JLARC Review of Virginia's Disease Presumptions

Epidemiology Consultant Technical Report

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Prepared by the Johns Hopkins Bloomberg School of Public Health

Mary Fox

Kelsey Babik

Thomas Burke

Erin Morin

Beth Resnick

Wendy Shields

Andrea Uhlig

Ahsan Zil-E-Ali

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Epidemiology Consultant Report: Executive Summary

Under contract with Virginia's Joint Legislative Audit and Review Commission (JLARC), John Hopkins University (JHU) investigators prepared the following report to inform a review and potential modifications to Virginia's occupational disease presumption policies. The work included a review of health outcomes and a review of requirements to claim cancer presumption.

Approach – Health outcomes

Health outcomes included: Cancer outcomes, pneumoconiosis, post-traumatic stress disorder and suicide were outcomes requested by JLARC. JLARC also requested review of cardiovascular and respiratory diseases without further specification. As the research progressed and the literature was reviewed JHU worked with JLARC to add and further specify outcomes for inclusion to ensure timely completion of the project. The selected cardiovascular and respiratory outcomes are those that are most prevalent in the US population.

Cancer	Cardiovascular	Respiratory	Mental Health
Brain (proposed) Breast Colon (proposed) Leukemia Ovarian Pancreatic Prostate Rectal Testicular (proposed) Throat	Hypertension Ischemic heart disease (IHD) Myocardial infarction (MI) Sudden cardiac death (SCD)	Asthma Chronic obstructive pulmonary disease (COPD) Emphysema Respiratory mortality Pneumoconiosis	Post-traumatic stress disorder (PTSD) Suicide

Summary of literature search: We conducted an electronic literature search of the public health, medical and psychology databases for articles published between January 1, 2009 and May 31, 2019. We also included works recommended by JLARC constituents if they met the date and topical criteria. Included articles: (1) were human epidemiology studies; (2) assessed exposure-disease or occupation-disease association; (3) specified the worker populations of interest; (4) focused on the specified diseases only; and (5) were published in English. Articles were excluded if they were: (1) not published in English; (2) focused on treatment; (3) were focused on exposures or risk factors only; (4) were hypothesis-generating or mechanism studies (animal toxicology, cell-culture); or (5) were popular press or news articles. In total about 8000 unique articles were gathered and screened but the vast majority were excluded based on the criteria above. The final tally of articles by outcome was:

- Cancer: 19
- Cardiovascular: 35
- Post-traumatic stress disorder: 17
- Respiratory: 14
- Suicide: 14
- Pneumoconiosis: 12

Summary of literature evaluation: In assessing study quality and evaluating the dataset developed from the literature search, the epidemiology consultants adapted a standard framework similar to that applied by committees of the National Academies of Science, Engineering and Medicine, e.g., in the Veterans and Agent Orange and other reports. The evaluation process requires an assessment of each study individually and then collectively as group. The categories of "strength of evidence" are: Sufficient evidence; Supportive evidence; Suggestive evidence; Insufficient evidence; and No evidence.

Approach – Review of requirements to claim cancer presumption

The epidemiology consultants reviewed background JLARC provided on the toxic exposure and length of service requirements. Based on that background, the epidemiology consultants summarized and presented: 1) current research on firefighter exposure assessment methods and findings; 2) and information on exposure duration and development of cancer including cancer latency. Recommendations were made on the basis of the information presented.

Main findings on health outcomes

Overview: The epidemiological studies reviewed had mixed results for almost all outcomes of interest, that is, there was evidence of both increased and decreased risk. The evaluation approach described above was designed to consider all of the studies gathered to identify the "signals" of increased or decreased risk within the mixed results.

Dose-response: A few studies addressing dose-response were found in the datasets for cancer, cardiovascular disease and PTSD and suicide. There is supportive evidence of dose-response relationships indicating increased risk for the listed outcomes for longer length of service and numbers of fire incidents attended.

Cancer in firefighters

Sufficient evidence of **increased risk**: prostate cancer

Supportive evidence of **increased risk**: brain cancer, throat cancer

Suggestive evidence of **increased risk**: leukemia, rectal cancer, testicular cancer

Insufficient evidence to determine: breast cancer, colon cancer, pancreatic cancer

No evidence: ovarian cancer

Cardiovascular disease in firefighters

Suggestive evidence of **increased risk**: coronary heart disease, myocardial infarction (heart attack)

Suggestive evidence of **decreased risk**: heart disease mortality

Insufficient evidence to determine: hypertension, ischemic heart disease, sudden cardiac death

Cardiovascular disease in police

Suggestive evidence of **increased risk**: hypertension, myocardial infarction (heart attack)

Insufficient evidence to determine: coronary heart disease

No evidence: ischemic heart disease, heart disease mortality, sudden cardiac death

Respiratory disease in firefighters

Sufficient evidence of **decreased risk**: respiratory mortality

Supportive evidence of **decreased risk**: chronic obstructive pulmonary disease

Suggestive evidence of **increased risk**: asthma

Insufficient evidence to determine: emphysema

Post-traumatic stress disorder in firefighters and police

Supportive evidence of **increased risk** of PTSD in firefighters and police

Suicide in firefighters and police

Supportive evidence of **decreased risk** of suicide in firefighters

Insufficient evidence to determine in police

Pneumoconiosis: JLARC also requested a descriptive review of information on pneumoconiosis, not linked to firefighter or police occupations. The pneumoconiosis review focused on the types of jobs prone to the disease(s) and risk determinations were not made. Several diseases are classified under pneumoconiosis by US NIOSH: asbestosis, silicosis, and coal worker's pneumoconiosis (CWP). The intensity and duration of dust exposures that lead to pneumoconiosis are not found outside of occupational settings; therefore, pneumoconiosis is not typically found in the general population. A NIOSH surveillance database collected between 1990 and 1999 identified many jobs with higher than expected mortality from pneumoconiosis in several industrial sectors: construction; manufacturing; mining; services; transport/warehousing/utilities; and wholesale and retail trade. Jobs where deaths from pneumoconiosis were observed much more frequently than expected included mining machine operators, insulation workers, boilermakers, and plumbers, pipefitters, and steamfitters.

Review of Requirements for Claiming Cancer Presumption

The toxic exposure requirement

- **Recommendation: Demonstrating exposure and absorption of a specific carcinogen is not a feasible task for a firefighter.**
    - Sampling equipment and analysis costs hundreds of dollars to document exposures from a single event.
    - Smoke is a complex mixture of chemicals and particles (and particles can carry chemicals). Smoke exposures from different types of fires (training, structural, vehicle, wild land) have been shown to contain carcinogenic and mutagenic chemicals and particles.
    - Firefighters are exposed to and absorb carcinogenic mixtures in smoke.
    - Wearing protective gear and SCBA reduces exposure, however, firefighters are exposed to the constituents of smoke even when wearing and removing protective gear

Twelve years of continuous service requirement

- **Recommendation: The data summarized on exposure duration and minimum cancer latency indicates scientific support to lower or reduce Virginia's length of service requirement.**
    - No data identified by the consultants supports a 12-year length of service requirement.
    - There is indirect evidence from the cancer epidemiology literature reviewed that exposure durations less than 12 years can result in increased cancer risk.
    - Although data are limited, most cancers of interest to JLARC could have a minimum latency of as few as 4 years.
    - These data on exposure duration and minimum cancer latency may also inform statute of limitations timeframes.

Epidemiology Consultant Report on Cancer Outcomes

Approach in Brief (see further details in methods appendix)

Search results - Cancer

- Final total of papers included/summarized:
    - Cancer papers: 19
        - Includes two systematic reviews: one on prostate cancer and one with multiple cancer outcomes (Jalilian et al., 2019; Sritharan et al., 2017). These papers will be identified in the report where their findings contribute.

Study quality and use of data for determinations

In assessing study quality and evaluating the dataset developed from the literature search, the epidemiology consultants adapted a standard framework similar to that applied by committees of the National Academies of Science, Engineering and Medicine, e.g., in the Veterans and Agent Orange reports. The evaluation process requires assessing each study on: (1) the quality of the data; (2) appropriateness of methods used; and (3) putting the findings of each study in the context of the larger dataset of other studies. The assessment of data collection addresses several key areas of scientific concern ranging from the identification of study participants and controls and their representativeness to the population of concern in the policy matter, whether exposures and outcomes are correctly defined, and whether the data collected is free from potential bias. Assessing the methods addresses how well the results actually inform the questions asked in the study. The topic of contribution to the dataset is covered below in “Considerations for “strength of evidence” determinations”. An overall summary of the study and dataset quality considerations and features of the dataset are presented in Table C1.

Most types of cancer develop slowly over time – this time period is called latency. For the cancer of interest to JLARC, cancer latencies range from 8 – 50 years (Nadler & Zurbenko, 2014). Therefore, length of follow-up is an important study quality issue in a cancer assessment. A good-quality cancer study will allow for an adequate number of years of latency in the follow-up of the participants.

Table C1. Description of study quality and dataset evaluation - Cancer

Evaluation Areas	Scientific concerns	Features specific to the cancer studies gathered
1) Data collection	Well-defined populations (exposed and unexposed) Sample size or number of participants (if small the study may not be representative of the population of concern) Data free of potential bias (over-reporting or under-reporting)	Worker and comparison groups well-defined Mostly large sample sizes Data from independent surveillance systems or systematic reviews
2) Analytical methods applied	Appropriate statistical methods Control for known risk factors and potential confounders Adequate follow-up time	Standard methods used Age always included and most studies also controlled for other common confounders 24 years on average
3) Contribution to overall dataset	Statistically significant findings Consistent findings Replicated in different places Similar magnitude of risk Similar direction of increase or decrease	All studies reported 1 or more statistically significant findings Studies from multiple US states and other countries Generally small increases and decreases Mixed for most outcomes

The included cancer studies are of good quality and methodologically sound. Most studies are large cohort studies. The data analyzed were drawn from surveillance systems and standard analyses were applied to present standardized incidence and mortality ratios (SIR or SMR) or odds ratios (a few presented Relative Risks or Hazard Ratios). Age was uniformly accounted for and some studies also adjusted for other important factors including race, ethnicity, and education. Because cancer is a group of diseases with a latency period between the start of exposure and the development of illness, it is important to check that cancer studies have allowed for enough time to actually observe cancer outcomes in the population of concern. Most studies included in this review provided details of follow-up time ranging from 9 to 45 years with an average of 24 years of follow-up.

A note about colon and rectal cancers: While JLARC asked for colon and rectal cancer data separately, in US cancer statistics it is common to find the combined data for colorectal cancer and there are several common risk factors including age, diet high in red and processed meats, alcohol consumption, and overweight according to the American Cancer Society (ACS, 2019). Genetic profiling of mutations in colon and rectal cancer cells suggest some differences in these cancers (Hong, Clark, & Haigis, 2012). Different latency periods are reported for colon (40-50 years) and rectal cancers (~30 years) (Nadler & Zurbenko, 2014). After diagnosis, there are important differences in the approach to treatment relating to the sizes and locations of these body parts: the colon is part of the abdomen and is about 5 feet long; the rectum is part of the pelvic area and is about 5 inches long. Surgery is easier for colon cancer than rectal cancer due to these differences of location and size and rectal cancer has a greater rate of recurring in the pelvic area (Hong et al., 2012).

- Although often presented together in national statistics, it is appropriate to consider colon and rectal cancers as separate cancers due to differences identified above.

The Statement of Work also asked that the studies reviewed be evaluated for "independence" or freedom from potential stakeholder influence. Nine of the cancer studies had an author or funding from fire service or insurance agencies. However, because of the quality assessment indicating good data sources and study methods it is our view that **the potential for influence was NOT evident** in the dataset itself. There were no differences in their data or methods compared to other studies in the cancer dataset; therefore, all of the studies were considered in the determinations of strength of evidence below.

Following the quality review, the evaluation of the cancer studies continued with consideration of how each study contributed to the dataset as a whole to define the overall "strength of evidence". The main criteria used to assess the dataset for each cancer outcome were strength of association including statistical significance and consistency/replication (summarized in Table C2). Strength of association means measures of association of 2 or greater – indicating at least of doubling of risk[1]; replication means multiple studies in different settings; and consistency means generally similar quantitative results. Each cancer type/site of interest to JLARC was then categorized accordingly. All nineteen cancer studies were reviewed in developing the "strength of evidence" determinations, however, not every study reported statistically significant results for every outcome. Statistically significant results of both increased and

1 A risk measure of 2 or greater is a commonly used indicator of strength of association.

decreased risk are evaluated as described to make a determination for each cancer type/site. Determinations are presented in Table C3.

Table C2. Guide for determinations

"Strength of Evidence" Category	**Features of the dataset**
Sufficient evidence	Several (5 or more) consistent studies with statistically significant positive associations and one or more studies finding relative risk/SMR/SIR more than 2; few (2-3) studies finding decreased risk
Supportive evidence	At least 3 studies with statistically significant positive associations with one or more studies finding relative risk/SMR/SIR more than 2; one or no studies finding statistically significant decreased risk
Suggestive evidence	Few (2-3) studies with statistically significant increased risk or positive associations with risks less than 2; one or no studies with statistically significant decreased risk
Insufficient evidence	Three (3) or fewer studies with: No statistically significant findings of increased and/or decreased risk; OR Statistically significant findings of both increased and decreased risk
No evidence	No data found

Literature Review Findings - Cancer

Overview

Overall, the cancer studies present mixed results. For most of the cancers of interest, there are statistically significant findings for increased and decreased risk. No data was found for ovarian cancer. Fifteen of the nineteen included studies reported data on male firefighters only. None of the four studies that did include females reported ovarian cancer (Daniels et al., 2014; Glass, Del Monaco, Pircher, Vander Hoorn, & Sim, 2019; Jalilian et al., 2019; Muegge et al., 2018). In this group of studies firefighting as an occupation is the exposure of interest and no other measures of specific exposures were reported, e.g., air monitoring for benzene or other components of smoke at fire scenes (further discussion included in the Phase 3 report). Only a small number of studies evaluated "dose-response" in terms of duration of employment/length of service or numbers of fire runs attended (see below).

IARC Monograph (2010)

The literature search conducted builds on the IARC 2010 monograph on firefighting and cancer. IARC concluded that firefighting was a possible carcinogen (IARC, 2010). The IARC committee also conducted a meta-analysis on several cancer sites including two of interest to JLARC. IARC reported findings of increased risks for prostate cancer based on 16 studies [1.30; 95% CI: 1.12–1.51] and testicular cancer based on 6 studies [1.47, 95% CI: 1.20–1.80].

Dose-response

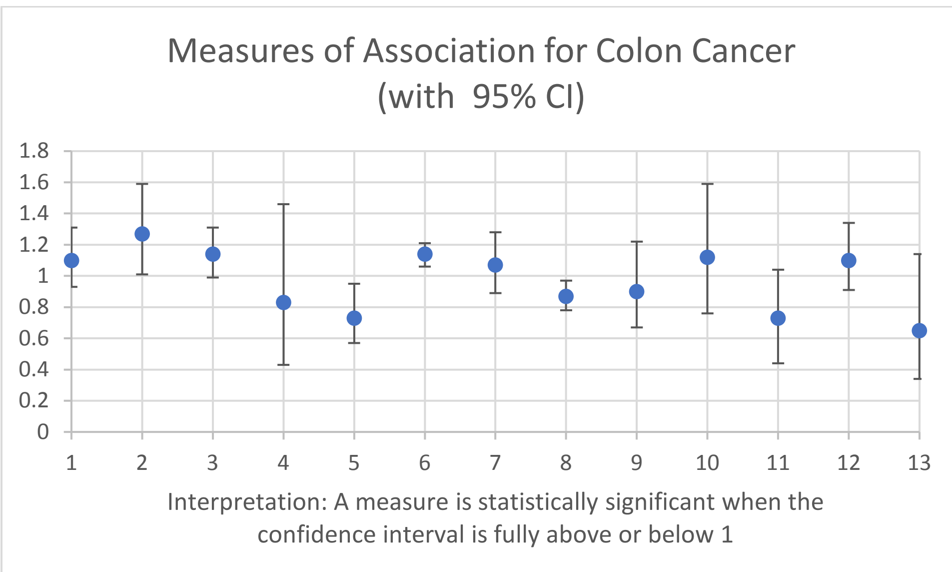
Information relevant to dose- or exposure-response was not uniformly assessed in the studies gathered in this review. Four studies did address this issue in different ways such as number of fire runs or incidents attended and length of service or employment duration: 1) increased incidence of total cancer with increasing employment duration (statistically significant trend) (Kullberg et al., 2018); 2) increased total cancer mortality among firefighters with 20 or more years of service (Ahn & Jeong, 2015); 3) significant positive association between leukemia mortality and greater than 2100 fire runs (Daniels et al., 2015); and 4) head and neck cancer risk (a surrogate for throat) was higher in firefighters with more than 10 years of service (Paget-Bailly et al., 2013).

