members exposed to the September 11, 2001 World Trade Center terrorist attacks, 2003–2014. Environmental research. 2018;163:270-9.

Karasek, R., & Theorell, T. (1990).Healthy Work: Stress, Productivity, and the Reconstruction of Working Life. New York: Basic Books.

Kivimäki M, Ferrie JE, Brunner E, Head J, Shipley MJ, Vahtera J, Marmot MG. Justice at work and reduced risk of coronary heart disease among employees: the Whitehall II Study. Arch Int Med. 2005; 165(19):2245-51.

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 Feb 28;65(2):e51-6.

Lee J, Lee WR, Yoo KB, Cho J, Yoon J. Risk of Cerebro-Cardiovascular Diseases among Police Officers and Firefighters: A Nationwide Retrospective Cohort Study. Yonsei Med J. 2022a;63(6):585-90.

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. 2022b;10:1070023.

Ma F, Fleming LE, Lee DJ, Trapido E, Gerace TA, Lai H, et al. Mortality in Florida professional firefighters, 1972 to 1999. Am J Ind Med. 2005;47(6):509-17.

Morris CJ, Purvis TE, Hu K, Scheer FA. Circadian misalignment increases cardiovascular disease risk factors in humans. Proceedings of the National Academy of Sciences. 2016 Mar 8;113(10):E1402-11.

Musk AW, Monson RR, Peters JM, Peters RK. Mortality among Boston firefighters, 1915--1975. Br J Ind Med. 1978;35(2):104-8.

Noh J, Lee CJ, Hyun DS, Kim W, Kim MJ, Park KS, et al. Blood pressure and the risk of major adverse cardiovascular events among firefighters. J Hypertens. 2020;38(5):850-7.

Orysiak J, Młynarczyk M, Piec R, Jakubiak A. Lifestyle and environmental factors may induce airway and systemic inflammation in firefighters. Environ Sci Pollut Res Int. 2022;29(49):73741-68.

Pedersen JE, Ugelvig Petersen K, Ebbehøj NE, Bonde JP, Hansen J. Incidence of cardiovascular disease in a historical cohort of Danish firefighters. Occup Environ Med. 2018;75(5):337-43.

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;91(6):759-66.

Pinkerton L, Bertke SJ, Yiin J, Dahm M, Kubale T, Hales T, et al. Mortality in a cohort of US firefighters from San Francisco, Chicago and Philadelphia: an update. Occup Environ Med. 2020;77(2):84-93.

Ras J, Smith DL, Kengne AP, Soteriades EE, Leach L. Cardiovascular Disease Risk Factors, Musculoskeletal Health, Physical Fitness, and Occupational Performance in Firefighters: A Narrative Review. J Environ Public Health. 2022; 2022:7246408; doi:10.1155/2022/7346408.

Richardson A, Terrazzini N, Gage C, Lee BJ, Bradley R, Watt P, Watkins ER. Inflammatory and psychological consequences of chronic high exposure firefighting. Journal of thermal biology. 2023 Jan 1;111:103399.

Ridker PM, Rifai N, Stampfer MJ, Hennekens CH. Plasma concentration of interleukin-6 and the risk of future myocardial infarction among apparently healthy men. Circulation. 2000 Apr 18;101(15):1767-72.

Ridker PM, Buring JE, Cook NR, Rifai N. C-reactive protein, the metabolic syndrome, and risk of incident cardiovascular events: an 8-year follow-up of 14 719 initially healthy American women. Circulation. 2003 Jan 28;107(3):391-7.

Sampath V, Shalakhti O, Veidis E, Efobi JA, Shamji MH, Agache I, Skevaki C, Renz H, Nadeau KC. Acute and chronic impacts of heat stress on planetary health. Allergy. 2023 Mar 8.

Sara JD, Prasad M, Eleid MF, Zhang M, Widmer J, Lerman A. Association Between Work-Related Stress and Coronary Heart Disease: A Review of Prospective Studies Through the Job Strain, Effort-Reward Balance, and Organizational Justice Models. J Am Heart Assoc. 2018; 7:e008073.

Sardinas A, Miller JW, Hansen H. Ischemic heart disease mortality of firemen and policemen. American journal of public health. 1986;76(9):1140-1.

Siegrist J. Adverse health effects of high-effort/low-reward conditions. J Occup Health Psychol. 1996;1:27–41. doi: 10.1037//1076-8998.1.1.27

Sloan NL, Shapiro MZ, Sabra A, Dasaro CR, Crane MA, Harrison DJ, et al. Cardiovascular disease in the World Trade Center Health Program General Responder Cohort. Am J Ind Med. 2021;64(2):97-107.

Stec AA, Robinson A, Wolffe TAM, Bagkeris E. Scottish Firefighters Occupational Cancer and Disease Mortality Rates: 2000-2020. Occup Med (Lond). 2023;73(1):42-8.

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

Torquati L, Mielke GI, Brown WJ, Kolbe-Alexander T. Shift work and the risk of cardiovascular disease. A systematic review and meta-analysis including dose–response relationship. Scandinavian Journal of Work, Environment & Health. 2018(3):229-38.

US Environmental Protection Agency. Integrated Science Assessment (ISA) for Particulate Matter (Final Report). U.S. Environmental Protection Agency, Washington, DC, EPA/600/R-19/188, 2019.

US Environmental Protection Agency. Supplement to the 2019 Integrated Science Assessment for Particulate Matter (Final Report). U.S. Environmental Protection Agency, Washington, DC, EPA/635/R-22/028, 2022.

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

Washington DOH. Washington State occupational mortality database, 1950–2010. Tumwater, WA2011.

Watkins ER, Hayes M, Watt P, Renshaw D, Richardson AJ. Extreme occupational heat exposure is associated with elevated haematological and inflammatory markers in Fire Service Instructors. Experimental physiology. 2021 Jan;106(1):233-43.

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;64(6):614-21.

SUPPLEMENTAL TABLES

Table 3. Characteristics of cohort and case-control studies of heart disease risk in firefighters

ID	First Author, year	Region	Year(s)		Study Population	Study Design	n	Data Source		Reference Population	Covariates/Cofactors
			Enrollment	Follow-up				Occ	Disease		
1	Ahn, 2015	South Korea	1980-2007	1992-2007	Male FFs	Cohort	29,453	ER	DC	Korean males	age
2	Amadeo, 2015	France	1979	1979-2008	Male FFs	Cohort	10,829	ER	DC	French males	age, year
3	Aronson, 1994	Toronto, Canada	1950-1989	1950-1989	Male FFs	Cohort	5,373	ER	DC	Ontario males	age, year
4	Baris, 2001	Philadelphia, PA	1925-1986	1986	Male FFs	Cohort	7,789	ER	DC	US white males	age and time periods
5	Beaumont, 1991	San Francisco, CA	1940-1970	1940-1982	White male FFs employed 3+ years	Cohort	1,186	ER	DC	US white males	age, time periods
6	Bates, 1987	Toronto, Canada	1949-1959	1970-1984	Male FFs employed 6+ years	Cohort	596	ER	DC	Toronto males	time periods
7	Cohen, 2019	NYC, NY	NR	2001-2017	Male FFs	WTC	9,796	FDNY MMP	ME, medical records	NA	race/ethnicity, BMI, hypertension, PTSD, hypercholesterolemia, diabetes, smoking
8	Demers, 1992	Seattle & Tacoma, WA; Portland, OR	1944-1979	1945-1989	Male FFs employed 1+ year	Cohort	4,401	ER	DC	US white men	age, time periods, test based Cis
9	Deschamps, 1995	France	1977	1977-1991	Male FFs employed 5+ years	Cohort	830	ER	DC	French males	age, time periods
10	Dibbs, 1982	Boston area	NR	10 years	Male FFs in VA-based aging study	Cohort	171	study intake	ME, HR	Non-FF males in study, matched on cholesterol, BP, BMI	NR
11	Eliopulos, 1984	Western Australia	1939-1978	1939-1978	Male FFs	Cohort	990	ER	DC	Western Australian males	age, time periods