- There is supportive evidence of positive dose-response relationships for cancer outcomes.

Discussion of cancer determinations (see Summary in Table C3)

Colon: Insufficient evidence

Studies identified in this review found statistically significant evidence of both increased and decreased risk of colon cancer in firefighters. There were two studies reporting increased risk including the Jalilian systematic review reporting a summary incidence risk estimate of 1.14 (95% CI: 1.06, 1.21) (Ahn, Jeong, & Kim, 2012; Jalilian et al., 2019). Two studies reported statistically significant decreased risk (Glass, Del Monaco, Pircher, Vander Hoorn, & Sim, 2017; Petersen, Pedersen, Bonde, Ebbehoj, & Hansen, 2018). One of these studies (on Korean firefighters) reported combined data on colorectal cancer (Ahn et al., 2012) but others reported the data separately for colon cancers and rectal cancers. Some studies report multiple results (incidence and mortality) as shown below. [Total studies: 12; Number lacking statistically significant findings: 8]

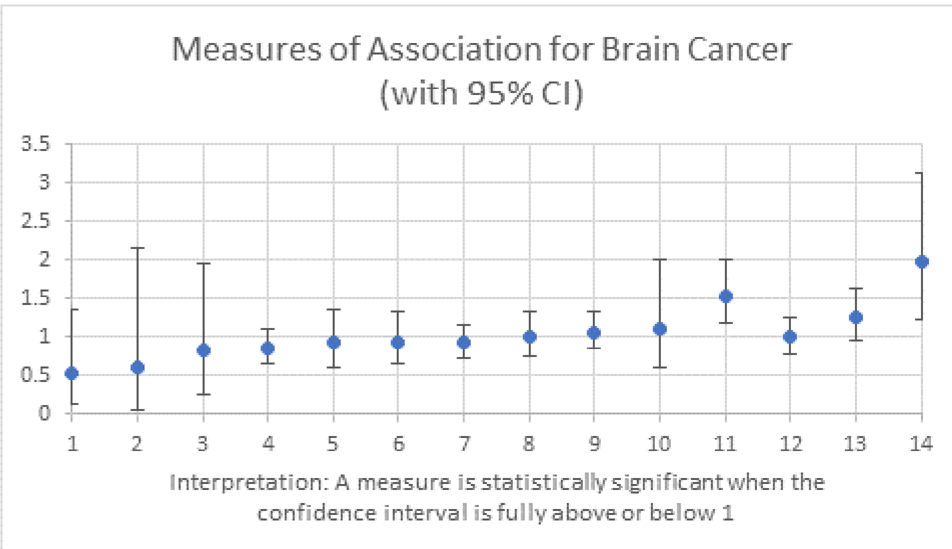


Statistically significant findings marked with *

1. Tsai et al. 2015 (Incidence)
2. Ahn et al. 2012 (Incidence)*
3. Pukkala et al. 2014 (Incidence)
4. Kullberg et al. 2018 (Incidence)
5. Petersen et al. 2018 (Incidence)*
6. Jalilian et al. 2019 (Incidence)*
7. Glass et al. 2016 Male Paid (Incidence)
8. Glass et al. 2017 Male Volunteer (Incidence)*
9. Harris et al. 2018 (Incidence)
10. Glass et al. 2019 Female (Incidence)
11. Brice et al. 2015 (Mortality)
12. Jalilian et al. 2019 (Mortality)
13. Ahn and Jeong 2015 (Mortality)

Brain: Supportive evidence of increased risk

Among three studies with statistically significant evidence of increased risk, one had a SIR of 5.7 (Glass, Del Monaco, Pircher, Vander Hoorn, & Sim, 2016; Muegge et al., 2018; Tsai et al., 2015). One of these studies, done in Australia investigated cancer risks related to firefighter training reported a SIR of 5.7 (Glass, Del Monaco, et al., 2016) (not included with chart below). This finding was considered as evidence of increased risk. However, the magnitude of this risk measure should be viewed with caution because of potential differences due to the setting, i.e., this greatly increased risk may not apply to firefighters or their trainers in general. There were no studies with statistically significant evidence of decreased risk. The Jalilian et al. systematic review and eight other studies reported findings that were not statistically significant. Some studies report multiple results (incidence and mortality) as shown below. [Total studies: 13; Number lacking statistically significant findings: 10]



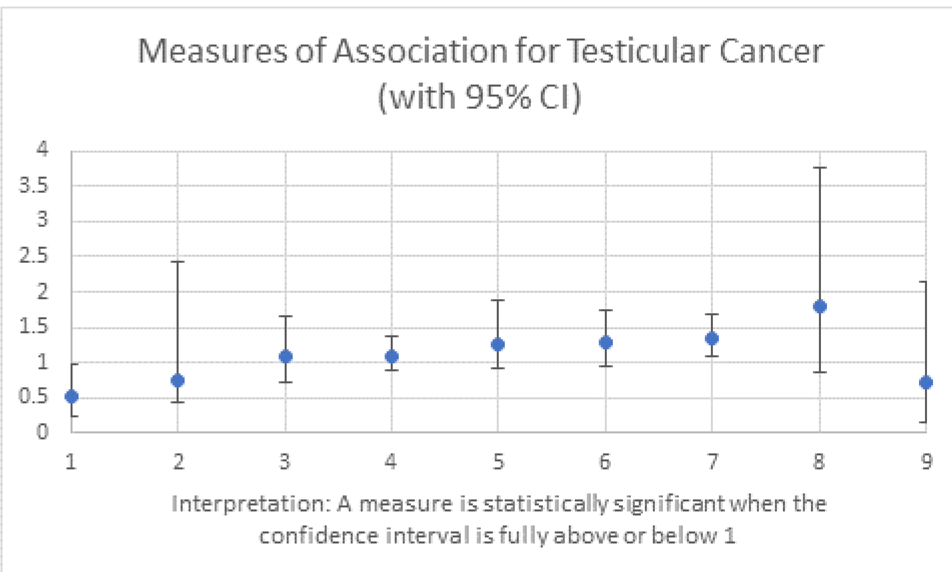
Statistically significant findings marked with *

1. Ahn et al. 2012 (Incidence)
2. Kullberg et al. 2018 (Incidence)
3. Glass et al. 2019 Female (Incidence)
4. Pukkala et al. 2014 (Incidence)
5. Glass et al. 2016 Male Paid (Incidence)
6. Petersen et al. 2018 (Incidence)
7. Glass et al. 2017 Male Volunteer (Incidence)
8. Daniels et al. 2014 (Incidence)
9. Jalilian et al. 2019 (Incidence)
10. Harris et al. 2018 (Incidence)
11. Tsai et al. 2015 (Incidence)*
12. Daniels et al. 2014 (Mortality)
13. Jalilian et al. 2019 (Mortality)
14. Muegge et al. 2018 (Mortality)*

Note: High results from Glass et al. study of fire trainers not plotted because it makes it difficult to read other results*

Testicular: Suggestive evidence of increased risk

There were two studies with statistically significant evidence of increased risk including the Jalilian et al. systematic review reported a summary incidence risk estimate of 1.34 (95% CI: 1.08, 1.68). One of these studies, done in Australia investigated cancer risks related to firefighter training reported a SIR of 11.9 (Glass, Del Monaco, et al., 2016) (not included with chart below). This finding was considered as evidence of increased risk. However, the magnitude of this risk measure should be viewed with caution because of potential differences due to the setting, i.e., this greatly increased risk may not apply to firefighters or their trainers in general.   There was one study of a large cohort with long follow-up finding with statistically significant evidence of decreased risk (Pukkala et al., 2014). Some studies report multiple results (incidence and mortality) as shown below.   [Total studies: 9; Number lacking statistically significant findings: 6]



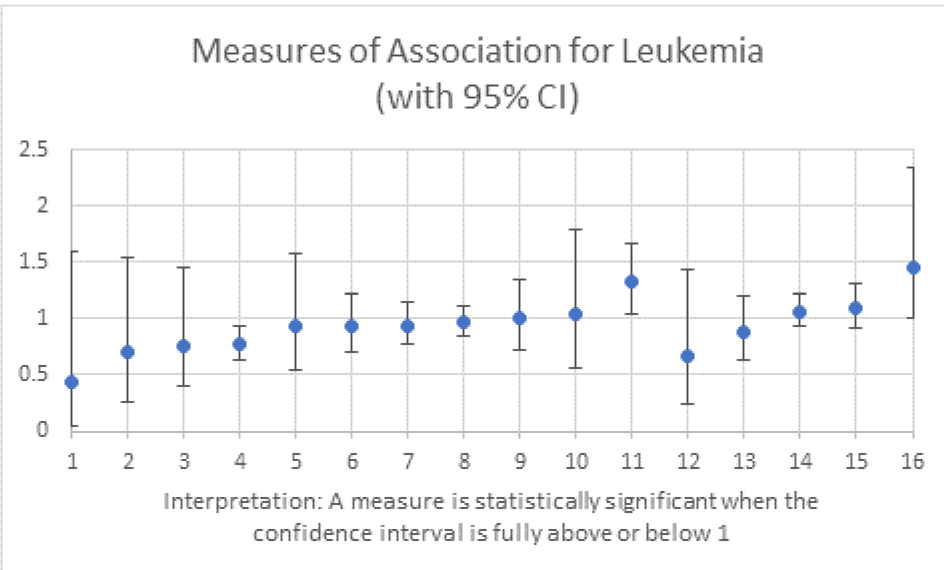
Statistically significant findings marked with *

1. Pukkala et al. 2014 (Incidence)*
2. Daniels et al. 2014 (Incidence)
3. Tsai et al. 2015 (Incidence)
4. Glass et al. 2017 Male Volunteer (Incidence)
5. Glass et al. 2016 Male Paid (Incidence)
6. Petersen et al. 2018 (Incidence)
7. Jalilian et al. 2019 (Incidence)*
8. Harris et al. 2018 (Incidence)
9. Daniels et al. 2014 (Mortality)

Note: High result from Glass et al. study of fire trainers not plotted because it makes it difficult to read other results*

Leukemia: Suggestive evidence of increased risk

There were three studies with statistically significant evidence of increased risk (Ahn & Jeong, 2015; Daniels et al., 2015; Tsai et al., 2015). One of these studies, done in South Korea, reported a relative risk of mortality of 84 in firefighters with more than 20 years of employment but this was calculated on the basis of only two deaths (Ahn & Jeong, 2015) (not included with chart below). This finding was considered as evidence of increased risk. However, this finding should be viewed with caution because of the small number of deaths and the possibility of other differences, e.g., in cancer detection or treatment, due to the setting (South Korea). There was one study with statistically significant evidence of decreased risk (Glass et al., 2017). The Jalilian et al. systematic review and seven other studies reported findings that were not statistically significant. Some studies report multiple results (incidence and mortality) as shown below. [Total studies: 14; Number lacking statistically significant findings: 10]



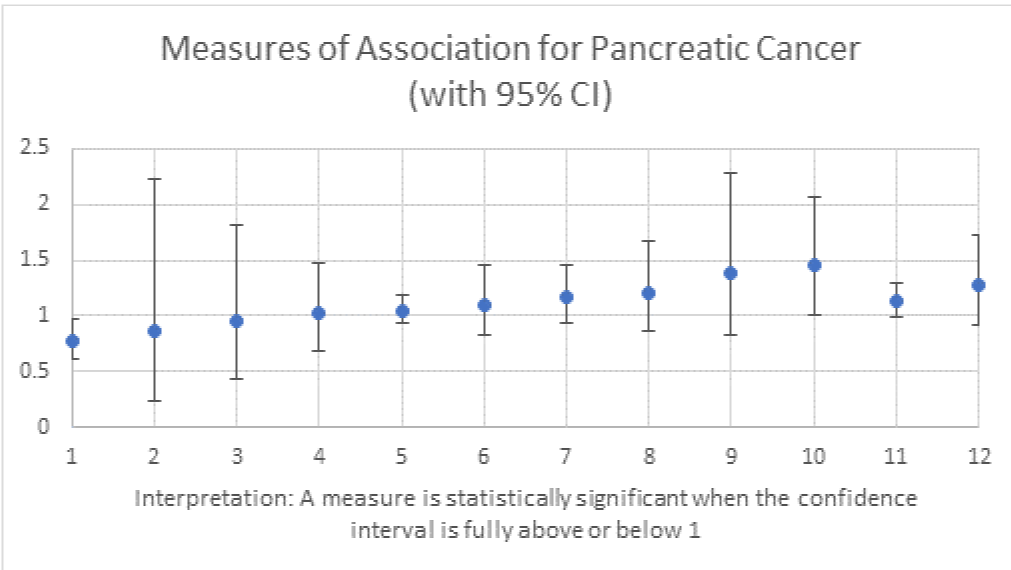
Statistically significant findings marked with *

1. Kullberg et al. 2018 (Incidence)
2. Glass et al. 2019 Female (Incidence)
3. Petersen et al. 2018 (Incidence)
4. Glass et al. 2017 Male Volunteer (Incidence)*
5. Harris et al. 2018 (Incidence)
6. Pukkala et al. 2014 (Incidence)
7. Daniels et al. 2014 (Incidence)
8. Glass et al. 2016 Male Paid (Incidence)
9. Jalilian et al. 2019 (Incidence)
10. Ahn et al. 2012 (Incidence)
11. Tsai et al. 2015 (Incidence)*
12. Ahn and Jeong 2015 (Mortality)
13. Brice et al. 2015 (Mortality)
14. Jalilian et al. 2019 (Mortality)
15. Daniels et al. 2014 (Mortality)
16. Daniels et al. 2015 (Mortality)*

Note: High adjusted relative risk results from Ahn and Jeong 2015 not plotted because they make it difficult to read other results; one of these two results was statistically significant as noted above*

Pancreatic: Insufficient evidence

There was one study with statistically significant evidence of increased mortality risk (Muegge et al., 2018) and one study with statistically significant evidence of decreased risk of pancreatic cancer incidence in firefighters (Glass et al., 2017). The Jalilian et al. systematic review and seven other studies reported findings that were not statistically significant. Some studies report multiple results (incidence and mortality) as shown below. [Total studies: 11; Number lacking statistically significant findings: 9]

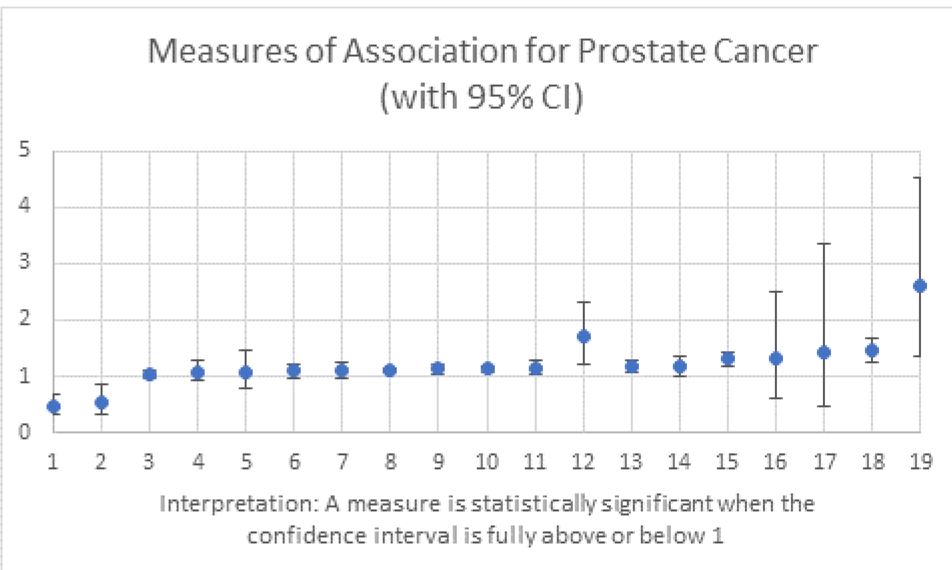


Statistically significant findings marked with *

1. Glass et al. 2017 Male Volunteer (Incidence)*
2. Kullberg et al. 2018 (Incidence)
3. Ahn et al. 2012 (Incidence)
4. Glass et al. 2016 Male Paid (Incidence)
5. Jalilian et al. 2019 (Incidence)
6. Tsai et al. 2015 (Incidence)
7. Pukkala et al. 2014 (Incidence)
8. Petersen et al. 2018 (Incidence)
9. Harris et al. 2018 (Incidence)
10. Muegge et al. 2018 (Mortality)*
11. Jalilian et al. 2019 (Mortality)
12. Brice et al. 2015 (Mortality)