ID	First Author, year	Region	Year(s)		Study Population	Study Design	n	Data Source		Reference Population	Covariates/Cofactors
			Enrollment	Follow-up				Occ	Disease		
12	Glass, 2017	Australia	1998-2000	1998-2011	Male volunteer FFs enrolled for 3+ months	Cohort	163,094	volunteer agency records	DC	Australian population	sex, time periods, age
13	Glass, 2016	Australia	1982-2009/2010	1982-2011	Male FFs (full- and part-time)	Cohort	30,057 (FT: 17,394; PT: 12,663)	ER	DC	Australian population	age, year
14	Grimes, 1991	Hawaii	1969-1988	1969-1988	Male FFs 20+ years old employed 1+ year at the Honolulu FD	Cohort	205	DC	DC	Males in Hawaii over 20 years old	NR
15	Guidotti, 1993	Edmonton & Calgary, Canada	1927-1987	1927-1987	FFs employed 1+ year	Cohort	3,328	ER	DC	Alberta males	age, time period
16	Han, 2018	South Korea	2002-2014	2002-2014	FFs with NHI claims data	Cohort	23,356	NHI	NHI	National gov. officers	age, sex
17	Hansen, 1990	Denmark	1970	1970-1980	Male FFs aged 15-69	Cohort	886	CD	DC	Male civil servants and salaried employees, aged 15-69	NR
18	Heyer, 1990	Seattle, WA	1945-1980	1945-1983	Male FFs employed 1+ year	Cohort	2289	ER	DC	US white males	NR
19	Ide 1998	Scotland	1985-1995	1985-1994	FFs who retired due to ill health and FF deaths	Cohort	505 (488 retired due to ill health; 17 deaths)	Firemaster's Annual Report	ER, DC	Scotland males aged 20-54	NR
20	Jeung, 2022	South Korea	2002-2014	2002-2014	FFs	Cohort	24,493	NHI	NHI	Public officials	NR
21	Jordan 2011a	New York, NY	2003-2004	2006-2008	WTC Health Registry participants[1]	WTC	8,337	NA	Questionnaire	NA	age, race/ethnicity, education, marital status, smoking, hypertension, diabetes

ID	First Author, year	Region	Year(s)		Study Population	Study Design	n	Data Source		Reference Population	Covariates/Cofactors
			Enrollment	Follow-up				Occ	Disease		
22	Jordan 2011b	New York, NY	2003-2004	2003-2009	WTC Health Registry participants residing in NYC[2]	WTC	13,337	Interview	DC	NYC rates from 2000-2009	age, sex, race, time periods
23	Jordan 2018	New York, NY	2003-2004	2003-2014	WTC Health Registry participants residing in NYC[2]	WTC	29,280	NA	DC	NYC & US mortality rates from 2003-2012	age, sex, race, time periods
24	Lee, 2022a	South Korea	2006-2017	2016-2017	FFs employed 3+ consecutive years during study	Cohort	27,493	NHI	NHI	Public employees	age
25	Lee, 2022b	South Korea	2006-2015	2006-2015	FFs	Cohort	23,855	NHI	NHI	All workers aged 25-64	age
26	Ma, 2005	Florida	1972-1999	1972-1999	FFs certified in FL	Cohort	36,813	FL State Fire Marshal's Office	DC	Florida general population	age and time periods
27	Musk, 1978	Boston	1915-1975	1915-1975	Male FFs with 3+ years of experience at the Boston FD	Cohort	5,655	ER	DC	Massachusetts males	age-time stratum
28	Noh, 2020	South Korea	2002-2003	2002-2015	FFs on active duty from 2002-2003 (excluding those who retired or were terminated in 2002-2003)	Cohort	8,242 (6,463 matched on clinical and demographic variables)	NHI	NHI, DC	Korean residents matched on (1) age and sex or (2) baseline clinical and demographic variables	NR

ID	First Author, year	Region	Year(s)		Study Population	Study Design	n	Data Source		Reference Population	Covariates/Cofactors
			Enrollment	Follow-up				Occ	Disease		
29	Pedersen, 2018	Denmark	1977-2014	1977-2014	Male FFs (full-time)	Cohort	4,678	ER, union records, Danish civil registration system	HR	random sample of employed males	age, time periods
30	Petersen, 2018	Denmark	1970-2014	1970-2014	Male FFs (full-and part-time/volunteers)	Cohort	11,775	ER, Danish civil registration system	DC	(1) Men in the Danish Military, (2) Age-matched sample of employed men in Denmark	age, time periods
31	Pinkerton, 2020	San Francisco, Chicago, and Philadelphia	1950-2009	1951-2016	Male FFs employed 1+ year	Cohort	29,992	ER	DC	US general population	sex, race, age , time periods
32	Sardinas, 1986	Connecticut	1960-1978	1960-1978	Male FFs aged 25- 59	Cohort & Case-Control	306	DC	DC	CT working population	time periods
33	Sloan, 2021	2003-2004	2011-2019	through March 31, 2019	Protective service workers in the WTC Health program	WTC	37,725	WTC Health program general cohort	Self-report of a physician's first DX or treatment for first time CAD, MI, stroke, or CHF	NA	race/ethnicity
34	Stec, 2023	Scotland	2000-2020	2000-2020	Male FFs (full-time), aged 30-74	Cohort	NR	National Records	National Records	Scottish males, aged 30-74	age, time periods
35	Tornling, 1994	Stockholm, Sweden	1931-1983	1951-1986	Male FFs employed 1+ year	Cohort	1,116	ER	DC	regional rates	age, time periods, sex
36	Vena, 1987	Buffalo, NY	1950-1979	1950-1979	White Male FFs	Cohort	1,867	ER	DC	US white males	age, time periods

ID	First Author, year	Region	Year(s)		Study Population	Study Design	n	Data Source		Reference Population	Covariates/Cofactors
			Enrollment	Follow-up				Occ	Disease		
37	Zhao, 2020	Spain	2001-2011	2001-2011	Male FFs	Cohort	27,365	CD	DC	Spanish males (aged 20-64) employed in 2001	age

CAD: Coronary artery disease **CD**: Census Data **CHF:** Congestive heart failure **DC:** Death certificates, records, & registers **DX**: Diagnosis **ER:** Employment records **FD:** Fire department **FDNY MMP:** Fire Department New York Medical Monitoring Program **FF:** Firefighter **HR:** Hospital records **ME:** Medical Examination **NR:** Not reported **NA:** Not applicable **NHI:** National health insurance data

[1] includes rescue/recovery workers/volunteers; Lower Manhattan area residents, workers, and students; commuters and passersby on 9/22) aged ≥ 18 on 9/11

[2] includes rescue and recover workers, and volunteers

Table 4: Extract estimates of heart disease risk and mortality in firefighters from case-control and cohort studies

ID	First Author, year	Category	obs	Risk Estimate	95% CI
1	Ahn, 2015	IHD	18	SMR=0.42	0.25-0.66
		By length of employment			
		<10 years	7	SMR=0.67	0.27-1.39
		10–20 years	4	SMR=0.27	0.07-0.68
		≥20 years	7	SMR=0.40	0.16-0.82
2	Amadeo, 2015	Diseases of the Circulatory System	308	SMR=0.76	0.68-0.85
3	Aronson, 1994	IHD (ICD9: 410-414,429.3)	289	SMR=1.04	0.92-1.17
		Acute MI (410)	205	SMR=1.07	0.93-1.23
		Years since first exposure			
		<20 Years	22	SMR=1.02	0.64-1.55
		20-29 years	48	SMR=1.26	0.93-1.67
		≥30 years	135	SMR=1.02	0.86-1.21
4	Baris 2001	IHD	820	SMR=1.09	1.02-1.16
		By duration of employment			
		9 years or less	172	SMR=1.02	0.88-1.18
		10-19 years	362	SMR=1.35	1.21-1.49
		20+ years	286	SMR=0.90	0.81-1.02
		By Hire Year			
		Hired before 1935	397	SMR=1.32	1.19-1.45
		Hired 1935-1944	229	SMR=0.93	0.77-1.05
		Hired after 1944	194	SMR=0.93	0.81-1.07
		By Cumulative number of runs (1935-1986)			
		Low (<3,323 runs)	221	SMR=1.05	0.92-1.19
		Medium (≥3,323 & <5,099 runs)	111	SMR=0.89	0.74-1.08
		High (≥5,099 runs)	91	SMR=0.77	0.62-0.95
		RR of IHD by cumulative runs (1935-1986)			
		Low (≤3,191 runs)	220	RR=1.00 (ref)	
		High (>3,191 runs)	203	RR=0.77	0.63-0.95
		RR by runs during first 5-years			
		Low (≤729 runs)	204	RR=1.00 (ref)	
		High (>729 runs)	219	RR=1.17	0.96-1.42
		RR by Lifetime Runs with Diesel Exposure (1935-1986)			
		Non-exposed	316	RR=1.00 (ref)	
		Low exposed (1-259 runs)	39	RR=0.74	0.53-1.04
		Medium (260-1,423 runs)	31	RR=0.52	0.36-0.76
		High (≥1,423 runs)	37	RR=0.70	0.47-1.04
5	Beaumont, 1991	IHD	457	RR=0.95	0.87-1.04
6	Bates, 1987	Circulatory deaths by age			
		45-49 years old	12	SMR=1.80	1.01-3.19
		50-54 years old	9	SMR=1.75	0.90-3.39
		45-54 years old	21	SMR=1.73	1.12-2.66
8	Demers, 1992	IHD	394	SMR=0.82	0.74-0.90
9	Deschamps, 1995	IHD	4	SMR=0.74	0.20-1.90
10	Dibbs, 1982	Coronary Heart Disease (MI, angina pectoris, and coronary heart disease deaths)	4	Rate Ratio: 0.5	0.2-1.4
		MI	2	Rate Ratio: 0.5	0.1-1.9
11	Eliopulos, 1984	IHD	39	SMR=0.84	0.60-1.14
12	Glass, 2017	IHD	718	SMR=0.49	0.46-0.53
		Volunteers FF who attended incidents (N=102,073)	411	SMR=0.46	0.41-0.50

ID	First Author, year	Category	obs	Risk Estimate	95% CI
		Relative Mortality Ratios by number of incidents attended (IHD)			
		Baseline (volunteers attending ≤383 incidences/≤fires)	381	Ref	
		Group 2 (volunteers attending 384-1058 incidents/221-576 fires)	15	RR=0.90	0.54-1.50
		Group 3 (Volunteers attending >1058 incidences/>576 fires)	15	RR=1.91	1.14-3.2
		Relative Mortality Ratios by number of fires attended (IHD)			
		Baseline (volunteers attending ≤383 incidences/≤fires)	382	Ref	
		Group 2 (volunteers attending 384-1058 incidents/221-576 fires)	16	RR=0.90	0.55-1.49
		Group 3 (Volunteers attending >1058 incidences/>576 fires)	13	RR=1.86	1.07-3.23
13	Glass, 2016	IHD	189	SMR=0.68	0.59-0.79
		Full time (n=17,394)	150	SMR=0.71	0.60-0.84
		Part time(n=12,663)	39	SMR=0.59	0.42-0.80
14	Grimes, 1991	Arteriosclerotic heart disease (410-414)	29.76%	RR=1.09	0.89-1.35
15	Guidotti, 1993	Circulatory disorders (390-459)	157	SMR=1.031	0.876-1.206
		Heart disease (390-398, 402, 404, 410-416, 420-429)	130	SMR=1.104	0.922-1.311
		IHD	109	SMR=1.059	0.869-1.277
		Arteriosclerosis (410-448)	12	SMR=1.497	0.773-2.615
		CVD by Duration of Employment			
		<1 year	5	SMR=1.18	NS
		1-9 years	27	SMR=1.75	NS
		10-19 years	17	SMR=1.03	NS
		20-29 years	36	SMR=1.02	NS
		30-39 years	58	SMR=0.91	NS
		40+ years	14	SMR=0.82	NS
16	Han, 2018	Angina pectoris		HR=1.06	1.02-1.10
		Acute MI		HR=1.21	1.10-1.32
17	Hansen, 1990	IHD	24	SMR=1.15	0.74-1.71
		First half of time period (1970-1974)	11	SMR=1.48	0.74-2.65
		Second half of time period (1975-1989)	13	SMR=0.97	0.52-1.66
18	Heyer, 1990	Circulatory System	172	SMR=0.78	0.68-0.92
		Arteriosclerotic disease	133	SMR=0.75	0.63-0.89
		Circulatory deaths by age			
		<65 years	83	SMR=0.68	0.54-0.85
		65+ years	89	SMR=0.92	0.74-1.14
		Circulatory deaths by time since first exposure			
		<15 years	3	SMR=0.29	0.06-0.85
		15-29 years	43	SMR=0.73	0.53-0.99
		30+ years	126	SMR=0.85	0.70-1.01
		Circulatory deaths by duration of exposure			
		<15 years	21	SMR=0.63	0.39-0.96
		15-29 years	107	SMR=0.75	0.62-0.91
		30+ years	44	SMR=1.03	0.75-1.38
19	Ide, 1998	IHD	5	SMR=0.22	NR
20	Jeung, 2022	Full Cohort (males and females)			
		Acute MI (20–29 yrs)		HR=4.155	3.041-5.677
		Acute MI (30–39 yrs)		HR=2.375	2.066-2.731
		Acute MI (40–49 yrs)		HR=2.034	1.776-2.330
		Acute MI (>50 yrs)		HR=1.630	1.300-2.044
		Angina pectoris (20–29 yrs)		HR=1.628	1.361-1.948
		Angina pectoris (30–39 yrs)		HR=1.370	1.289-1.456
		Angina pectoris (40–49 yrs)		HR=1.262	1.187-1.341
		Angina pectoris (>50 yrs)		HR=1.370	1.248-1.505