Prostate: Sufficient evidence of increased risk

Since the IARC 2010 monograph, seven more studies have found statistically significant increased risks of prostate cancer in firefighters with one study finding a SIR of 2.6 (Barry et al., 2017; Glass et al., 2017; Glass, Pircher, Del Monaco, Hoorn, & Sim, 2016; Harris et al., 2018; Jalilian et al., 2019; Pukkala et al., 2014; Sritharan et al., 2017). These included the Sritharan et al. systematic review with a summary incidence risk estimate of 1.17 (95% CI: 1.08, 1.28) and the Jalilian et al. systematic review reported summary incidence risk estimate of 1.15 (95% CI: 1.05, 1.27). One large study found evidence of increased risk of early-onset prostate cancer among firefighters (early onset defined as increased risk of prostate cancer in men aged 30 – 49 years) (Barry, Martinsen et al. 2017). Two studies found statistically significant decreased risk (Kullberg et al., 2018) (Brice et al., 2015). Some studies report multiple results as shown below (e.g., Jalilian et al. reported a statistically significant results for incidence [#11] but not for mortality [#4]). [Total studies: 13; Number lacking statistically significant findings: 4]

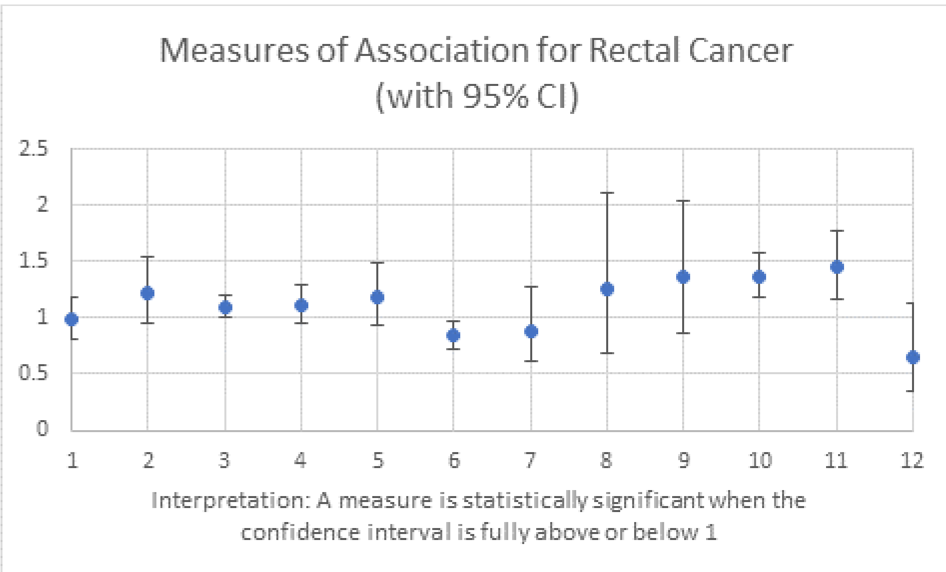


Statistically significant findings marked with *

1. Kullberg et al. 2018 (Incidence)*
2. Brice et al. 2015 (Mortality)*
3. Daniels et al. 2014(Incidence)
4. Jalilian et al. 2019 (Mortality)
5. Sritharan et al. 2017 (Mortality)
6. Daniels et al. 2014 (Mortality)
7. Petersen et al. 2018 (Incidence)
8. Barry et al. 2017 Late Onset (Incidence)*
9. Pukkala et al. 2014 (Incidence)*
10. Glass et al. 2017 Male Vol (Incidence)*
11. Jalilian et al. 2019 (Incidence)*
12. Barry et al. 2017 Early onset (Incidence)*
13. Sritharan et al. 2017 (incidence)*
14. Harris et al. 2018 (Incidence)*
15. Glass et al. 2016 Male Paid (Incidence)*
16. Ahn et al. 2012 (Incidence)
17. Glass et al. 2016 Trainers (Incidence)
18. Tsai et al. 2015 (Incidence)*
19. Pukkala et al. 2014 Early Onset (Incidence)*

Rectal: Suggestive evidence of increased risk

There were three statistically significant findings of increased risk but no risks greater than 2; this includes the Jalilian et al. systematic review reported summary incidence risk estimate of 1.09 (95% CI: 1.00, 1.20) (Daniels et al., 2014; Jalilian et al., 2019). There was one study with statistically significant evidence of decreased risk (Glass et al., 2017). Some studies report multiple results (incidence and mortality) as shown below. [Total studies: 10; Number lacking statistically significant findings: 7]

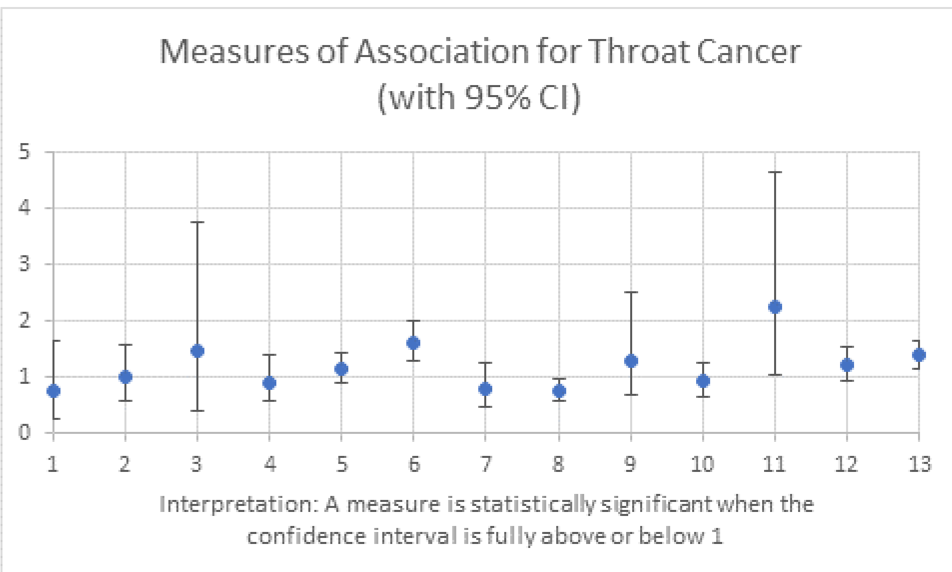


Statistically significant findings marked with *

1. Pukkala et al. 2014 (Incidence)
2. Petersen et al. 2018 (Incidence)
3. Jalilian et al. 2019 (Incidence)*
4. Daniels et al. 2014 (Incidence)
5. Glass et al. 2016 Male Paid (Incidence)
6. Glass et al. 2017 Male Volunteer (Incidence)*
7. Harris et al. 2018 (Incidence)
8. Glass et al. 2019 Female (Incidence)
9. Brice et al. 2015 (Mortality)
10. Jalilian et al. 2019 (Mortality)*
11. Daniels et al. 2014 (Mortality)*
12. Ahn and Jeong 2015 (Mortality)

Throat Cancer: Supportive evidence of increased risk

Cancers of the throat were not consistently reported in the literature reviewed. To inform the question about cancers of the throat, data were extracted for esophagus or pharynx, or buccal cavity and pharynx. One study reported on head and neck cancer, also used as a surrogate for throat cancer. Four studies found statistically significant increased risk for throat cancer based on the surrogate sites; two of these studies reported risks greater than 2 [ORs of 3.9 from Paget-Bailly et al. and 2.3 from Meugge et al.] (Daniels et al., 2014; Muegge et al., 2018; Paget-Bailly et al., 2013; Tsai et al., 2015). The highest OR was reported from a study done in France by Paget-Bailly et al. (not included with chart below). This finding was considered as evidence of increased risk. However, the magnitude of this risk measure should be viewed with caution because of potential differences due to the setting (France). There was one study finding decreased risk (Glass et al., 2017). The Jalilian et al. systematic review and six other studies reported findings that were not statistically significant. Some studies report multiple results (incidence and mortality) as shown below. [Total studies: 13; Number lacking statistically significant findings: 8]



Statistically significant findings marked with *

1. Ahn et al. 2012 (Incidence)
2. Pukkala et al. 2014 (Incidence)
3. Kullberg et al. 2018 (Incidence)
4. Petersen et al. 2018 (Incidence)
5. Jalilian et al. 2019 (Incidence)
6. Daniels et al. 2014 (Incidence)*
7. Glass et al. 2016 Male Paid (Incidence)
8. Glass et al. 2017 Male Vol. (Incidence)*
9. Harris et al. 2018 (Incidence)
10. Brice et al. 2015 (Mortality)
11. Muegge et al. 2018 (Mortality)*
12. Jalilian et al. 2019 (Mortality)
13. Daniels et al. 2014 (Mortality)*

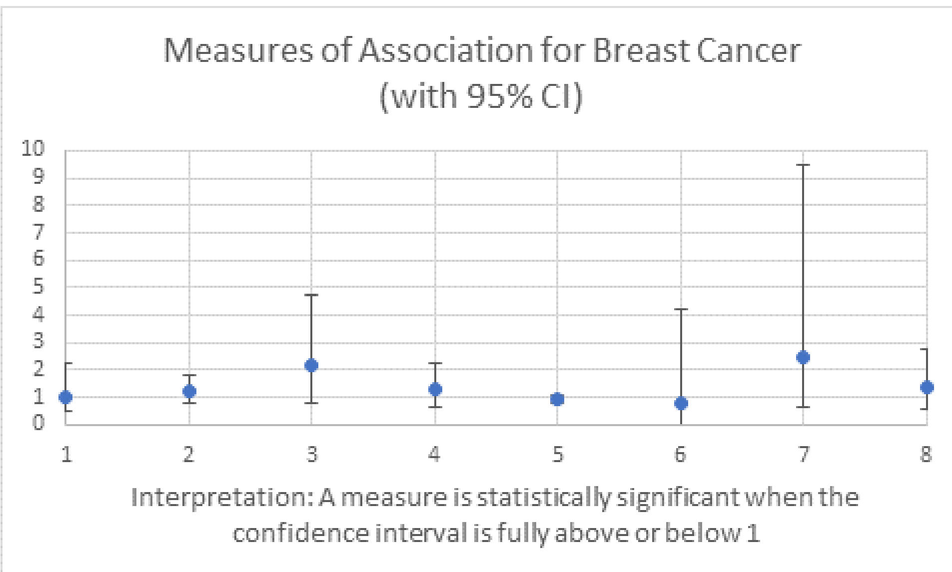
Note: High result from Paget-Bailly et al. study not plotted because it makes it difficult to read other results*

Ovarian: No evidence found

None of the four studies that included female firefighters reported data on ovarian cancer.

Breast: Insufficient evidence

There were six studies with breast cancer data with no statistically significant findings reported including the Jalilian et al. systematic review (Brice et al., 2015; Daniels et al., 2014; Glass et al., 2017, 2019; Glass, Pircher, et al., 2016; Jalilian et al., 2019). Only one of these studies was specific to females (volunteer firefighters with fire incident experience) (Glass et al., 2019). Some studies report multiple results (incidence and mortality) as shown below. [Total studies: 6; Number lacking statistically significant findings: 6]



1. Jalilian et al. 2019 (Incidence)
2. Daniels et al. 2014 (Incidence)
3. Glass et al. 2016 Male Paid (Incidence)
4. Glass et al. 2017 Male Volunteer (Incidence)
5. Glass et al. 2019 Female (Incidence)
6. Brice et al. 2015 (Mortality)
7. Jalilian et al. 2019 (Mortality)
8. Daniels et al. 2014 (Mortality)

Table C3. Determinations for firefighter cancer

Cancer Type/Site	Total Studies and Number without statistically significant findings	"Strength of Evidence" Determination	Evidence of increased risk	Evidence of decreased risk
Colon (proposed)	Total: 12 NSS: 8	Insufficient evidence	2 studies with statistically significant findings[J]	2 studies with statistically significant findings
Brain (proposed)	Total: 13 NSS: 10[J]	Supportive evidence of *increased* risk	3 studies with statistically significant findings	Not found
Testicular (proposed)	Total: 9 NSS: 6	Suggestive evidence of *increased* risk	2 studies with statistically significant findings[J]	1 study with statistically significant findings
Leukemia	Total: 14 NSS: 10[J]	Suggestive evidence of *increased* risk	3 studies with statistically significant findings	1 study with statistically significant findings
Pancreatic	Total: 11 NSS: 9[J]	Insufficient evidence	1 study with statistically significant findings	1 study with statistically significant findings
Prostate	Total: 13 NSS: 4	Sufficient evidence of *increased* risk	7 studies with statistically significant findings[J,S]	2 studies with statistically significant findings
Rectal	Total: 10 NSS: 7	Suggestive evidence of *increased* risk	2 studies with statistically significant findings[J]	1 study with statistically significant findings
Throat	Total: 13 NSS: 8[J]	Supportive evidence of *increased* risk	4 studies with statistically significant findings	1 study with statistically significant findings
Ovarian	Total: 0 NSS: 0	No evidence found	Not found	Not found
Breast	Total: 6 NSS: 6[J]	Insufficient evidence	No statistically significant findings	No statistically significant findings

Abbreviations and notations: NSS: not statistically significant; Superscript J indicates the Jalilian et al. systematic review, superscript S indicates the Sritharan systematic review

Summary of increased risk

For the purposes of the planned actuarial analysis, a summary of the statistically significant increased risk estimates for those cancer sites/types where evidence of *increased risk* was found is presented in Table C4. Where available the following risk measures are presented, Hazard Ratio (HR), odds ratio (OR) standardized incidence ratio (SIR), or standardized mortality ratio (SMR). These measures can be interpreted as percentages, i.e., a SIR of 1.20 indicates a 20% increase in disease incidence in firefighters over the comparison population. Three studies done outside the US setting reported very high measures of association; in Australian fire trainers an OR of 5.74 for brain cancer (only 4 cases) and SIR of 11.9 for testicular cancer (only 2 cases) (Glass, Del Monaco, et al., 2016); in France an OR of 3.9 for throat cancer (Paget-Bailly et al., 2013); and in Korean firefighters a relative risk of leukemia mortality of 84 (this was based on only 2 deaths in an internal comparison among firefighters with 20 years of service to firefighters employed less than 10 years) (Ahn & Jeong, 2015). These results were included in the determinations as indicators of increased risk, however, these data may not be relevant to the US context due to differences in the settings and they are not included in Table C4 (or in charts). Data from the IARC meta-analysis and the Jalilian et al. and Sritharan et al. systematic reviews are included as marked in Table C4 (IARC, 2010; Jalilian et al., 2019; Sritharan et al., 2017).

Table C4. Risk estimates for cancers with evidence of increased risk

Cancer Type/Site	**"Strength of Evidence" Determination**	**Measures of association (risk)**
Brain (proposed)	Supportive evidence of *increased* risk	ORs: 1.54, 1.98
Testicular (proposed)	Suggestive evidence of *increased* risk	SIRs: 1.34, 1.47[I]
Leukemia	Suggestive evidence of *increased* risk	HR: 1.45 OR: 1.32
Prostate	Sufficient evidence of *increased* risk	HR: 1.18 SIRs: 1.13, 1.15, 1.17[S], 1.30[I], 1.31, 1.71, 2.59
Rectal	Suggestive evidence of *increased* risk	SIR: 1.09[J] SMR: 1.36[J], 1.45
Throat	Supportive evidence of *increased* risk	ORs: 1.39, 1.59, 1.62, 2.26

Notes: Superscript I indicates IARC; Superscript J indicates the Jalilian et al. systematic review, superscript S indicates the Sritharan et al. systematic review.

Epidemiology Consultant Report on Cardiovascular Disease (CVD) Outcomes

Approach in Brief (see further details in methods appendix)

Search results CVD

- 35 CVD studies included
- Breakdown by occupation:
  - 18 firefighters alone
    - 1 included men and women firefighters
  - 13 police alone
    - 1 included men and women police officers
  - 4 had combined populations of first responders
    - 1 hazardous materials (HazMat) officers and firefighters
    - 3 police and firefighters
- Breakdown by CVD outcome
  - Hypertension
    - 17 hypertension alone
    - 5 hypertension and other CVD outcomes
  - Coronary heart disease (CHD)
    - 5 CHD alone
  - Ischemic heart disease (IHD)
    - 2 IHD alone
  - Myocardial infarction (MI)
    - 2 MI alone
    - 1 MI and other CVD outcomes
  - Heart disease mortality
    - 2 heart disease mortality alone
      - 1 was sudden cardiac death only
    - 2 assessed other CVD outcomes
      - 1 was sudden cardiac death

Study quality and use of data for determinations

Nineteen of the CVD studies were deemed High Quality. Eleven of the CVD studies were deemed Middle Quality. These included 7 self-reports, 2 systematic reviews, and 3 studies that had a mix of small sample sizes and questionable independence. Finally, 5 CVD studies were considered Limited Quality due to small sample sizes, self-reporting, and an inability to determine funding independence. These Limited Quality studies were still included as the outcomes were either clinically assessed or they included women firefighters, a group that is typically underrepresented in fire-industry studies. For details on analysis of study results, please refer to the Methods Section. All studies are included in the narrative analysis below; however, determinations of increased or decreased risk are limited to studies that statistically assessed an association between of firefighting or police work and the outcomes of interest.