ID	First Author, year	Category	obs	Risk Estimate	95% CI
		By Sex			
		Male			
		Acute MI (20–29 yrs)		HR=2.267	1.532-3.355
		Acute MI (30–39 yrs)		HR=1.426	1.217-1.670
		Acute MI (40–49 yrs)		HR=1.530	1.328-1.762
		Acute MI (>50 yrs)		HR=1.510	1.200-1.902
		Angina pectoris (20–29 yrs)		HR=1.005	0.818-1.233
		Angina pectoris (30–39 yrs)		HR=1.004	0.938-1.075
		Angina pectoris (40–49 yrs)		HR=1.065	1.000-1.134
		Angina pectoris (>50 yrs)		HR=1.39	1.264-1.529
		Female			
		Acute MI (20–29 yrs)		HR=4.745	2.514-8.956
		Acute MI (30–39 yrs)		HR=3.225	1.819-5.719
		Acute MI (40–49 yrs)		HR=2.066	0.857-4.979
		Acute MI (>50 yrs)		HR=1.461	0.364-5.869
		Angina pectoris (20–29 yrs)		HR=1.186	0.745-1.889
		Angina pectoris (30–39 yrs)		HR=0.910	0.646-1.282
		Angina pectoris (40–49 yrs)		HR=1.049	0.702-1.566
		Angina pectoris (>50 yrs)		HR=0.690	0.359-1.327
24	Lee, 2022a	MI	88	SIR=1.54	1.23-1.90
		Male	87	SIR=1.10	0.88-1.36
		Female	1	SIR=12.15	0.31-67.72
25	Lee, 2022b	IHD	1,464	SIR=1.21	1.15-1.27
		MI	157	SIR=0.98	0.83-1.15
26	Ma, 2005	CVD by sex			
		Male FFs	263	SMR=0.73	0.65-0.83
		Male FF certified between 1972 and 1976	222	SMR=0.76	0.66-0.86
		Female FF	8	SMR=3.85	1.66-7.58
27	Musk, 1978	Circulatory (400-468)	1058	SMR=0.86	NR
28	Noh, 2020	MI			
		Compared to Age- and sex-matched group			
		Death or Hospital Admission	579	HR=1.22	1.10-1.35
		Hospital Admission	570	HR=1.23	1.11-1.37
		Death	14	HR=0.90	0.49-1.68
		Compared to Propensity score-matched group			
		Death or Hospital Admission	450	HR=1.24	1.07-1.43
		Hospital Admission	441	HR=1.23	1.07-1.43
		Death	14	HR=1.42	0.61-3.29
		CVD Deaths			
		Compared to Age- and sex-matched group	258	HR=0.85	0.73-0.98
		Compared to Propensity score-matched group	244	HR=1.63	1.32-2.02
29	Pedersen, 2018	All CVDs	1088	SIR=1.12	1.05-1.19
		By duration of employment			
		<5 years	501	SIR=1.19	1.09-1.29
		5-9 years	62	SIR=1.50	1.17-1.93
		10-15 years	53	SIR=1.30	0.99-1.70
		>15 years	472	SIR=1.01	0.91-1.10
		Angina pectoris (413, I20)	495	SIR=1.21	1.11-1.32
		By duration of employment			
		<5 years	235	SIR=1.32	1.16-1.50
		5-9 years	23	SIR=1.33	0.88-2.00

ID	First Author, year	Category	obs	Risk Estimate	95% CI
		10-15 years	24	SIR=1.44	0.96-2.14
		>15 years	213	SIR=1.08	0.94-1.23
		Acute MI (410,411,I21)	344	SIR=1.18	1.06-1.31
		By duration of employment			
		<5 years	164	SIR=1.22	1.04-1.41
		5-9 years	22	SIR=2.02	1.33-3.07
		10-15 years	17	SIR=1.57	0.97-2.52
		>15 years	141	SIR=1.04	0.88-1.23
		Chronic IHD (412, I25)	410	SIR=1.19	1.08-1.31
		By duration of employment			
		<5 years	205	SIR=1.30	1.13-1.49
		5-9 years	18	SIR=1.40	0.88-2.22
		10-15 years	20	SIR=1.62	1.05-2.52
		>15 years	167	SIR=1.03	0.89-1.20
		Cardiac arrest (427.27, I46)	59	SIR=1.12	0.87-1.44
		By duration of employment			
		<5 years	34	SIR=1.46	1.05-2.05
		5-9 years	1	SIR=2.30	0.06-3.08
		10-15 years	5	SIR=2.29	0.95-5.51
		>15 years	19	SIR=0.76	0.48-1.18
		Arteriosclerosis (440, I70)	128	SIR=1.13	0.95-1.35
		By duration of employment			
		<5 years	76	SIR=1.35	1.08-1.69
		5-9 years	7	SIR=2.00	0.98-4.32
		10-15 years	2	SIR=0.58	0.14-2.30
		>15 years	43	SIR=0.86	0.63-1.16
30	Petersen, 2018	Compared to the Military:			
		IHD	134	SMR=1.00	0.84-1.18
		By full/part time:			
		Full-time (by duration of employment)	98	SMR=1.08	0.89-1.32
		<1 year	53	SMR=1.19	0.91-1.56
		≥ 1 year	45	SMR=0.98	0.73-1.31
		≥ 10 years	35	SMR=0.85	0.61-1.18
		≥ 20 years	24	SMR=0.68	0.45-1.01
		Part-time/volunteer	36	SMR=0.82	0.59-1.13
		Compared to Employed Men:			
		IHD	134	SMR=0.86	0.73-1.02
31	Pinkerton, 2020	IHD	3945	SMR=0.98	0.95-1.01
		By race			
		White	3832	SMR=0.99	0.96-1.02
		Other	113	SMR=0.79	0.65-0.95
		By age			
		<65 years	1365	SMR=0.89	0.84-0.93
		65+	2580	SMR=1.04	1.00-1.08
32	Sardinas, 1986	IHD	115	SMR=1.52	1.23-1.81
		IHD	115	MOR=1.07	0.91-1.23
34	Stec, 2023	Acute MI (I21)	57	SMR=0.99	0.75-1.26
		Other acute IHD (I24)	6	SMR=5.27	1.90-10.33
		Chronic IHD (I25)	56	SMR=1.02	0.77-1.31
35	Tornling, 1994	IHD	118	SMR=0.98	0.81-1.17
		By age at death			

ID	First Author, year	Category	obs	Risk Estimate	95% CI
		<50 years old	0	SMR=0.0	0.00-1.07
		50-64	24	SMR=0.90	0.58-1.34
		65+	94	SMR=1.04	0.84-1.27
		By years of employment			
		<20 years	7	SMR=0.65	0.26-1.33
		20-30 years	59	SMR=1.06	0.81-1.37
		>30 years	52	SMR=0.97	0.72-1.27
		By years since first employment			
		<30 years	3	SMR=0.19	0.04-0.56
		30-40 years	27	SMR=0.77	0.50-1.11
		>40 years	131	SMR=0.93	0.78-1.11
		By number of fires attended			
		<800	23	SMR=0.98	0.62-1.46
		800-1000	38	SMR=1.00	0.71-1.38
		>1000	57	SMR=0.97	0.73-1.25
36	Vena 1987	Arteriosclerotic heart disease (410-413)	173	SMR=0.92	0.79-1.07
		By years worked as a FF			
		1-9 years	5	SMR=0.51	NS
		10-19 years	15	SMR=0.81	NS
		20-29 years	44	SMR=0.83	NS
		30-39 years	68	SMR=0.94	NS
		40+ years	41	SMR=1.19	NS
		By calendar year of death			
		1950-1959	41	SMR=1.09	NS
		1960-1969	66	SMR=1.01	NS
		1970-1979	66	SMR=0.77	p≤.05
		By year of hire			
		Prior to 1930	105	SMR=1.11	NS
		1930-1939	27	SMR=0.76	NS
		1940-1949	29	SMR=0.75	NS
		1950+	12	SMR=0.64	NS
		By years of latency			
		<20 years	14	SMR=0.67	NS
		20-29 years	32	SMR=0.89	NS
		30-39 years	52	SMR=0.94	NS
		40-49 years	53	SMR=0.98	NS
		50+ years	22	SMR=0.95	NS
37	Zhao, 2020	CVD (ICD 10: I00-I99)	127	MRR=0.88	0.73-1.06

IHD: Ischemic Heart Disease (ICD9:410–414 and/or ICD: 10-I20-I25, unless otherwise noted) **MI:** Myocardial Infarction **NR:** Not reported **NS:** not statistically significant

Table 5. Extract estimates of heart disease risk and mortality in World Trade Center studies

ID	First Author, year	Category	obs	Risk estimate	95% CI
7	Cohen, 2019	Primary CVD outcome by arrival group			
		Arrival Group 1 (morning of 9/11)		HR=1.44	1.09-1.90
		Arrival Group 2 (afternoon of 9/11)		HR=1.24	1.00-1.54
		Arrival Groups 3&4 (9/12- 9/24)		ref	
		Primary CVD by Duration on WTC Site			
		Duration ≥6 months		HR=1.30	1.05-1.60
		Duration <6 months		ref	
21	Jordan 2011a	Heart Disease by sex and time of arrival			
		Women:			
		9/11, on pile	4	aHR=2.25	0.79-6.40
		9/11, other WTC site	19	aHR=1.94	1.10-3.42
		9/12-9/17	39	aHR=1.76	1.11-2.77
		9/18-6/2022	44	ref	
		Men:			
		9/11, on pile	87	aHR=1.39	1.04-1.86
		9/11, other WTC site	71	aHR=1.21	0.89-1.63
		9/12-9/17	216	aHR=1.24	0.98-1.56
		9/18-6/2022	112	ref	
22	Jordan 2011b	Diseases of the heart	34	SMR=0.39	0.27-0.54
23	Jordan 2018	Disease of the heart			
		Reference: NYC	188	SMR=0.56	0.48-0.64
		Reference: US population	188	SMR=0.40	0.35-0.47
		By smoking status at study enrollment			
		Never		ref	
		Former		aHR=1.38	0.94-2.02
		Current		aHR=4.17	2.86-6.09
		Ischemic heart disease (reference: NYC)	140	SMR=0.53	0.44-0.62
33	Sloan, 2021	CVD by sex			
		Men	NR	HR=2.16	1.97-2.37
		Women	NR	HR=2.94	2.10-4.11

CVD: cardiovascular disease **WTC:** World Trade Center

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 Y-S, Jeong KS. Mortality due to malignant and non-malignant diseases in Korean professional emergency responders. PLoS ONE. 2015;10:1–14.	Additional Search
2	Amadeo, B., et al., French firefighter mortality: analysis over a 30-year period. Am J Ind Med, 2015. 58(4): p. 437-43.	Pubmed Search
3	Anderson, T.J., et al., Microvascular function predicts cardiovascular events in primary prevention: long-term results from the Firefighters and Their Endothelium (FATE) study. Circulation, 2011. 123(2): p. 163-9.	Pubmed Search
4	Anderson, T.J., et al., The fate of endothelial function testing: rationale and design of the Firefighters And Their Endothelium (FATE) study. Can J Cardiol, 2003. 19(1): p. 61-6.	Pubmed Search
5	Angleman, A.J., V.B. Van Hasselt, and B.B. Schuhmann, Relationship Between Posttraumatic Stress Symptoms and Cardiovascular Disease Risk in Firefighters. Behav Modif, 2022. 46(2): p. 321-351.	Pubmed Search
6	Aronson KJ, Tomlinson GA, Smith L. 1994. Mortality among fire fighters in metropolitan Toronto. Am J Ind Med 26:89–101.	Additional Search
7	Barger, L.K., et al., Common sleep disorders increase risk of motor vehicle crashes and adverse health outcomes in firefighters. J Clin Sleep Med, 2015. 11(3): p. 233-40.	Pubmed Search
8	Baris, D., et al., Cohort mortality study of Philadelphia firefighters. Am J Ind Med, 2001. 39(5): p. 463-76.	Pubmed Search
9	Barnard RJ, Duncan HW, Diaco NV (1976) "Ischemis" heart disease in firefighters with normal coronary arteries. J Occup Med 18: 818-820	Additional Search
10	Barrett TW, Norton VC, Busam M, et al. Self-reported cardiac risk factors in emergency department nurses and paramedics. Prehosp Disaster Med 2000;15:14–17.	Additional Search
11	Bates JT. 1987. Coronary artery disease deaths in the Toronto Fire Department. J Occup Med 29:132–135.	Additional Search
12	Baxter, C.S., et al., Ultrafine particle exposure during fire suppression--is it an important contributory factor for coronary heart disease in firefighters? J Occup Environ Med, 2010. 52(8): p. 791-6.	Pubmed Search
13	Beaumont, J.J., et al., An epidemiologic study of cancer and other causes of mortality in San Francisco firefighters. Am J Ind Med, 1991. 19(3): p. 357-72.	Pubmed Search
14	Bos, J., et al., Risk of health complaints and disabilities among Dutch firefighters. Int Arch Occup Environ Health, 2004. 77(6): p. 373-82.	Pubmed Search
15	Brant-Rauf PW, Fallon Jr. LF, Tarantini T, Idema, C, Andrews, L. 1988. Health hazards of Freighters: Exposure assessment. Br J Ind Med 45:606±612.	Additional Search
16	Burnett CA, Halperin WE, Lalich NR, Sestito JP. 1994. Mortality among ®re ®ghters: a 27 state survey. Am J Ind Med 26:831±883.	Additional Search
17	Burris, J.C., C.M. Werner, and K. Woolf, The Relationship Between Dietary Intake and Dietary-Focused Lifestyle Interventions on Risk Factors Associated with Cardiovascular Disease in Firefighters. Curr Nutr Rep, 2022. 11(2): p. 206-224.	Pubmed Search
18	Calvert, G.M., J.W. Merling, and C.A. Burnett, Ischemic heart disease mortality and occupation among 16- to 60-year-old males. J Occup Environ Med, 1999. 41(11): p. 960-6.	Pubmed Search
19	Carlén, A., et al., ST/HR variables in firefighter exercise ECG - relation to ischemic heart disease. Physiol Rep, 2019. 7(2): p. e13968.	Pubmed Search