Literature Review Findings – CVD

Overview

Overall, the CVD studies present mixed results. For most of the CVD outcomes of interest, there are statistically significant findings for increased and decreased risk in both firefighters and police. In police, no data was found for ischemic heart disease (IHD), heart disease mortality, or sudden cardiac death.

Only five of the 35 included studies reported CVD data on female firefighters and police (three and two, respectively). Hypertension, coronary heart disease (CHD), and myocardial infarction (MI or heart attack) were the only CVD outcomes where females were included in the analysis (hypertension: (Gendron, Lajoie, Laurencelle, & Trudeau, 2018a, 2018b); CHD: (Wanahita et al., 2010; Wolkow et al., 2014); MI:(Gendron et al., 2018a). Furthermore, only one study (Gendron et al., 2018a) had participants who were all female firefighters. This was also the only study on MI in in women.

In this group of studies, the exposure of interest was occupation, either firefighting or police work, and not specific chemical exposures. Almost half of the studies (16 of 35) used clinical assessments to determine the presence of CVD outcomes. The remaining used participant self-report and surveillance data.

Discussion of Prevalence Data

The majority of CVD studies were focused on hypertension. This was expected as 1 in 3 adults in the US (750 million people) has high blood pressure (CDC, 2019). Table CVD1 shows the prevalence of hypertension and all other CVD outcomes in firefighters and police compared to the general US population. For almost all outcomes, firefighter and police populations have higher prevalence rates than the general US population. While prevalence only tells us how common a disease is in a population and not if the disease is associated with a particular exposure, worker populations with a higher prevalence of disease (compared to the general population) should be examined more closely to determine effective public health measures that can be taken to reduce the burden of disease.

Table CVD1. Prevalence of CVD outcomes in worker populations compared to US population

CVD Outcome	US Adult Prevalence Data	Firefighter Prevalence Data *(no. studies)*	Police Prevalence Data *(no. studies)*
Hypertension	29%	5 - 45% *(13)*	4.1 - 52.4% *(12)*
CHD	6%	1 - 11% *(2)*	0 - 4.3% *(2)*
IDH	6.7%	none found	none found
MI*	7.2 per 100,000 PY	216.8 per 100,000 PY *(1)*	342.2 per 100,000 *(1)*
HD mortality	14%	35% *(1)*	none found
Sudden Cardiac Death	20%	none found	none found

PY: person year – a measurement used in epidemiology studies that takes into account both the number of people in the study and the amount of time each person spends in the study.

* Reported as incidence rates as MI are considered an acute condition.

(AHA, 2018; Albert C, 2013; CDC, 2011a, 2017c)

Studies on hypertension reported on both the prevalence of hypertension and its association with firefighting and police work. The prevalence studies generally did not make statistical comparisons to other populations. The range of prevalence for firefighters' hypertension ranges from 5% (Gendron et al., 2018b) to 45% (Risavi & Staszko, 2016). Only one prevalence study showed substantially higher prevalence (45%) of hypertension in firefighters then in the general US (29%) (Risavi & Staszko, 2016); other prevalence studies reported lower prevalence for firefighters than the general US population. The range of prevalence rates for police officers' hypertension ranged from a low of 4.1% (Moline et al., 2016) to 52.4% (Lestrina, Sihotang, & Siahaan). Four studies of police officers reported higher prevalence of hypertension than in the general US population; other prevalence studies in police officers reported similar or lower rates of hypertension than in the general US population. One study with police officers (Gendron et al., 2018b) looked at the difference in hypertension by sex of police officers and saw that female hypertension prevalence (4.1%) was significantly less ($p < 0.001$) than male hypertension prevalence (14.3%).

The range of prevalence for firefighters' CHD ranges from 1% to 11% (Risavi & Staszko, 2016) (Soteriades, Smith, Tsismenakis, Baur, & Kales, 2011). The range of prevalence rates for police officers' CHD ranged from 0 to 4.3% (Shiozaki et al., 2017) (Wanahita et al., 2010). Wanahita et al. indicated no increase in CHD prevalence in both male and female

NYPD officers compared to general population, however the study did suggest that due to healthy worker effects, these results might underestimate the risk of CHD in older/longer serving police officers.

While only five (of 35) studies were found focusing on MI, their findings were a mix of incidence rates and odds/hazard ratios. Incidence rate of MI for firefighters in Han et al was reported as 216.8 per 100,000 person-years. A similar finding was seen in in this same study for police, with an incident rate of MI as 342.2 per 100,000 person-years. An interesting result was seen in Gendron et al. (Gendron et al., 2018b) where they reported MI prevalence among female firefighters as 3%. While this finding was not significant, it is worth noting here since there is limited information on the health outcomes of female firefighters. Until there are more published studies on the health outcomes of female firefighters, limited studies such as this are the only insight researchers have on the burden of disease experienced by this subset of the firefighting population.

One study (Soteriades et al., 2011) reported the prevalence of mortality due to heart disease as 35%.

Figure 1. Prevalence - CVD Fire Fighters and Police

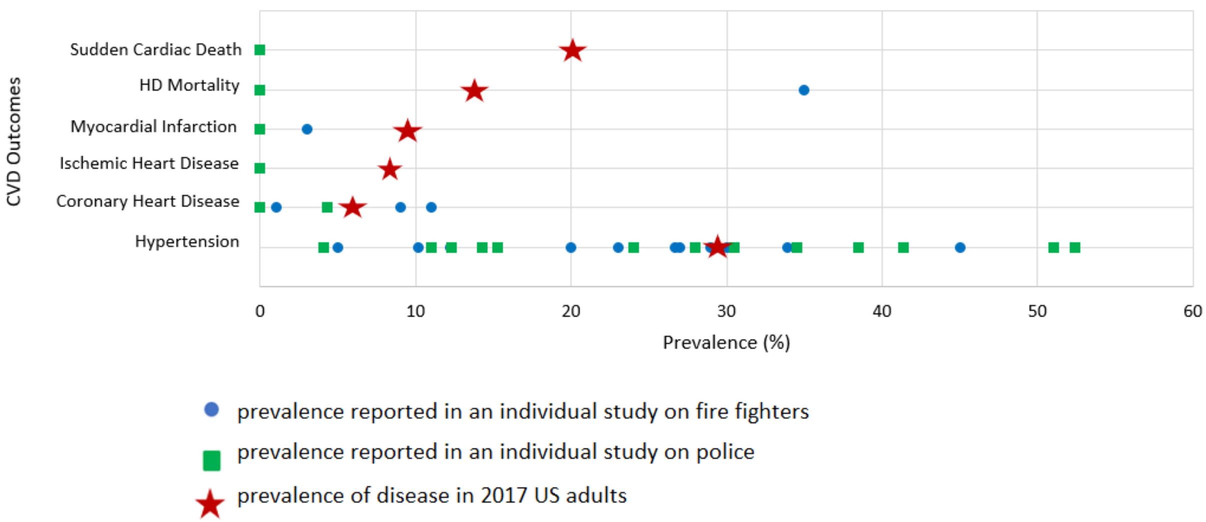


Figure interpretation using the prevalence of CVD in firefighters: Looking at hypertension, we can see that there are 10 studies that report prevalence of hypertension in fire fighters below the 2017 prevalence of hypertension in US adults (29%). However, three studies report the prevalence of hypertension in fire fighters to be higher than the 2017 prevalence of hypertension in US adults.

<u>Discussion of Measures of Association (Risk) and Determinations</u>

Hypertension: *Insufficient* evidence to determine for firefighters / *Suggestive* evidence of increased risk for police

Six studies reported on the association of firefighting and police work to hypertension (four and two, respectively). For firefighters, two (of four) studies (Glass et al., 2017; Han, Park, Park, Hwang, & Kim, 2018) reported decreased risk

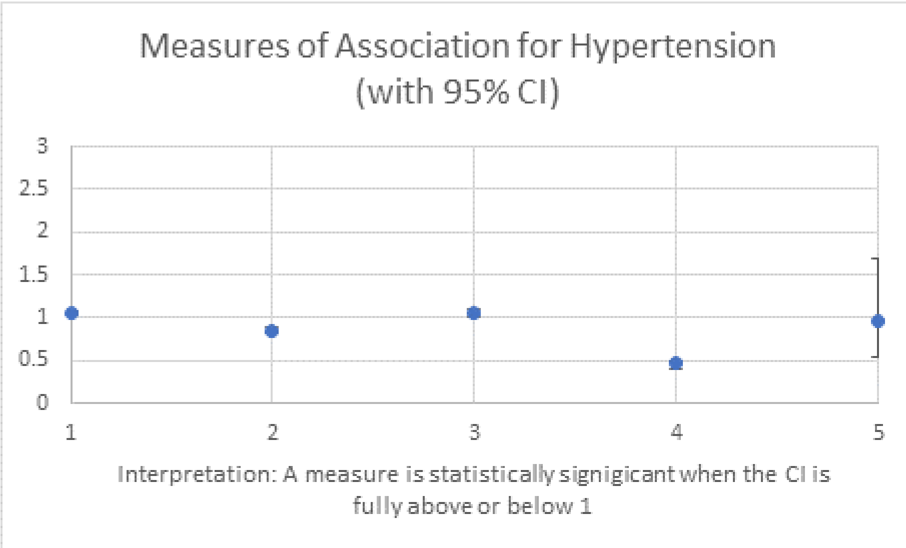
(HR=0.85, CI 0.82-0.88; SMR=0.46, CI 0.41-0.5). One (of four) study of wildland firefighters reported increased odds (OR = 4.2 for those with over 10 years of service and 5 for those with over 20 years of service) of developing hypertension with increasing length of service (combined 95% CI: 1.3, 20.2) (Semmens, Domitrovich, Conway, & Noonan, 2016). One study was not statistically significant (Petersen et al., 2018). For police, two studies (Han et al., 2018; Janczura et al., 2015) report increased odds (OR= 1.05, HR = 1.05) of developing hypertension with increasing length of service (combined CI: 1.01, 1.09).

Finally, eight studies (including three from the previous eight) assessing other CVDs saw evidence of hypertension occurring in these populations, six in firefighters (Gendron et al., 2018b; Han et al., 2018; Kales, Tsismenakis, Zhang, & Soteriades, 2009; Pedersen, Ugelvig Petersen, Ebbehoj, Bonde, & Hansen, 2018a; Risavi & Staszko, 2016; Soteriades et al., 2011) and two in police (Han et al., 2018; Kales et al., 2009). This suggests that hypertension is likely a co-occurring outcome for other CVDs in both populations.

Based on the analysis of these studies, there is insufficient evidence of increased risk of hypertension for firefighters and suggestive evidence of increased risk of hypertension for police. While there does appear to be an increased prevalence of hypertension for these groups, this observation could be due to selection bias. Hypertension is widely prevalent in the adult US population, so by looking at a small subpopulation of the US, data on its occurrence may be magnified since the population of first responders is not a total random sample of the greater US population.

Not seeing an increase in risk for hypertension could be due to bias and data limitations within the studies, namely the healthy worker effect and the use of self-reported data. Only those healthy enough to work and healthy enough to do the physically demanding jobs of first responders would have been captured in these studies. Additionally, many of these studies were based on self-reported data. This could lead to underreporting of hypertension due to participants either not knowing they have the disease or being unwilling to disclose it for fear of job loss.

A chart of measures of association for hypertension appears on the next page. Some studies included more than one result, as shown below.



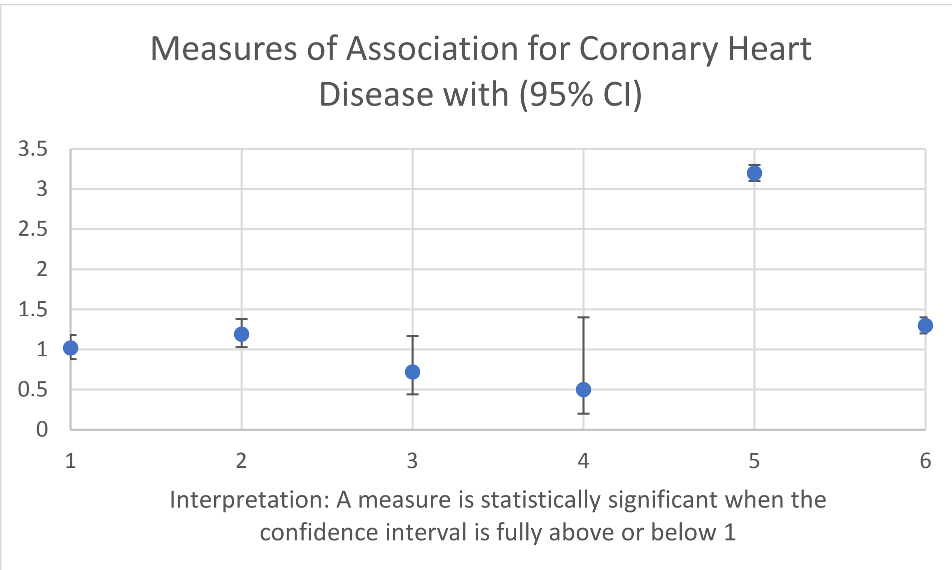
Statistically significant findings marked with *

1. Han et al. 2018 (Police)*
2. Han et al. 2018 (Firefighter)*
3. Janczura et al. 2015 (Police)*
4. Glass et al. 2017 (Male Volunteer Firefighter)*
5. Petersen et al. 2018 (Firefighter)

Note: Semmens et al. 2016 findings not plotted because high upper CI made it difficult to read other results*

Coronary Heart Disease (CHD or Atherosclerosis): *Suggestive* evidence of increased risk for firefighters / *Insufficient* evidence for police

Six studies reported on the association of firefighting and police work to CHD (five and one, respectively). For firefighters, two studies with statistically significant findings report increased risks: in Kales et al. an OR = 5.5 (CI=2.1,14.2); and in Wolkow et al. incidence risk ratios of 3.2 (CI=3.1, 3.3) for males and 1.3 (CI=1.2, 1.32) for females of developing CHD with increasing length of service (Kales et al., 2009; Wolkow et al., 2014). Three studies did not have statistically significant findings (Crawford & Graveling, 2012; Pedersen et al., 2018a; Petersen et al., 2018). For police, one study reported an increased odds (OR= 1.19) of developing CHD with increasing length of service (combined 95% CI: 1.03, 1.38) (Kales et al., 2009). Some studies included more than one result, as shown below.



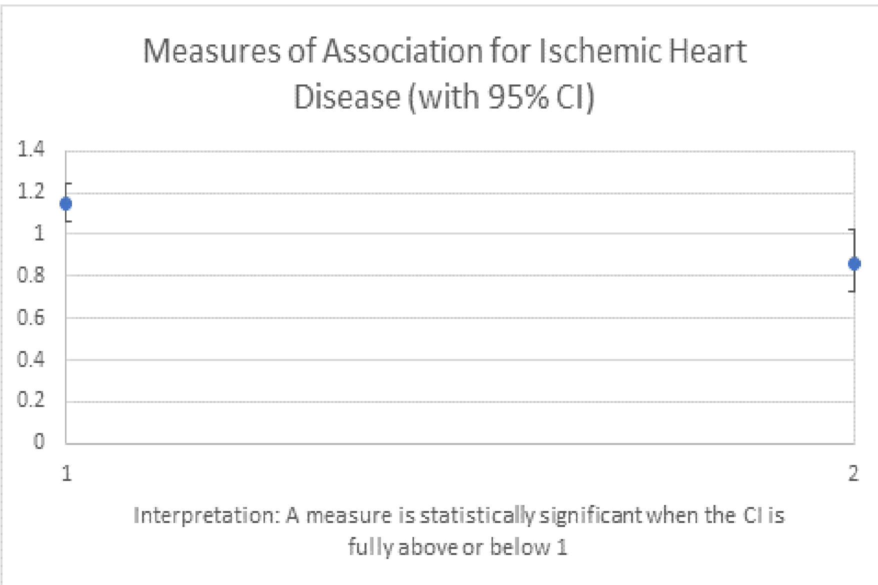
Statistically significant findings marked with *

1. Pedersen et al. 2018
2. Kales et al. 2009 (Police)*
3. Petersen et al. 2018
4. Crawford et al. 2012
5. Wolkow et al. 2014 Male Firefighters*
6. Wolkow et al. 2014 Female Firefighters*

Note: High results from Kales et al. 2009 for firefighters not plotted because it makes it difficult to read other results*

Ischemic Heart Disease (IHD): *Insufficient* evidence to determine for firefighters / *No evidence* for police

Findings for IHD were limited to two studies in firefighters (Pedersen et al., 2018a; Petersen et al., 2018). Pedersen (Pedersen et al., 2018a) reported an increased risk (incidence rate ratio (IRR) = 1.15) of developing IHD with increasing length of service (95% CI: 1.06, 1.24). While Petersen et al.(Petersen et al., 2018) showed a decrease in risk (SMR = 0.86), this finding was not significant (95% CI: 0.73, 1.02). While both studies were based on non-US populations, exposures are expected to be similar to the US firefighter experience (Alarie, 2002).