20	Choi, B.C., A technique to re-assess epidemiologic evidence in light of the healthy worker effect: the case of firefighting and heart disease. Journal of occupational and environmental medicine, 2000. 42(10): p. 1021-1034.	Pubmed Search
21	Choi, B.C., Mathematical procedure to adjust for the healthy worker effect: the case of firefighting, diabetes, and heart disease. J Occup Environ Med, 2001. 43(12): p. 1057-63.	Pubmed Search
22	Cohen, H.W., et al., Long-term Cardiovascular Disease Risk Among Firefighters After the World Trade Center Disaster. JAMA Netw Open, 2019. 2(9): p. e199775.	Pubmed Search
23	Crawford, J.O. and R.A. Graveling, Non-cancer occupational health risks in firefighters. Occup Med (Lond), 2012. 62(7): p. 485-95.	Pubmed Search
24	Daniels RD, Bertke S, Dahm MM, et al. Exposure-response relationships for select cancer and non-cancer health outcomes in a cohort of US firefighters from San Francisco, Chicago and Philadelphia (1950– 2009). Occup Environ Med. 2015;0:1–8.	Additional Search
25	Daniels RD, Kubale TL, Yiin JH, Dahm MM, Hales TR, Baris D, Zahm SH, Beaumont JJ, Waters KM, Pinkerton LE. 2013. Mortality and cancer incidence in a pooled cohort of US firefighters from San Francisco, Chicago and Philadelphia (1950–2009). Occup Environ Med doi:10.1136/oemed-2013-101662.	Additional Search
26	Decoufle P, Lloyd JW, Salvin LG. Mortality by cause among stationary engineers and stationary firemen. J Occup Med 1977; 19:679-82.	Additional Search
27	Demers, P.A., N.J. Heyer, and L. Rosenstock, Mortality among firefighters from three northwestern United States cities. Br J Ind Med, 1992. 49(9): p. 664-70.	Pubmed Search
28	Deschamps, S., I. Momas, and B. Festy, Mortality amongst Paris fire-fighters. Eur J Epidemiol, 1995. 11(6): p. 643-6.	Pubmed Search
29	Dibbs E, Thomas HEJ, Weiss ST, Sparrow D. Fire fighting and coronary heart disease. Circulation 1982;65:943–946.	Additional Search
30	Douglas DB, Douglas RB, Oakes D, Scott G (1985): Pulmonary functon of London firemen. Br J Ind Med 42:55-58	Additional Search
31	Dubrow R, Burnett CA, Gute DM, Brockert JE. Ischemic heart disease and acute myocardial infarction mortality among police officers. J Occup Med 1988;30:650-4.	Additional Search
32	Dueñas-Laita, A., J.L. Peréz-Castrillón, and M. Ruiz-Mambrilla, Heart disease deaths among firefighters. N Engl J Med, 2007. 356(24): p. 2535; author reply 2536-7.	Pubmed Search
33	Dzikowicz, D.J. and M.G. Carey, Exercise-Induced Premature Ventricular Contractions Are Associated With Myocardial Ischemia Among Asymptomatic Adult Male Firefighters: Implications for Enhanced Risk Stratification. Biol Res Nurs, 2020. 22(3): p. 369-377.	Pubmed Search
34	Dzikowicz, D.J. and M.G. Carey, Severity of Myocardial Ischemia Is Related to Career Length Rather Than Age Among Professional Firefighters. Workplace Health Saf, 2021. 69(4): p. 168-173.	Pubmed Search
35	Eliopulos E, Armstrong BK, Spickett JT, Heyworth F. 1984. Mortality of fire fighters in Western Australia. Br J Ind Med 41:183–187.	Additional Search
36	Fahy RF. U.S. Firefighter Fatalities Due to Sudden Cardiac Death, 1995– 2004. Quincy, MA: National Fire Protection Association, June 2005. Available at: http://www.nfpa.org/assets/files/PDF/OSCardiacDeath.pdf. Accessed February 21, 2009.	Additional Search
37	Fatalities among volunteer and career firefighters--United States, 1994-2004. MMWR Morb Mortal Wkly Rep, 2006. 55(16): p. 453-5.	Pubmed Search
38	Felton JS (1973) Conducting cardiopulmonary evaluations of County of Los Angeles safety personnel. Health serv Res 88:515	Additional Search
39	Feuer, E. and K. Rosenman, Mortality in police and firefighters in New Jersey. Am J Ind Med, 1986. 9(6): p. 517-27.	Pubmed Search
40	Franke WD, Collins SA, Hinz PN. Cardiovascular disease morbidity in an Iowa law enforcement cohort, compared with the general Iowa population. J Occup Environ Med 1998;40:441–4.	Additional Search
41	Franke WD, Cox DF, Schultz DP, et al. Coronary heart disease risk factors in employees of Iowa's Department of Public Safety compared to a cohort of the general population. Am J Ind Med 1997;31:733–7.	Additional Search
42	Franke WD, Ramey SL, Shelley MC. Relationship between cardiovascular disease morbidity, risk factors, and stress in a law enforcement cohort. J Occup Environ Med 2002;44:1182–9.	Additional Search

43	Friel, J.K. and M. Stones, Firefighters and heart disease. Am J Public Health, 1992. 82(8): p. 1175-6.	Pubmed Search
44	Gellissen J, Pattloch D, Mohner M. Effects of occupational exposure to respirable quartz dust on acute myocardial infarction. Occup Environ Med. 2019;76(6):370–375. [PubMed: 31010894]	Additional Search
45	Glass D, Pircher S, Del Monaco A, et al. Austalian firefighters' Health study. Melbourne: Monash University, 2014.	Additional Search
46	Glass DC, Pircher S, Del Monaco A, Vander Hoorn S, SimMR. Mortality and cancer incidence in a cohort of male paid Australian firefighters. Occup Environ Med. (2016) 73:761–71. doi: 10.1136/oemed-2015-103467	Additional Search
47	Glass, D.C., et al., Mortality and cancer incidence among male volunteer Australian firefighters. Occup Environ Med, 2017. 74(9): p. 628-638.	Pubmed Search
48	Glueck, C.J., et al., Risk factors for coronary heart disease among firefighters in Cincinnati. Am J Ind Med, 1996. 30(3): p. 331-40.	Pubmed Search
49	Grimes G, Hirsch D, Borgeson D. Risk of death among Honolulu firefighters. Hawaii Med J. 1991;50:82–85.	Additional Search
50	Guidotti TL, Clought V (1992) Occupational health concerns of firefighting. Ann Rev Public Health 13	Additional Search
51	Guidotti, T.L., Human factors in firefighting: ergonomic-, cardiopulmonary-, and psychogenic stress-related issues. Int Arch Occup Environ Health, 1992. 64(1): p. 1-12.	Pubmed Search
52	Guidotti, T.L., Mortality of urban firefighters in Alberta, 1927-1987. Am J Ind Med, 1993. 23(6): p. 921-40.	Pubmed Search
53	Guidotti, T.L., Occupational mortality among firefighters: assessing the association. J Occup Environ Med, 1995. 37(12): p. 1348-56.	Pubmed Search
54	Haas, N.S., et al., Latent health effects in firefighters. Int J Occup Environ Health, 2003. 9(2): p. 95-103.	Pubmed Search
55	Hammar N, Alfredsson L, Smedberg M, Ahlbom A. Differences in the incidence of myocardial infarction among occupational groups. Scand J Work Environ Health. 1992;18:178–185.	Additional Search
56	Han, M., et al., 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): p. e019987.	Pubmed Search
57	Hansen, E.S., A cohort study on the mortality of firefighters. Br J Ind Med, 1990. 47(12): p. 805-9.	Pubmed Search
58	Hegg-Deloye, S., et al., Current state of knowledge of post-traumatic stress, sleeping problems, obesity and cardiovascular disease in paramedics. Emerg Med J, 2014. 31(3): p. 242-7.	Pubmed Search
59	Heyer N, Weiss nS, Demers P, Rosenstock L (1990): Cohort mortality study of Seattle fire fighters: 1945-1983. Am J Ind Med 17:493-504	Additional Search
60	Holder, J.D., et al., Firefighter heart presumption retirements in Massachusetts 1997-2004. J Occup Environ Med, 2006. 48(10): p. 1047-53.	Pubmed Search
61	Holtermann, A., Mortensen, O. S., Søgaard, K., Gyntelberg, F., & Suadicani, P. (2012). Risk factors for ischaemic heart disease mortality among men with different occupational physical demands. A 30-year prospective cohort study. BMJ Open, 2(1), Article e000279.	Additional Search
62	Ide, C.W., A longitudinal survey of the evolution of some cardiovascular risk factors during the careers of male firefighters retiring from Strathclyde Fire Brigade from 1985-1994. Scott Med J, 2000. 45(3): p. 79-83.	Pubmed Search
63	Ide, C.W., 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. 48(6): p. 381-8.	Pubmed Search
64	International Association of Fire Fighters. Available at: http://www.iaff.org/ hs/phi/disease/heartDisease.asp. Accessed February 5, 2010.	Additional Search
65	Jeung, D.Y., et al., Effects of Emergency Duties on Cardiovascular Diseases in Firefighters: A 13-Year Retrospective Cohort Study. J Occup Environ Med, 2022. 64(6): p. 510-514.	Pubmed Search
66	Jordan HT, Brackbill RM, Cone JE, et al. Mortality among survivors of the Sept 11, 2001, World Trade Center disaster: results from the World Trade Center Health Registry cohort. Lancet. 2011;378(9794):879–887. [PubMed: 21890052]	Additional Search

67	Jordan HT, Miller-Archie SA, Cone JE, Morabia A, Stellman SD. Heart disease among adults exposed to the September 11, 2001 World Trade Center disaster: results from the World Trade Center Health Registry. Prev Med. 2011;53(6):370–376. [PubMed: 22040652]	Additional Search
68	Jordan HT, Stein CR, Li J, et al. Mortality among rescue and recovery workers and community members exposed to the September 11, 2001 World Trade Center terrorist attacks, 2003–2014. Environ Res. 2018;163:270–279. [PubMed: 29477875]	Additional Search
69	Kales, S.N., et al., Emergency duties and deaths from heart disease among firefighters in the United States. N Engl J Med, 2007. 356(12): p. 1207-15.	Pubmed Search
70	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	Additional Search
71	L'Abbe KA, Tomlinson GA. Scientific Report: Mortality Study of Fire Fighters in Metropolitan Toronto. Toronto, Ontario Industrial Disease Standards Panel, 1992	Additional Search
72	Lee, J., et al., Risk of Cerebro-Cardiovascular Diseases among Police Officers and Firefighters: A Nationwide Retrospective Cohort Study. Yonsei Med J, 2022. 63(6): p. 585-590.	Pubmed Search
73	Lee, W.R., et al., 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, 2022. 10: p. 1070023.	Pubmed Search
74	Li, K., et al., Correlates of atherosclerotic cardiovascular disease risk in older Colorado firefighters. Occup Med (Lond), 2018. 68(1): p. 51-55.	Pubmed Search
75	Licciardone, J.C., et al., Projected incidence of cardiovascular disease in male firefighters based on current risk factor prevalence. J Am Osteopath Assoc, 1989. 89(10): p. 1293-4, 1297-301.	Pubmed Search
76	Lin S, Gomez MI, Gensburg L, LiuW, Hwang SA. Respiratory and cardiovascular hospitalizations after theWorld Trade Center disaster. Arch Environ Occup Health. 2010;65(1):12-20. doi:10.1080/19338240903390230	Additional Search
77	Ma, F., et al., Mortality in Florida professional firefighters, 1972 to 1999. Am J Ind Med, 2005. 47(6): p. 509-17.	Pubmed Search
78	Maguire BJ, Hunting KL, Smith GS, Levick NR. Occupational fatalities in emergency medical services: a hidden crisis. Ann Emerg Med. 2002; 40:625–632. [PubMed: 12447340]	Additional Search
79	Mastromatteo E (1959) Mortality in city firemen: II. A study of mortality in firemen of a city fire department. AMA Arch Ind Health 20: 277-283	Additional Search
80	Mbanu I, Wellenius GA, Mittleman MA, Peeples L, Stallings LA, Kales SN. Seasonality and coronary heart disease deaths in United States firefighters. Chronobiol Int. 2007;24(4):715-26.	Pubmed Search
81	Melius, J.M., Cardiovascular disease among firefighters. Occup Med, 1995. 10(4): p. 821-7.	Pubmed Search
82	Milham S, Jr (1983): "Occupational mortality in Washington State, 1950-1979." DHHS (NIOSH) Publication No. 83-116. Washington DC: USGPO	Additional Search
83	Mochtar, I. and R.W. Hooper, Assessment of the 10-year risk of coronary heart disease events for Qatar Petroleum's firefighters and non-firefighter staff in Qatar. East Mediterr Health J, 2012. 18(2): p. 127-31.	Pubmed Search
84	Moffatt SM, Stewart DF, Jack K, Dudar MD, Bode ED, Mathias KC, Smith DL. Cardiometabolic health among United States firefighters by age. Prev Med Rep. 2021;23:101492. doi: 10.1016/j.pmedr.2021.101492. PMID: 34354906; PMCID: PMC8322457.	Additional Search
85	Muegge, C.M., et al., Excess mortality among Indiana firefighters, 1985-2013. Am J Ind Med, 2018. 61(12): p. 961-967.	Pubmed Search
86	Musk, A.W., et al., Mortality among Boston firefighters, 1915--1975. Br J Ind Med, 1978. 35(2): p. 104-8.	Pubmed Search
87	NIOSH. Alert: Preventing Firefighter Fatalities Due To Heart Attacks and Other Sudden Cardiovascular Events. DHHS (NIOSH) Publication No. 2007–133. Atlanta, GA: NIOSH; 2007.	Additional Search

88	Noh, J., et al., Blood pressure and the risk of major adverse cardiovascular events among firefighters. J Hypertens, 2020. 38(5): p. 850-857.	Pubmed Search
89	Nowbar AN, Gitto M, Howard JP, Francis DP, Al-Lamee R. Mortality from ischemic heart disease. Circ Cardiovasc Qual Outcomes. 2019; 12(6):e005375. [PubMed: 31163980]	Additional Search
90	Pedersen, J.E., et al., Incidence of cardiovascular disease in a historical cohort of Danish firefighters. Occup Environ Med, 2018. 75(5): p. 337-343.	Pubmed Search
91	Petersen GR, Milham S Jr, et al (1983) Occupoational mortality in the State of California, 1959-1961. US Public Health Service, Cincinnati, DHHS (NIOSH) pub no 83-116	Additional Search
92	Petersen KU, Pederson JE, Bonde JP, Ebbehoj NE, Hansen J. Mortality in a cohort of Danish firefighters; 1970–2014. Int Arch Occup Environ Health. 2018;91:759–766.	Additional Search
93	Pinkerton L, Bertke SJ, Yiin J, Dahm M, Kubale T, Hales T, et al. Mortality in a cohort of US firefighters from San Francisco, Chicago and Philadelphia: an update. Occup Environ Med. 2020;77(2):84-93.	Additional Search
94	Raymond, L.W. and T.A. Barringer, Proper testing for myocardial ischemia in firefighters. Am J Cardiol, 2009. 103(9): p. 1329.	Pubmed Search
95	Raymond, L.W., T.A. Barringer, and J.C. Konen, Heart disease deaths among firefighters. N Engl J Med, 2007. 356(24): p. 2535-6; author reply 2536-7.	Pubmed Search
96	Remch M, Laskaris Z, Flory J, Mora-McLaughlin C, Morabia A. Post-traumatic stress disorder and cardiovascular diseases: a cohort study of men and women involved in cleaning the debris of the World Trade Center complex. Circ Cardiovasc Qual Outcomes. 2018; 11(7):e004572. [PubMed: 29991645]	Additional Search
97	Risavi, B.L. and J. Staszko, Prevalence of Risk Factors for Coronary Artery Disease in Pennsylvania (USA) Firefighters. Prehosp Disaster Med, 2016. 31(1): p. 102-7.	Pubmed Search
98	Rosenstock L, Demers P, Heyer N, Barnhart S (1988): Mortality experience of fire fighters in the Northwest University States. Arbete Och Halsa 16:102	Additional Search
99	Rosenstock L, Demers P, Heyer NJ, Barnhart S. 1990. Respiratory mortality among firefighters. Br J Ind Med 47:462–465.	Additional Search
100	Rosenstock, L. and J. Olsen, Firefighting and death from cardiovascular causes. N Engl J Med, 2007. 356(12): p. 1261-3.	Pubmed Search
101	Santora, L.J., et al., Coronary calcium scanning independently detects coronary artery disease in asymptomatic firefighters: a prospective study. J Cardiovasc Comput Tomogr, 2013. 7(1): p. 46-50.	Pubmed Search
102	Sardinas a, Miller JW, Hansen H. ischemic heart disease mortality of firemen and policemen. Am J Public Health 1986;76:1140–1.	Additional Search
103	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.	Additional Search
104	Schnall PL, Dobson M, Landsbergis P. Globalization, work, and cardiovascular disease. Int J Health Serv. 2016;46(4):656–692. [PubMed: 27604540]	Additional Search
105	Shockey TM,SA, Odom EC. Cardiovascular Health Status by Occupational Group—21 States, 2013. Centers for Disease Control and Prevention. 2016;65:793–798.	Additional Search
106	Sidor R, Peters JM (1974b): Prevalence rates of chronic non-specific respiratory diseases in fire fighters. Amer Rev Rsp Dis 109: 255-261	Additional Search
107	Sjögren, B. and G. Johanson, Mortality in Florida professional firefighters, 1972-1999. Am J Ind Med, 2006. 49(2): p. 138-40.	Pubmed Search
108	Skogstad M, Johannessen HA, Tynes T, Mehlum IS, Nordby KC, Lie A. Systematic review of the cardiovascular effects of occupational noise. Occup Med (Lond) 2016;66:10-6.	Additional Search