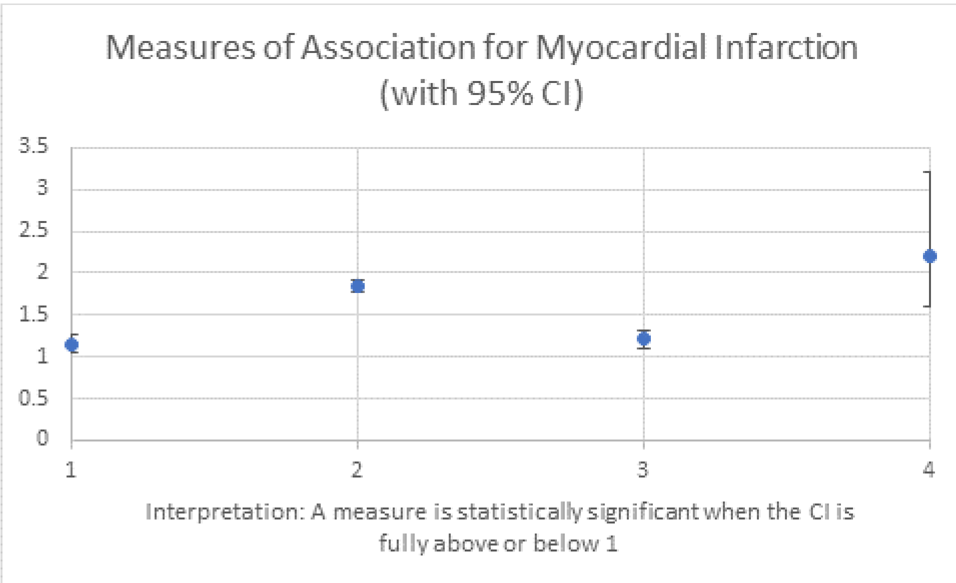


Statistically significant findings marked with *

1. Pedersen et al. 2018 (Firefighters)*
2. Petersen et al. 2018 (Firefighters)

Myocardial Infarction (MI or Heart Attack): *Suggestive* evidence of increased risk for both firefighters and police

Four studies reported on the association of firefighting and police work to MI. For firefighters, two of these four studies (Han et al., 2018; Pedersen et al., 2018a) reported increased risk (HR = 1.21 and OR = 1.16) of experiencing an MI with increasing length of service (combined 95% CI: 1.06, 1.32). Police see a similar, if not stronger association in Han et al. and Kales et al. with a hazard ratio of 1.84 and an odds ratio of 2.2, respectively (combined 95% CI: 1.06, 3.2).



Statistically significant findings marked with *

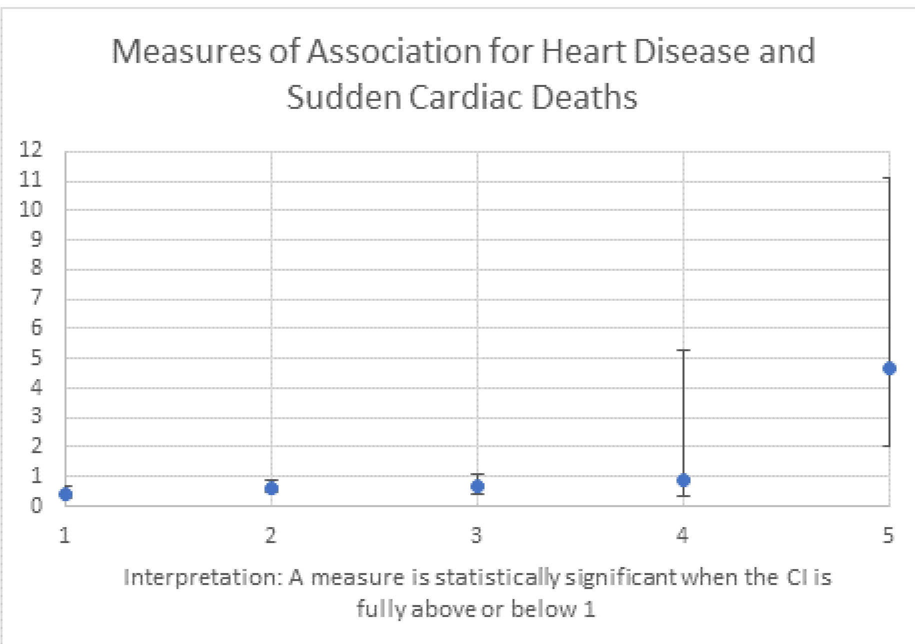
1. Pedersen et al. 2018 (Firefighters)*
2. Han et al. 2018 (Police)*
3. Han et al. 2018 (Firefighters)*
4. Kales et al. 2009 (Police)*

Heart Disease Mortality: *Suggestive* evidence of decreased risk in firefighters / *No evidence* for police

Petersen et al. and Ahn and Jeong reported reduced risk of mortality in firefighters (SMRs = 0.42 and 0.64; combined 95% CI: 0.25, 0.89) (Ahn & Jeong, 2015; Petersen et al., 2018).

Sudden Cardiac Death: *Insufficient* evidence to determine in firefighters / *No evidence* for police

Findings for sudden cardiac death (SCD) were limited to two studies of firefighters. One study (Kales et al.) reported on-duty cardiac death, included here as surrogate for sudden cardiac death. Kales et al. reported increased risk of sudden cardiac death associated with firefighting, adjusted OR = 4.7 (CI: 2.0, 11.1) (Kales et al., 2009). Farioli et al. reported an overall decreased risk in firefighters compared to both military (summary ratio of 0.90, CI 0.33-5.26) and general population (summary ratio of 0.65, CI 0.41-1.07) comparisons but results were not statistically significant; in an age-group analysis only firefighters aged 45 to 54 years had a 32% increased risk of SCD compared to the general population (Farioli, Christophi, Quarta, & Kales, 2015).



Firefighters only. Statistically significant findings marked with *

1. Ahn and Jeong 2015 Heart Disease Mortality*
2. Petersen et al. 2018 Heart Disease Mortality*
3. Farioli et al. 2015 Sudden Cardiac Death (General population comparison)
4. Farioli et al. 2015 Sudden Cardiac Death (Military comparison)
5. Kales et al. 2009 Sudden Cardiac Death*

Table CVD2. Summary of determinations for firefighter CVD

CVD Outcome	No. Studies	"Strength of Evidence" Determination	Evidence of increased risk	Evidence of decreased risk
Hypertension	tot no. studies: 5 tot no. sig.studies: 5	*Insufficient evidence*	2 significant studies	3 significant studies
CHD	tot no. studies: 5 tot no. sig.studies: 3	*Supportive evidence* of increased risk	3 significant studies	none
IHD	tot no. studies: 2 tot no. sig.studies: 1	*Insufficient* evidence	1 significant study	none
MI	tot no. studies: 2 tot no. sig.studies: 2	*Suggestive evidence* of increased risk	2 significant studies	none
HD mortality	tot no. studies: 2 tot no. sig.studies: 2	*Suggestive* evidence of decreased risk	none	2 significant studies
Sudden Cardiac Death	tot no. studies: 2 tot no. sig.studies:1	*Insufficient* evidence	1 significant study	none

Table CVD3. Summary of determinations for police CVD

CVD Outcome	No. Studies	"Strength of Evidence" Determination	Evidence of increased risk	Evidence of decreased risk
Hypertension	tot no. studies: 2 tot no. sig.studies: 2	*Suggestive evidence* of increased risk	2 significant studies	none
CHD	tot no. studies: 1 tot no. sig.studies: 1	*Insufficient evidence*	1 significant study	none
IHD		*No evidence*	None	none
MI	tot no. studies: 2 tot no. sig.studies: 2	*Suggestive evidence* of increased risk	2 significant studies	none
HD mortality		*No evidence*	None	none
Sudden Cardiac Death		*No evidence*	None	none

Epidemiology Consultant Report on Respiratory Disease Outcomes

Approach in brief (see further details in methods appendix)

Search results -Respiratory

- Selection of respiratory diseases was based on frequency of their occurrence in the US adult population (CDC, 2017a; DHHS, 2016).
- 14 respiratory disease studies included

- Breakdown by occupation:
  - 14 firefighter (100%)
- Breakdown by respiratory disease outcome
  - Asthma
    - 2 asthma alone
    - 3 assessed asthma and other respiratory outcomes
  - COPD
    - 2 COPD alone
    - 2 assessed COPD other respiratory outcomes
  - Emphysema
    - none assessed emphysema alone
    - 2 assessed emphysema other respiratory outcomes
  - Respiratory mortality
    - 1 respiratory mortality alone
    - 1 assessed respiratory and other respiratory outcomes

Study quality and use of data for determinations

Six of the 14 respiratory disease studies were deemed High Quality. Six were deemed Middle Quality. These included two self-reports and four with questionable independence. Finally, two respiratory disease studies were considered Limited Quality due to small sample sizes, self-reporting, and/or an inability to determine funding independence. These Limited Quality studies were still included as they compared firefighters to other first responders (i.e. police) or they included women firefighters, a group that is typically underrepresented in fire-industry studies. For details on analysis of study results, please refer to Quality Assessment in the Methods appendix. All studies are included in the narrative analysis below; however, determinations of increased/decreased risk are limited to studies that statistically assessed an association between of firefighting or police work and the outcomes of interest.

Literature Review Findings – Respiratory Disease

Overview

Overall, the respiratory studies present mixed results. The majority of respiratory disease studies were focused on asthma. In this group of studies, the exposure of interest was occupation (i.e., firefighting) and not specific chemical exposures. Only one of the studies (out of 14) used clinical assessments to determine the presence of respiratory disease outcomes. The remaining used participant self-report and surveillance data.

Only one of the 14 included studies reported respiratory disease data on female firefighters(Gendron et al., 2018a); however, it focused on evaluating the common risk factors for respiratory disease (obesity, smoking, etc.) and not the occurrence or association of those outcomes in that population.

Discussion of Prevalence Data

Table R1 shows the prevalence of the respiratory disease outcomes in firefighters compared to the general US population. For almost all outcomes, the firefighter population has higher prevalence rates than the general US population. While prevalence only tells us how common a disease is in a population and not if the disease is associated with a particular exposure, worker populations with a higher prevalence of disease (compared to the general population) should be examined more closely to determine effective public health measures that can be taken to reduce the burden of disease.

Table R1. Prevalence of respiratory disease outcomes in worker populations compared to US population

Respiratory Disease Outcome	US Adult Prevalence Data	Firefighter Prevalence Data *(no. studies)*
Asthma	7.7%	9.3 - 16.1% *(7)*
COPD	3.7%	16% *(6)*
Emphysema	1.4%	none found
Respiratory Mortality	5.7%	9.9% *(6)*

(CDC, 2017a, 2017b; Kenneth D. Kochanek, 2019; NIH, 2018)

The range of prevalence for firefighters' asthma was from 9.3% to 16.1% (Greven et al., 2011; Ribeiro, de Paula Santos, Bussacos, & Terra-Filho, 2009). One study reported COPD prevalence for firefighters' COPD at 16%. (Gendron et al., 2018b). Findings for emphysema were limited to two studies, with only one study (Schermer et al) reporting a surrogate measure for the prevalence of emphysema (more description below). One study (Muegge et al., 2018) reported the prevalence of mortality due to respiratory disease as 9.9%, higher than US prevalence at 5.7%.

Schermer et al. (Schermer, Malbon, Morgan, Smith, & Crockett, 2014) assessed asthma, COPD, and emphysema outcomes in firefighters through health survey scores from firefighters' responses to questions and physical examinations (including spirometry) post-use of their self-contained breathing apparatus (SCBA). Those firefighters who reported inconsistent use of SCBA during knockdown had 5.54 points lower scores on physical survey than those reporting consistent use of respiratory protection. As a higher score on the survey indicates a better health-related quality of life, these results suggest that firefighters who do not use their SCBA consistently are likely going to experience a worse quality of life. It must be noted that these survey scores are not quantitative risk metrics but they do suggest that firefighters who do not use SCBA consistently are at increased risk for respiratory disease.

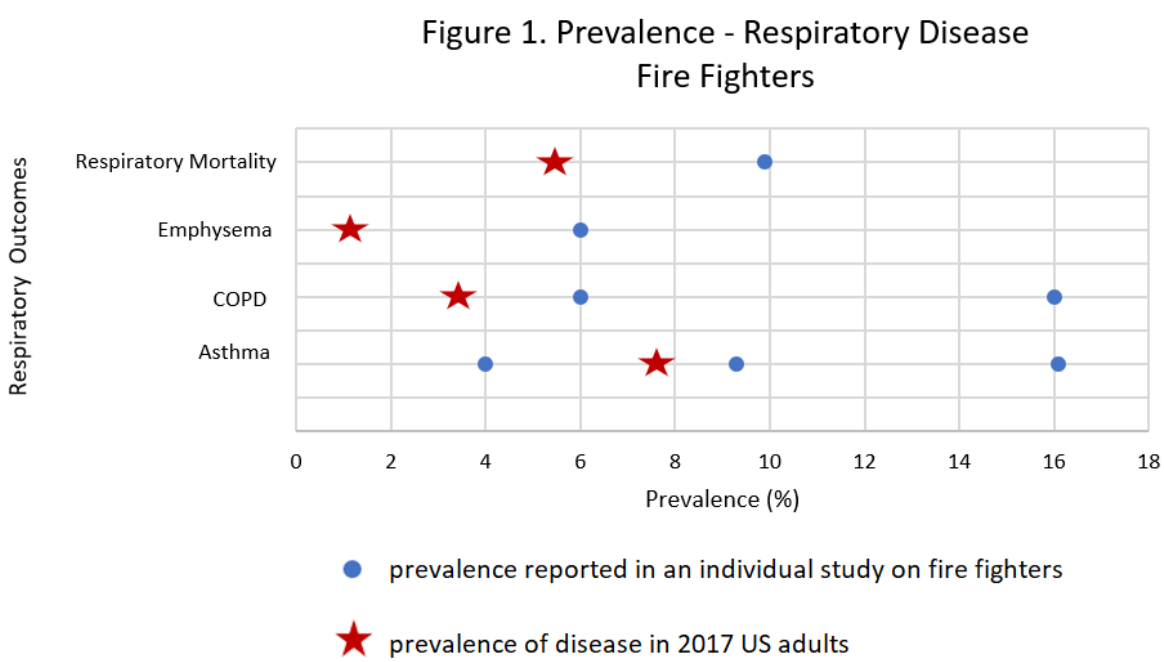
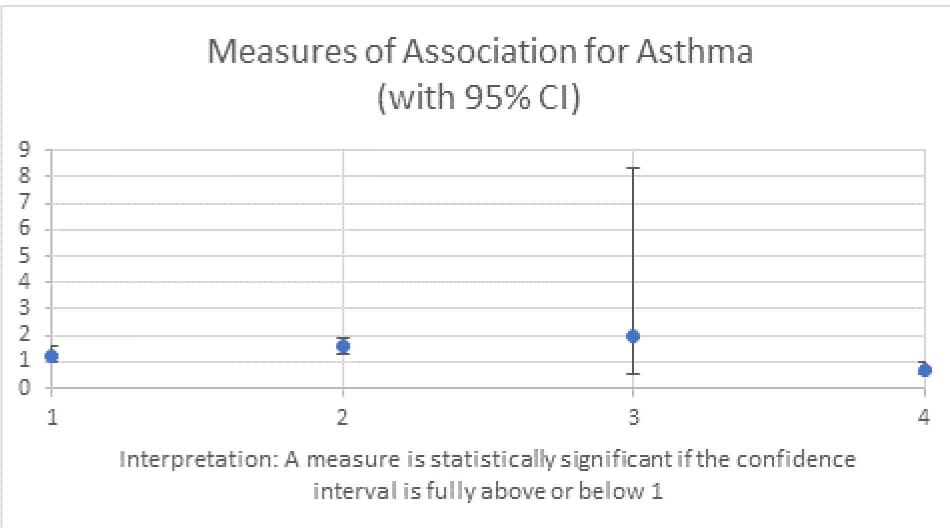


Figure interpretation using the prevalence of respiratory disease in firefighters: Looking at asthma, we can see that there are two studies that report prevalence of asthma in fire fighters above the 2017 prevalence of asthma in US adults (7.7%). However, one study reports the prevalence of asthma in fire fighters to be less than the 2017 prevalence of asthma in US adults.