109	Sloan, N.L., et al., Cardiovascular disease in the World Trade Center Health Program General Responder Cohort. Am J Ind Med, 2021. 64(2): p. 97-107.	Pubmed Search
110	Smith DL, Barr DA, Kales SN. Extreme sacrifice: sudden cardiac death in the US Fire Service. Extrem Physiol Med. 2013;2:6.	Additional Search
111	Smith DL, Fehling PC, Frisch A, Haller JM, Winke M, Dailey MW. The prevalence of cardiovascular disease risk factors and obesity in firefighters. J Obes. 2012;2012:908267.	Additional Search
112	Smith DL, Manning TS, Petruzzello SJ. Effect of strenuous live-fire drills on cardiovascular and psychological responses of recruit firefighters. Ergonomics. 2001;44:244–254.	Additional Search
113	Smith, D.L., et al., Cardiovascular Disease Risk Factor Changes Over 5 Years Among Male and Female US Firefighters. J Occup Environ Med, 2020. 62(6): p. 398-402.	Pubmed Search
114	Smith, D.L., et al., Cardiovascular Strain of Firefighting and the Risk of Sudden Cardiac Events. Exerc Sport Sci Rev, 2016. 44(3): p. 90-7.	Pubmed Search
115	Smith, D.L., et al., The Relation of Emergency Duties to Cardiac Death Among US Firefighters. Am J Cardiol, 2019. 123(5): p. 736-741.	Pubmed Search
116	Soteriades, E.S., et al., Cardiovascular disease in US firefighters: a systematic review. Cardiol Rev, 2011. 19(4): p. 202-15.	Pubmed Search
117	Staley, J.A., B. Weiner, and L. Linnan, Firefighter fitness, coronary heart disease, and sudden cardiac death risk. Am J Health Behav, 2011. 35(5): p. 603-17.	Pubmed Search
118	Stec, A.A., et al., Scottish Firefighters Occupational Cancer and Disease Mortality Rates: 2000-2020. Occup Med (Lond), 2023. 73(1): p. 42-48.	Pubmed Search
119	Steenland K. Epidemiology of occupation and coronary heart disease: research agenda. Am J Ind Med 1996;30:495-9	Additional Search
120	Stewart RD, Stewart RS, Stamm W, Seelen RP. Rapid estimation of carboxyhemoglobin level in fire fighters. JAMA 1976;235: 390-2.	Additional Search
121	Straif K, Baan R, Grosse Y, Secretan B, El Ghissassi F, Bouvard V, Altieri A, Benbrahim-Tallaa L, Cogliano V. 2007. Carcinogenicity of shift-work, painting, and fire-fighting. Lancet Oncol 8:1065–1066.	Additional Search
122	Superko, H.R., et al., Firefighters, heart disease, and aspects of insulin resistance: the FEMA Firefighter Heart Disease Prevention study. J Occup Environ Med, 2011. 53(7): p. 758-64.	Pubmed Search
123	Tharkar S, Kumpatla S, Muthukumaran P, et al. High prevalence of metabolic syndrome and cardiovascular risk among police personnel compared to general population in India. J Assoc Physicians India 2008;56:845–9.	Additional Search
124	Tonne C, Melly S, Mittleman M, Coull B, Goldberg R, Schwartz J. A case-control analysis of exposure to traffic and acute myocardial infarction. Environ Health Perspect. 2007;115:53–57.	Additional Search
125	Tonne C, Yanosky J, Gryparis A, et al. Traffic particles and occurrence of acute myocardial infarction: a case-control analysis. Occup Environ Med. 2009;66:797–804.	Additional Search
126	Tornling G, Gustavsson P, Hogstedt C. 1994. Mortality and cancer incidence in Stockholm fire fighters. Am J Ind Med 25:219–228.	Additional Search
127	Tridata Corporation. Firefighter Fatality Retrospective Study (April 2002). Prepared for Federal Emergency Management Agency, United States Fire Service, National Fire Data Center; Arlington, VA: 2002.	Additional Search
128	United States Fire Administration. Firefighter fatalities. (Accessed February 21, 2007, at http://www.usfa.fema.gov/ fatalities/.)	Additional Search
129	Vanchiere, C., et al., Association Between Atrial Fibrillation and Occupational Exposure in Firefighters Based on Self-Reported Survey Data. J Am Heart Assoc, 2022. 11(7): p. e022543.	Pubmed Search
130	Vena JE, Fiedler RC. 1987. Mortality of a municipal-worker cohort: IV. Fire®ghters. Am J Ind Med 11:671±684.	Additional Search
131	Violanti JM, Andrew ME, Burchfiel CM, et al. Posttraumatic stress symptoms and subclinical cardiovascular disease in police officers. Int J Stress Manag 2006;13:541–54.	Additional Search

132	Violanti JM, Fekedulegn D, Hartley TA, et al. Life expectancy in police officers: a comparison with the U.S. general population. Int J Emerg Ment Health 2013;15:217–28.	Additional Search
133	Violanti JM, Fekedulegn D, Hartley TA, et al. Police trauma and cardiovascular disease: association between PTSD symptoms and metabolic syndrome. Int J Emerg Ment Health. 2006;8:227–237.	Additional Search
134	von Rotz, M., Aeschbacher, S., Bossard, M., Schoen, T., Blum, S., Schneider, S., Estis, J., Todd, J., Risch, M., Risch, L., & Conen, D. (2017). Risk factors for premature ventricular contractions in young and healthy adults. Heart, 103(9), 702–707.	Additional Search
135	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. Env Health 4:5–27.	Additional Search
136	Washburn AE, LeBlanc PR, Fahy RF. 1997 Firefighter Fatalities. National Fire Protection Association Journal. 1998; 92:50–62.	Additional Search
137	Wimberley, P. (2016). Improving cardiovascular risk profiles in firefighters. Nursing and Health, 4(3), 32–35.	Additional Search
138	Wisnivesky JP, Teitelbaum SL, Todd AC, et al. Persistence of multiple illnesses in World Trade Center rescue and recovery workers: a cohort study. Lancet. 2011;378(9794):888–97. [PubMed: 21890053]	Additional Search
139	Witt, M. and J. Pluczyńska, [Can smoking habit be a real risk factor of coronary heart disease in firefighters?]. Przegl Lek, 2007. 64(10): p. 848-52.	Pubmed Search
140	Wolkow, A., et al., Coronary heart disease risk in volunteer firefighters in Victoria, Australia. Arch Environ Occup Health, 2014. 69(2): p. 112-20.	Pubmed Search
141	Wright BR, Barbosa-Leiker C, Hoekstra T. Law enforcement officer versus non-law enforcement officer status as a longitudinal predictor of traditional and emerging cardiovascular risk factors. J Occup Environ Med 2011;53:730–4.	Additional Search
142	Yook YS. Firefighters' occupational stress and its correlations with cardiorespiratory fitness, arterial stiffness, heart rate variability, and sleep quality. PLoS One. 2019;14:1– 9. doi: 10.1371/journ al.pone.0226739	Additional Search
143	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;64:614-21.	Additional Search
144	Zimmerman FH. Cardiovascular disease and risk factors in law enforcement personnel: a comprehensive review. Cardiol Rev 2012;20:159–66.	Additional Search