Discussion of Measures of Association (Risk) and Determinations

Asthma: *Suggestive* evidence of increased risk for firefighters

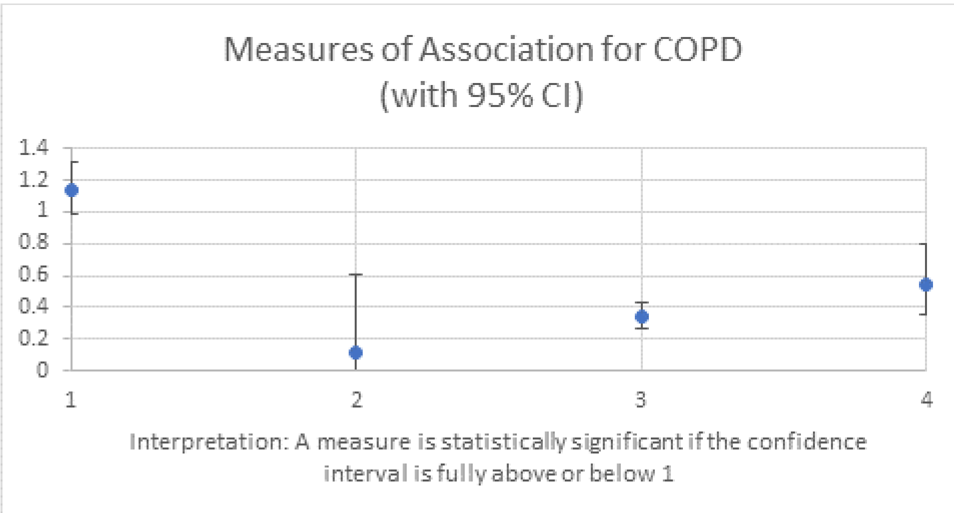
Four studies also reported on the association of firefighting to asthma. Overall, three of the four studies reported statistically significant findings, two of which indicated increased risk of asthma in firefighters. One study (Ribeiro et al., 2009) reported an increased odds (OR = 1.23; 95% CI: 1.01, 1.56) of developing asthma with increasing length of service while another study (Pedersen, Ugelvig Petersen, Ebbehoj, Bonde, & Hansen, 2018b) reports an increased incident rate ratio (IRR = 1.58; 95% CI: 1.32, 1.88) of asthma in firefighters. One study reported decreased risk (SMR = 0.71; 95% CI: 0.52, 0.98) (Petersen et al., 2018). Semmens et al. included asthma but the finding was not statistically significant (Semmens et al., 2016).



1. Ribeiro et al. 2009 (Prevalence)*
2. Pedersen et al. 2018 (Incidence)*
3. Semmens et al. 2016 (Prevalence)
4. Petersen et al. 2018 (Mortality)*

Chronic Obstructive Pulmonary Disease (COPD): *Supportive* evidence of decreased risk for firefighters

Four studies reported on the association of firefighting COPD. Three studies (Glass et al., 2017, 2019; Glass, Pircher, et al., 2016) report statistically significant decreased mortality ratios (SMRs = 0.54, 0.34, and 0.11; combined 95% CI: 0.01, 0.8). Another study (Pedersen et al., 2018b) with non-statistically significant findings reports an increased incident rate ratio of developing COPD with increased length of service (IRR = 1.58; 95% CI: 0.98, 1.32).



Statistically significant findings marked with *

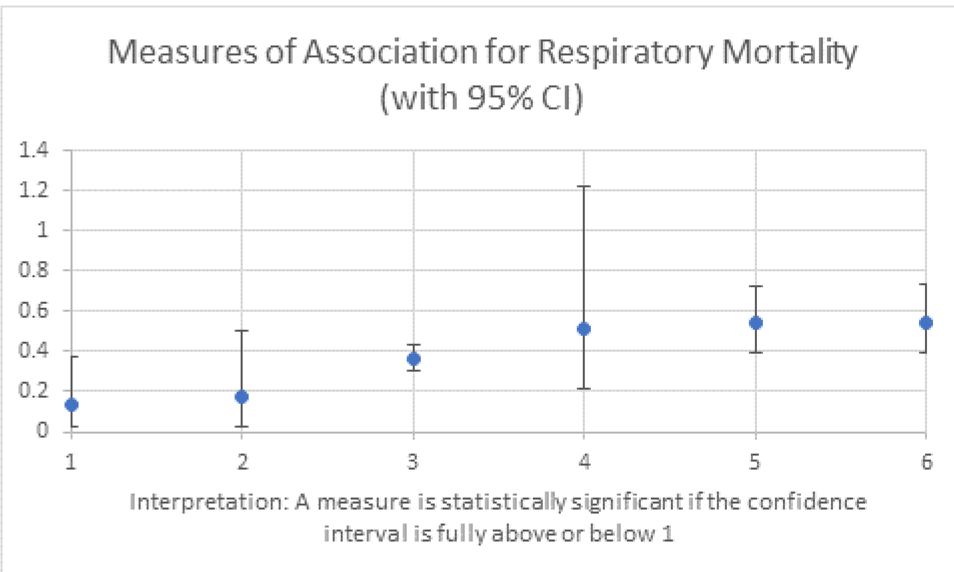
1. Pedersen et al. 2018 (Incidence)
2. Glass et al. 2019 Female (Mortality)*
3. Glass et al. 2017 Male Volunteer (Mortality)*
4. Glass et al. 2016 Male Paid (Mortality)*

Emphysema: *Insufficient* evidence to make a determination

Petersen et al (Petersen et al., 2018) reported a decreased mortality ratio due to emphysema (SMR = 0.71; 95% CI: 0.52, 0.98); no chart provided.

Respiratory Disease Mortality: *Sufficient* evidence of decreased risk for firefighters

Findings for the association of firefighting to respiratory disease mortality were limited to six studies, five of which reported statistically significant findings of decreased risk with SMRs ranging from 0.13 to 0.54 (Ahn & Jeong, 2015; Brice et al., 2015; Glass et al., 2017, 2019; Glass, Pircher, et al., 2016; Pedersen et al., 2018b). Petersen et al. 2018 and Ahn & Jeong 2015 results were not statistically significant (because the Ahn and Jeong result had a very large CI it was not included in the chart because other results would then be difficult to read). As some of these studies used other occupational groups as comparisons there is less concern about bias due to the healthy worker effect.



Statistically significant findings marked with *

1. Ahn and Jeong 2015*
2. Glass et al. 2019 Female*
3. Glass et al. 2017 Male Volunteer*
4. Petersen et al. 2018
5. Glass et al. 2016 Male Paid*
6. Brice et al. 2015*

Summary discussion – Respiratory disease

Results from the literature on respiratory outcomes in firefighters show a higher prevalence (i.e., occurrence) of these respiratory diseases in the worker population yet a lower risk of death due to these conditions (see Table R2). This seemingly contradictory finding may be explained by two things. First, there was limited data on the prevalence of these outcomes and some of the prevalence data were self-reported. Less than half of the studies found (7 out of 15) measured prevalence at all. Furthermore, some, like Schermer et al, provide ranges or surrogate measures for prevalence and not exact point estimates.

The second part of the explanation is that compared to the general population, firefighters have more physical examinations and health screenings as part of their job. Diagnosis of any respiratory outcomes could result in a firefighter being considered "unfit for duty" and reassigned to a less hazardous task or taken out of active service completely. The National Fire Protection Association (NFPA) Standard on Comprehensive Occupational Medical Program for Fire Departments requires, at minimum, annual medical exams and other health screenings (i.e., chest x-rays, cancer screenings, etc.) as fire chiefs see fit (NFPA, 2018). That would provide the firefighters' healthcare providers the ability to diagnose respiratory health outcomes sooner than if the firefighter were in the general population. Additionally, all of the respiratory outcomes described here are conditions that may result in a firefighter being disqualified for work (NIFC, 2019). Taken together, identifying respiratory outcomes sooner and removing firefighters from the worker population would reduce the overall number of firefighters at risk for death from respiratory outcomes. In turn, this would result in a lower risk of death from respiratory outcomes, as we see here.

Table R2. Determinations for Firefighter Respiratory Disease

Respiratory Disease Outcome	No. Studies	"Strength of Evidence" Determination	Evidence of increased risk	Evidence of decreased risk
Asthma	total no. studies: 4 total no. sig.studies: 3	*Suggestive* evidence of increased risk	2 significant studies	1 significant study
Chronic Obstructive Pulmonary Disease (COPD)	total no. studies: 4 total no. sig.studies: 3	*Supportive* evidence of decreased risk	none	3 significant studies
Emphysema	total no. studies: 1 total no. sig.studies: 1	*Insufficient* evidence	none	1 significant study
Respiratory Mortality	total no. studies: 6 total no. sig.studies: 5	*Sufficient* evidence of decreased risk	none	5 significant studies

Epidemiology Consultant Report on PTSD and Suicide Outcomes

Approach in Brief (see further details in methods appendix)

Search results – PTSD and Suicide

PTSD

- 17 studies examining PTSD in emergency personnel were included on our review
- Breakdown by occupation:
  - 9 firefighters only (53%)
  - 3 police only (18%)
  - 3 EMS personnel (18%)
  - 2 combination of emergency personnel (12%)
  - 0 hazardous materials (HazMat) officer

Suicide

- In total 14 studies examining suicide in emergency personnel were included on our review.
- Breakdown by occupation:
  - 8 firefighters only (57%)
  - 5 police only (36%)
  - 1 firefighter and police (7%)
  - 0 EMS personnel
  - 0 hazardous materials (HazMat) officer

Background on emergency responders with previous military service

It is estimated that between 27% and 44% of first responders report previous military status (Bartlett et al., 2018; Meyer et al., 2012). To date, there have been no published studies examining nationally representative samples of U.S. firefighters, and as a result, no estimates on national rates. Rates of veteran first responders is likely associated with preferential hiring practices of the jurisdiction. The states of Virginia and at least one county (Loudon) provide a hiring preference for military veterans.

Little work has been done examining the relationship between veteran status and mental health outcomes in first responders. One study Stanley et al. (2015) found that active duty military status among firefighters was associated with increased risk for reporting suicidal thoughts and behaviors. Another study Bartlett et al. 2019 found that the military veteran subsample reported significantly higher levels of sleep disturbance, depression, and posttraumatic stress symptom severity in comparison to the non-veteran subsample; however, effect sizes were small indicating that between group differences are actually negligible. The small effect sizes in the context of a relatively large sample are noteworthy and suggest careful interpretation of the results. Indeed, despite statistical significance, the effect size comparisons indicate that military veteran versus non-veteran differences are actually negligible. The limited research available indicates that more work is needed to understand the extent to which military veteran status effects mental health outcomes.

Study quality and use of data for determinations

PTSD

Twelve of the PTSD studies were deemed of high quality. Five of the PTSD studies were deemed of middle quality. All five of the middle quality ranking were deemed such because their funding sources were not named making it not possible to deem their independence.

Suicide

Eleven of the suicide studies were deemed of high quality. Two of the suicide studies were deemed of middle quality. Both of the middle quality ranking were deemed such because their funding sources were not named making it not possible to deem their independence. One of the suicide studies was deemed of low quality because it had a small sample size, insignificant finding and noted missing data as a limitation which is problematic from a small sample (Costa, Passos, & Queiros, 2019). This study was not included in discussion or determinations.

Use of data for determinations

Because of the small dataset all studies are discussed in the narrative below (except Costa et al., as noted). PTSD studies used self-reported surveys that are the “gold standard” for evaluation of this outcome, therefore the prevalence data from these studies were used to inform the determinations.

Literature Review Findings – PTSD and Suicide

Overview

Overall, the PTSD and suicide studies present mixed results with indications of increased risk for PTSD in first responders and decreased risk for suicide in firefighters. For PTSD the data indicate that first responders have higher prevalence of PTSD than the general population. Higher prevalence rates as compared to the general population were found for fire fighters (6 studies), police (4 studies) and EMS responders (3 studies). Only one study reported on measure of association for PTSD which found that firefighters had statistically significant increased PTSD prevalence compared to other government workers with a Hazard Ratio (HR) of 1.4 (95% CI 1.26, 1.5) (Han 2018). Studies reporting on measures of association for suicide risk demonstrated a decreased risk for firefighters (3 studies). Insufficient data was available to make a determination about suicide police officers. No studies evaluated "dose-response" in terms of duration of employment/length of service or exposure to stressful events.

Discussion of prevalence data

Data presented in Table PS1 on US prevalence rates for PTSD and suicide attempts is from the National Institute of Mental Health and the US Department of Veteran Affairs. The data for firefighters and police came from the literature search. Prevalence data for non US countries rates is provided as the studies include in the prevalence dataset draw from Australia, Canada, Greece, Ethiopia, Korea, South Africa, and the UK. National prevalence rates for were available and reflected in the non-US column for all countries with the exception of Greece and Ethiopia which were not available.

PTSD

Sixteen studies reported on prevalence rates of PTSD in emergency personnel derived from cross sectional studies. Overall prevalence rates ranged from a lows of 4% to a high of 35% (Austin-Ketch et al., 2012; Kahn, Woods, & Rae, 2015; Mishra, Goebert, Char, Dukes, & Ahmed, 2010). The range of prevalence rates for firefighters ranges from a low of 4% (Khan et al. 2015) to a high of 26% (Jones, Nagel, McSweeney, & Curran, 2018). The range of prevalence rates from police officers ranged from a low of 8% for municipal police officers in Canada (Martin, Marchand, & Boyer, 2009) to a high of 35% (Austin-Ketch et al., 2012). The range of prevalence rates from EMS personnel ranged from a low of 4% (Khan et al. 2015) to a high of 22% (Carleton, Afifi, Turner, Taillieu, Duranceau, et al., 2018). The Carleton study additionally reported that 911 operators had a PTSD prevalence rate of 19%.

- On balance these data indicate that first responders have higher prevalence of PTSD than the general population.
    - Of 9 studies of firefighter PTSD prevalence, 6 show increased prevalence compared to general population rates.
    - Of 4 studies of police PTSD prevalence, all 4 show increased prevalence compared to general population rates.
    - EMS personnel were also included in this group of studies. Four studies included EMS workers; 3 showed increased prevalence compared to the general population and one found the EMS worker rate to be the same as the general population.

Suicide

Four of the suicide studies reported prevalence rates of suicide attempts for fire fighters (n=4) and one reported on both police and fire fighters (n=1). Prevalence rates of suicide attempts range from a lows of 2.1% for police and 3.3% for structural firefighters to a high of 15.5% (Stanley 2015) for wildland firefighters (Carleton, Afifi, Turner, Taillieu, LeBouthillier, et al., 2018; Stanley, Hom, Gai, & Joiner, 2018). No US prevalence data was found for suicide attempts so comparisons cannot be made.

Table PS1. Prevalence of PTSD and Suicide Attempts in the US and in firefighters, police and EMT

Mental Health Outcome	US Adult Prevalence Data	Non-US Prevalence Rates	Firefighter Prevalence Data	Police Prevalence Data	EMT Prevalence Data
PTSD	3.6%	0.7-4.4%	4.0 – 26.0%	8%-35%	4.0%-22%
Suicide Attempts	n/a	n/a	3.3%-15.5	2.1%	n/a

*In the U.S., no complete count of suicide attempt data are available https://afsp.org/about-suicide/suicide-statistics/

Sources: (US Veteran Affairs, National Institute of Mental Health, American Foundation for Suicide Prevention)

Rates in Non-US countries (Australian Family Physician, Atwoli 2013, Burri 2014, Jeon 2007, Van Ameringen 2008)

Figure PS1. Prevalence of Mental Health Outcomes for Fire Fighters

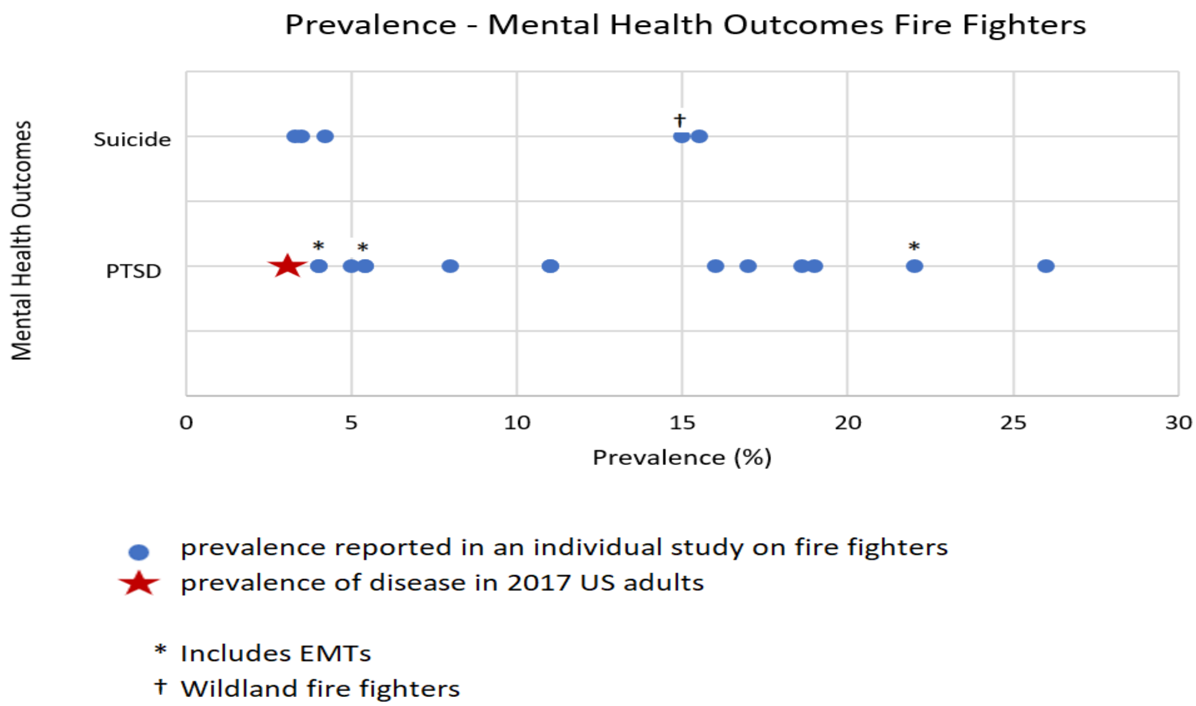
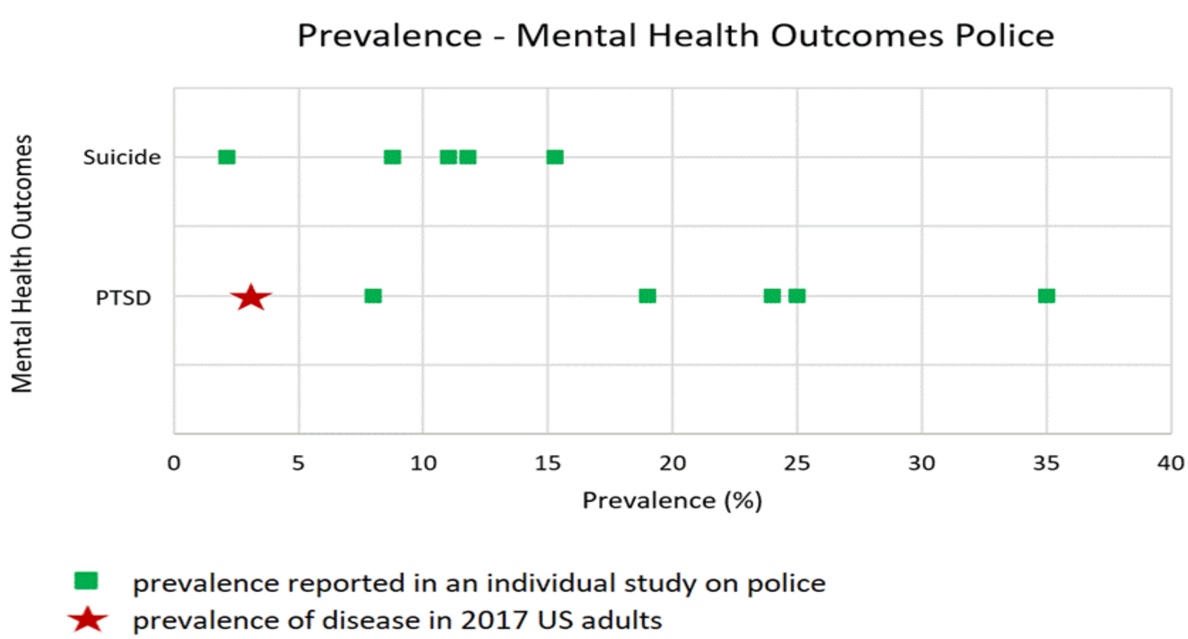


Figure PS2. Prevalence of Mental Health Outcomes for Police Officers



Data presented in Table PS2 presents the rates of suicide for police compared to general population from the US. National Institute of Mental Health and the American Foundation for Suicide Prevention. No data were found for firefighter or EMT suicide rates.

Two studies identified in the literature review reported lower suicide rates among police compared to the US population rate (8.8 and 11.8 per 100,000 in police vs 14 US) (Grassi et al., 2019; Violanti et al., 2011) and one study reported a higher suicide rate of 15.3 per 100,000 in police (Violanti, Mnatsakanova, Burchfiel, Hartley, & Andrew, 2012).

Table PS2. Rate of Suicide for Emergency Personnel compared to the general population

Mental Health Outcome	US Adult Suicide Rate	Firefighter Suicide Rate	Police Suicide Rate	EMT Suicide Rate
Suicide Rate	14 per 100K	n/a	8.8-15.3 per 100K	n/a

*Available https://afsp.org/about-suicide/suicide-statistics/; n/a: not available

Discussion and determinations

Table PS3 provides a summary of data and determinations for firefighters and Table PS4 provides a summary of data and determinations for police.

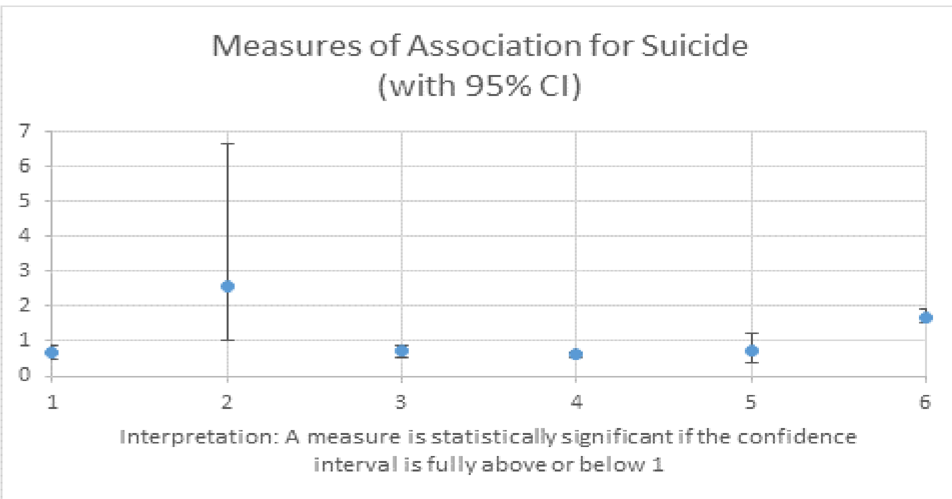
PTSD: Supportive evidence of *increased* risk for firefighters and police

One study reported that firefighters had statistically significant increased PTSD prevalence compared to other government workers with a Hazard Ratio (HR) of 1.4 (95% CI 1.26, 1.5) (Han 2018). Most studies assessed prevalence rates without formally evaluating association, however the majority of those studies show increased PTSD rates for firefighters, police and EMS workers, as discussed above. [Note: as there is only one measure of association for PTSD no chart is provided.]

Suicide: Supportive evidence of *decreased* risk for firefighters / Insufficient evidence for police

Most of the studies reported measures of association for suicide were firefighter studies (n=5); there was one study of police officers. Overall results were mixed. Three of the firefighter studies found statistically significant evidence of decreased suicide risk (Glass et al., 2017; Glass, Pircher, et al., 2016; Petersen et al., 2018). One study found increased risk of firefighter suicide among firefighters with more than 20 years of service (Ahn & Jeong, 2015). One study of female volunteers was not statistically significant (Glass et al., 2019). An additional finding of potential interest from the suicide studies was that wildland fire fighters have increased suicide attempt prevalence rate (15% vs 4%) compared to other firefighters (Stanley et al., 2018).

There are insufficient data to make a determination for police suicide. Two of three prevalence studies indicated decreased risk; one prevalence study indicated increased risk, as discussed above (Grassi et al., 2019; Stanley, Hom, Spencer-Thomas, & Joiner, 2017; Violanti et al., 2012). One study reported a statistically significant PMR for police suicide (Violanti, Robinson, & Shen, 2013).



Statistically significant findings marked with *

1. Petersen et al. 2018*
2. Ahn and Jeong 2015*
3. Glass et al. 2016 Male Paid*
4. Glass et al. 2017 Male Volunteer*
5. Glass et al. 2019 Female
6. Violanti et al. 2013*

Table PS3. Determinations for firefighter mental health outcomes

Mental Health Outcome	No. Studies	"Strength of Evidence" Determination	Evidence of increased risk	Evidence of decreased risk
PTSD	Prevalence: 9 total; 3 not different from general population Of association: 1 NSS: 0	Supportive evidence of *increased* risk	In 6 of 9 prevalence studies 1 statistically significant study	Not found
Suicide	Total: 5 NSS: 1	Supportive evidence of *decreased* Risk	1 statistically significant study *for firefighters with greater than 20 years experience	3 statistically significant studies

NSS: not statistically significant

Table PS4. Determinations for police mental health outcomes

Mental Health Outcome	No. Studies	"Strength of Evidence" Determination	Evidence of increased risk	Evidence of decreased risk
PTSD	Prevalence: 4 total; 0 not different from general population Of association: 1 NSS: 0	Supportive evidence of *increased* risk	4 of 4 prevalence studies 1 statistically significant study	Not found
Suicide	Prevalence: 3 total; 0 not different from general population Of association: 1 NSS: 0	Insufficient evidence	1 of 3 prevalence studies 1 statistically significant study	2 of 3 prevalence studies

NSS: not statistically significant

Epidemiology Consultant Report on Pneumoconiosis

Approach in Brief

The Statement of Work requested a "review of existing research on the association between occupations exposed to hazards causing pneumoconiosis". Completing such a review would have required all the available resources to complete to the exclusion of the other outcomes of interest. In consultation with JLARC, the question regarding pneumoconiosis was re-framed to identify evidence on the types of jobs where pneumoconiosis has been observed. Pneumoconiosis was not included in the formal literature search, instead, a variety of sources were consulted including several recent reviews and US National Institute for Occupational Safety and Health (NIOSH) surveillance data.

The following report provides background on pneumoconiosis focusing on the three diseases NIOSH identifies in this category: silicosis; asbestosis; and coal workers' pneumoconiosis (CWP). We summarize a NIOSH surveillance dataset to identify the industry sectors and types of jobs where the burden of pneumoconiosis is high.

Pneumoconiosis Findings

<u>Overview</u>

Pneumoconiosis is a general term used for interstitial lung diseases by inhalation of dust leading to fibrosis. This pathology causes restrictive impairment of lung function (ATS, 2003; Kumar, 2013). The symptoms may arise in months or years, or they may never arise at all. This variable symptomatology can be a hurdle in diagnosing the disease. Also, depending on the extent and the severity of the disease, the outcomes can be different. The intensity and duration of dust exposures that lead to pneumoconiosis are not found outside of occupational settings; pneumonconiosis is not typically found in the general population (CHEST, 2018)[3].

Burden of Disease and Recent Trends

It was estimated that in 2013, pneumoconiosis results 260,000 deaths globally. The global burden of disease report covering 1990-2013 estimates that there was a reduction in deaths by silicosis (approximately 46,000 deaths, change -16.0%) and coal workers pneumoconiosis (25,000 deaths, change -13.7%) but an increase in deaths by asbestosis (24,000 deaths, change +14%); however, age-adjusted death rates for all of these diseases declined from 1990-2013 (Murray, 2015).

Asbestosis

Over the time period of 1968 – 2000, a similar trend was noted in the United States; overall pneumoconiosis deaths decreased but asbestosis deaths increased (CDC, 2004). Asbestosis is directly related to higher risk of lung carcinoma, malignant mesothelioma, carcinomas of the upper respiratory tract, esophagus, biliary system and kidney cancers. The combined exposures of asbestos and smoking increase the risk of developing cancer many fold (Antao, Pinheiro, & Wassell, 2009; Hammond, Selikoff, & Seidman, 1979).

Coal Workers' Pneumoconiosis

Coal workers' pneumoconiosis (black lung disease) is also a major contributor to the overall burden of pneumoconiosis. Blackley et al. carried out a prevalence study using the radiograph images of the coal workers' pneumoconiosis from 1970 to 2017. They observed an increase of CWP over the years examined in central Appalachia. Prevalence is a measure of the overall burden of disease and the upward trend Blackley et al. observed suggests a future increasing trend of CWP complications, including progressive massive fibrosis due to the nature of this disease that progresses or worsens over time (Blackley, Halldin, & Laney, 2018).

Silicosis

Another major cause of pneumoconiosis is the inhalation of silica. The World Health Organization and International Labor Organization started an effort in 1995 focused on public awareness and prevention that has led to reduction in silicosis. This effort intends to globally eradicate silicosis by 2030. Preventive interventions, ventilation practices and effective respirators for all the workers have greatly impacted in reduction of this diseases. These occupational health and safety protocols have already decreased the incidence of silicosis in the USA (The Lancet Respiratory, 2019).

Pathophysiology

The underlying pathophysiology of pneumoconiosis is not very complex. It is a routine immunological response by the human body to the organic and inorganic materials but the sequelae can lead to fibrosis and development of restrictive patterns of lung function. Normally, foreign dust particles are entrapped in the mucus that lines the respiratory tract, and is removed by ciliary movement from the conducting zones to pharynx and out of the mouth or nose. If not removed, dust particles are taken up by local immune cells and activate an inflammatory response that can cause fibroblast proliferation and collagen deposition. This multi-stage process leads to fibrosis and scarring in the lung tissue that can reduce function and eventually impair respiration. Sometimes these dust particles can also become part of the lymphatic circulation, where more immune cells come in contact with them and the development of fibrosis is amplified (Kumar, 2013).

Diagnosis and Prognosis

The diagnosis of the pneumoconiosis is easier if the symptoms are present. Shortness of breath is a major symptom that can lead the patient to the primary healthcare physician for evaluation. But if there are no symptoms, the patient may not get further evaluation, leading to late or no diagnosis.

Chest x-ray or a computerized axial tomography (CAT) scans can be the initial diagnostic tools. These may show interstitial infiltration or small cystic radiolucencies called honeycombing. If the patient has shortness of breath, spirometry studies can also be done, although they are very basic and only assess the restrictive nature of the lungs.

The prognosis of pneumoconiosis largely depend on the extent of the fibrosis (Ross & Murray, 2004). If the patient is diagnosed earlier in the course of disease development, there is a chance of better prognosis due to treatment to reduce the rapid progression.

Treatment

There is no definitive treatment or drug of choice. Most of the treatment is to reduce the progression of the disease by using immunotherapies and steroids. More recently drugs have been developed that focus on reducing the process of fibrotic changes. But not much evidence is available to comment about the efficacy of these drugs at this point. The lung transplant is the only one absolute treatment to this disease.

Public Health Note

Asbestosis, silicosis and CWP are preventable diseases. Reducing exposure and routine screening of the workers exposed to dust particles can help in early diagnosis and improved outcomes. Occupational exposure reduction and healthcare policies should be devised to protect workers exposed to various dust particles that cause pneumoconiosis.

Jobs with deaths from pneumoconiosis

The following discussion is informed by a NIOSH surveillance system under the National Occupational Research Agenda (NORA) that tracked mortality for work-related respiratory diseases by industrial sector and job (NIOSH, 2019). These data were collected between 1990 and 1999. Data were available on all pneumoconiosis deaths by several industrial sectors: construction; manufacturing; mining; services; transport/warehousing/utilities; and wholesale and retail trade. The statistic available in this dataset is the proportionate mortality ratio (PMR) – an indicator of which jobs bear the burden of pneumoconiosis. The PMR is not a measure of risk. These data provide information on the various jobs where deaths from pneumoconiosis have occurred including a relative ranking of those jobs where the burden of these diseases is highest. Agriculture and healthcare sectors were also included in this surveillance system but all-pneumoconiosis PMR data was not provided for those industries.

A note about PMR data: In occupational epidemiology, proportionate mortality is used to compare deaths observed in a population of interest (say, a workplace) with the proportionate mortality expected in the broader population of workers. A PMR greater than 1.0 indicates that a particular cause accounts for a greater proportion of deaths in the population of interest than you might expect (NIOSH, 2003). The PMRs reported below illustrate how deaths from pneumoconiosis are distributed amongst the many job types within each sector. One can infer that a job with a high PMR is likely a high-exposure job but the PMR calculation does not directly compare an exposed group to an unexposed group as is done in other mortality analyses such as a Standard Mortality Ratio (SMR). For other outcomes evaluated in this report (cancers, cardiovascular, etc.) SMRs were calculated by comparing mortality rates in firefighters or police (exposed workers) to mortality in the general population (unexposed). The SMR does reflect the risk of death from the work exposure.

For the period 1990-1999, the greatest number of pneumoconiosis deaths were observed in the mining sector (4,837), followed by manufacturing (1,960), construction (1,078), services (731), transport/warehousing/utilities (460), and wholesale/retail (300). There are many jobs, particularly in the manufacturing and mining sectors where pneumoconiosis deaths were observed. The jobs with highest PMRs by sector (top 3) are shown in Table Pn1. Detailed listing of all PMRs from these six industrial sectors are presented in Tables Pn2a, b, c.

Table Pn1. Jobs with highest PMR by sector

Industrial Sector	Jobs with highest PMR (top 3 jobs)
Mining	Mining machine operator Locomotive operators Inspectors and compliance officers
Manufacturing	Insulation workers Miscellaneous metal and plastic processing machine operators Boilermakers
Construction	Insulation workers Boilermakers Plumbers, pipefitters, and steamfitters
Wholesale/retail	Lumber and construction materials workers (only 1 job listed)
Services	Insulation workers Plumbers, pipefitters, and steamfitters Electricians
Transport/warehousing/utilities (only 2 jobs listed)	Boilermakers Plumbers, pipefitters, and steamfitters (only 2 jobs listed)

Table Pn2a. PMRs by job for manufacturing and mining

Manufacturing Sector	
Job type	PMR (CI)
Insulation workers	27.2 (18, 40)
Miscellaneous metal and plastic processing machine operators	8.8 (4, 18)
Boilermakers	5 (3, 8)
Hand molding, casting, and forming occupations	4.8 (2, 9)
Brickmasons and stonemasons	4.8 (3, 8)
Plumbers, pipefitters, and steamfitters	4 (3, 5)
Crushing and grinding machine operators	3.7 (2, 6)
Hand molders and shapers, except jewelers	3.5 (2, 7)
Heating, air conditioning, and refrigeration mechanics	3.1 (1, 7)
Molding and casting machine operators	2.8 (2, 4)
Lay-out workers	2.6 (1, 5)
Millwrights	1.8 (1, 2)
Separating, filtering, and clarifying machine operators	1.6 (1, 2)
Electricians	1.6 (1, 2)
Welders and cutters	1.6 (1, 2)

Mining Sector	
Job type	PMR (CI)
Mining machine operators	32.9 (32, 34)
Locomotive operating occupations	30 (19, 45)
Inspectors and compliance officers, except construction	26.6 (14, 46)
Freight, stock, and material handlers, n.e.c.[2]	24.2 (12, 44)
Electricians	23.5 (18, 30)
Grader, dozer, and scraper operators	18.2 (7, 37)
Miscellaneous machine operators, n.e.c.	12.2 (5, 27)
Carpenters	11.4 (4, 25)
Crushing and grinding machine operators	11.1 (5, 21)
Supervisors, extractive occupations	10.9 (9, 14)
Explosives workers	10.9 (4, 25)
Supervisors, production occupations	8.4 (5, 13)
Laborers, except construction	7.3 (6, 9)
Excavating and loading machine operators	6.9 (3, 14)
Mining engineers	6.7 (4, 11)
Operating engineers	6.1 (4, 9)
Heavy equipment mechanics	5.9 (4, 9)
Machinists	5.7 (2, 12)
Welders and cutters	5.6 (3, 10)
Managers and administrators, n.e.c.	4.5 (3, 6)
Miscellaneous material moving equipment operators	4.2 (2, 7)
Mining occupations, n.e.c.	4.1 (3, 6)

[2] Not elsewhere classified (n.e.c.)

Table Pn2b. PMRs by job for construction and wholesale/retail

Construction Sector	
Job type	PMR (CI)
Insulation workers	25.8 (21, 32)
Boilermakers	9.5 (6, 14)
Plumbers, pipefitters, and steamfitters	2.6 (2, 3)
Millwrights	2.5 (1, 5)
Sheet metal workers	2.3 (1, 4)
Plasterers	2.2 (1, 4)
Welders and cutters	1.8 (1, 3)
Electricians	1.4 (1, 2)

Wholesale/Retail Trade Sector	
Job type	PMR (CI)
Lumber and construction materials workers	2.3 (1, 7)

Table Pn2c. PMRs by job for services and transport/warehousing/utilities

Services Sector	
Job type	PMR (CI)
Insulation workers	38.4 (12, 90)
Plumbers, pipefitters, and steamfitters	2.6 (1, 5)
Electricians	1.9 (1, 3)

Transport/Warehousing/Utilities Sector	
Job type	PMR (CI)
Boilermakers	4.6 (2, 10)
Plumbers, pipefitters, and steamfitters	2.5 (1, 5)

Focus on coal worker's pneumoconiosis (CWP)

From the same surveillance program described above (collected between 1990-1999) (NIOSH, 2019), data specific to CWP is provided and summarized here. A total of 3,805 CWP deaths were reported, 99% (3,765 deaths) were in coal mining and 1% (40 deaths) were from other types of mining industries (e.g., metal). The top three jobs with highest PMR were mining machine operators, locomotive operating occupations, and inspectors and compliance officers (except construction).

Table Pn3. PMRs coal worker's pneumoconiosis

Coal and Metal Mining	
Job type	PMR (CI)
Mining machine operators	51.8 (50, 54)
Locomotive operating occupations	48.7 (29, 76)
Inspectors and compliance officers, except construction	44.2 (21, 81)
Freight, stock, and material handlers, n.e.c.	38.1 (16, 75)
Electricians	36.3 (27, 48)
Grader, dozer, and scraper operators	31.6 (12, 69)
Carpenters	22 (8, 48)
Miscellaneous machine operators, n.e.c.	20.1 (6, 47)
Supervisors, extractive occupations	14.6 (11, 19)
Supervisors, production occupations	13 (8, 21)
Laborers, except construction	10.4 (8, 14)
Excavating and loading machine operators	9.9 (3, 23)
Truck drivers	8.6 (5, 14)
Operating engineers	8.3 (5, 14)
Welders and cutters	8.2 (4, 16)
Heavy equipment mechanics	7.9 (4, 14)
Mining engineers	7.1 (3, 14)
Managers and administrators, n.e.c.	6.2 (4, 9)
Miscellaneous material moving equipment operators	5.7 (3, 10)
Mining occupations, n.e.c.	4.6 (3, 8)

Epidemiology Consultant Assessment of Requirements to Claim Cancer Presumption

Key provisions of Code of Virginia Title 65.2 – 402.C:

- From JLARC: “Virginia’s cancer presumption, § 65.2-402.C, includes a toxic exposure requirement which requires that firefighters or HAZMAT officers demonstrate they have had contact with a known or suspected carcinogen, as defined by the IARC, in the line of duty in order to claim the presumption. This law, as interpreted by Virginia administrative and appellate courts, requires firefighters to prove their exposure to a known or suspected carcinogen that causes their particular type of cancer for the presumption to apply to their case.”
- Completed 12 years of continuous service

A public health perspective on the key provisions

Contact/Exposure and Presumption of Occupational Disease (Toxic Exposure Requirement)

The concept of contact of a chemical with the human body is the basic definition of exposure for environmental epidemiology and human health risk assessment of chemicals. There are three main routes of exposure: dermal, ingestion and inhalation. Firefighters are exposed to smoke which is a complex mixture of chemicals and particles. Firefighters may be exposed to the components of smoke by all three routes when training or working at a fire scene with dermal absorption and inhalation expected to be the most important contributors to overall exposure (when breathing by mouth some particles or dust may be ingested incidentally). Self-contained breathing apparatus (SCBA) and turnout gear help to minimize but do not fully eliminate these exposures.

Historically, exposure assessment studies have relied on measurements of chemicals (or particles) in the air, water, food, etc., external to the body. These types of studies are informative but do not show if the chemicals of concern are absorbed into the body where they can interact with biological processes and contribute to toxic, potentially health-damaging changes. In the past few years, exposure assessment studies have advanced to include measurement of chemicals that have been absorbed in the body by measuring the chemicals and related metabolites in exhaled breath, blood and/or urine samples (biomonitoring). Very rigorous studies, e.g., Fent et al. 2019b below, take both external and internal measurements, thereby demonstrating that the exposure (or contact) has resulted in absorption or intake of the chemicals of concern.

Several studies during training and controlled residential fires have shown that firefighters are exposed and that their bodies absorb and then excrete chemicals and related metabolites even when protective gear is used. The chemicals of interest in these studies include benzene and 1,3 butadiene (both IARC Group 1) volatile organic chemicals (VOCs) and selected poly-aromatic hydrocarbons (PAHs) - a family of chemicals that also have been associated increased cancer risks; among the group of PAHs is benzo[a]pyrene (IARC Group 1) and dibenz[a,h]anthracene (IARC Group 2A)(IARC, 2010).

The studies summarized below were conducted by a group headed by NIOSH in collaboration with the US Environmental Protection Agency, Underwriters Laboratories, university researchers and others. Exposures were sampled with a combination of techniques that measure chemicals external to the body (wipe samples of the skin or turnout gear), as well as samples representing the chemicals inside the body (what was absorbed and then excreted in exhaled breath or urine). The general approach for the Fent et al. studies summarized below is a multi-step design where: 1) pre-exposure samples are taken; 2) the firefighters participated in the training or controlled burn exercise; and 3) immediately after the exercise post-exposure samples are taken. The pre- and post-exposure samples of breath and urine were analyzed for benzene and PAHs at government laboratories at CDC and EPA.

Note on costs: The epidemiology consultants held a conference call with the NIOSH investigators to ask about costs to inform the question about feasibility of firefighters doing their own sampling to document carcinogenic exposures. As summarized above, to adequately document exposures from a firefighting task multiple samples are required. Equipment and sampling costs vary depending on the chemicals of interest but can range from about $100 to $300 per sample. These costs estimates are consistent with other occupational research studies being conducted by the consultants at JHU. Therefore, costs to obtain and analyze samples for a single fire event could be at least hundreds of dollars for an individual firefighter (and this does not include ancillary equipment and costs such as a proper cold storage and shipping to the analytical lab, etc.).

Summary of recent firefighter exposure studies

Assessing the risk to firefighters from chemical vapors and gases during vehicle fire suppression (Fent & Evans, 2011).

- A mixture of chemicals were detected in smoke from training exercise vehicle fires including benzene and 1,3 butadiene (both IARC Group 1 carcinogens). Benzene was also detected in samples of breathing zone air of individual firefighters while working to suppress the vehicle fire.
- Although vehicle fires are usually suppressed quickly, concentrations of chemicals in samples of breathing zone air exceeded short-term exposure limits for health effects on the lungs and eyes.

Understanding airborne contaminants produced by different fuel packages during training fires (Fent et al., 2015).

- Firefighters had higher concentrations of PAHs and benzene during training fires than the instructors
- Similar to other studies, during training fires firefighters are exposed to high levels of airborne contaminants, especially during training fires containing synthetic materials.

Firefighters' and instructors' absorption of PAHS and benzene during training exercises (Fent et al., 2019a).

- Instructors' during training fires increase their cumulative exposure to PAHs when continuing to repeat exercises for training. This could be several times a day frequently throughout the year.
- Different training exercises (exercises with higher quantities of adhesive) expose instructors to higher amount of PAH and benzene.
- Residential fires would likely expose firefighters to higher levels of benzene and PAHs than training fires. However, some of the training exercises using oriented strand board as fuel exposed firefighters and instructors to higher levels.

Firefighters' absorption of PAHs and VOCs during controlled residential fires by job assignment and fire attack tactic (Fent et al., 2019b).

- Different fire attack tactics expose firefighters to different levels of PAHs and VOCs.
    - Interior fire attackers were found to have higher levels of PAHs and benzene
    - Transitional fire attackers get high levels of PAH and VOCs when not wearing SCBA (and many don't since they are outside of the building)
- Urinary output measured PAHs - breath output measured VOCs
- This study found that dermal absorption is important in as a route of exposure for firefighters.

Another recent study from a group led by US Environmental Protection Agency scientists investigated wildland fire smoke resulting from smoldering and flaming of different biofuels (Kim et al., 2018). Particles were the exposure of concern in this case. Particle (or particulate matter) exposure is associated with cardiovascular and respiratory morbidity and mortality including lung cancer. Samples of the particles from the smoke were then tested in bacteria cell cultures to assess potential mutagenicity or changes to DNA as an indicator of carcinogenicity.

- Kim et al. found highest mutagenic potency for particles from flaming pine, peat, and eucalyptus and smoldering peat and pine needles.
- Kim et al. compared their findings to other similar studies looking at different types of smoke from oak burned in cookstoves and from municipal waste incinerators; their findings on smoldering emissions from wildland fires had higher mutagenicity than these other sources of smoke (Kim et al., 2018).

Conclusions based on all the information gathered on costs and the studies summarized above (Fent et al., 2015; Fent et al., 2019a; Fent et al., 2019b; Kim et al., 2018):

- Sampling equipment and analysis costs hundreds of dollars to document exposures from a single event.
- Firefighters are exposed to and absorb carcinogenic mixtures in smoke.
- Smoke is a complex mixture of chemicals and particles (and particles can carry chemicals). Smoke exposures from different types of fires (training, structural, vehicle, wild land) have been shown to contain carcinogenic and mutagenic chemicals and particles.
- Wearing protective gear and SCBA reduces exposure, however, firefighters are exposed to the constituents of smoke even when wearing protective gear (Fent et al., 2015; Fent et al., 2019a; Fent et al., 2019b).
- Limitations of knowledge/research:
  - Technology and techniques exist to assess exposures but such assessments require specialized equipment and expertise.
  - Studies of firefighter exposures typically focus on known toxicants. However, given the complexity of smoke mixtures there are likely toxic components of smoke that have not yet been characterized.
  - Although there is information on the major constituents of smoke under some conditions, smoke will vary from fire to fire making a complete understanding of smoke components, their health effects, and firefighter exposures difficult to study.
- Lack of evidence does not mean lack of exposure, absorption, or risk; in the field of human health risk assessment of chemicals and other exposures lack of knowledge (or uncertainty) is always present.

Recommendation on the toxic exposure requirement:

- **Demonstrating exposure and absorption of a specific carcinogen is not a feasible task for a firefighter.**

A tool under development may improve exposure assessments in the future

During the conference call with NIOSH scientists, they shared information about the National Fire Operations Reporting System (NFORS). Through a partnership with the International Association of Fire Fighters (IAFF), the International Associations of Fire Chiefs (IAFC), Metropolitan Fire Chiefs Association, and funding from the U.S. Federal Emergency Management Agency (FEMA), the International Public Safety Data Institute (IPSDI) has develop the NFORS Fighter Exposure Tracker for fire fighters to monitor their on-the-job exposures to numerous health and safety hazards (IAFF, 2019). The NIOSH scientists reported working with the developers to help validate the tool.

The Exposure Tracker is a phone app that allows fire fighters to log their exposures post-incident and record details about the fire or incident that may be applicable to health outcomes. It includes options for exposure to physical agents as well as psychological traumatic incidents that can impact a firefighter’s heath (IPSDI, 2019a, 2019b). According to the IPSDI, NFORS can serve fire fighters as a “personal database [that provides] a detailed history of work and exposures in a private, encrypted and secure online environment". Additionally, fire fighters can opt-in to sharing their data with researchers at the National Firefighter Cancer studies.

Years of service requirement

A firefighter's years of service may relate both to exposure duration and to the time required for cancer development (latency). The following summary of these topics may help inform policy changes.

Exposure duration and risk of cancer

Recent research has found that random mutations in normal stem cells account for about two-thirds of mutations in human cancers (Tomasetti & Vogelstein, 2015). The remaining one-third of human cancers are estimated to have environmental or behavioral causes such as workplace exposures (chemicals, dust), virus exposures, smoking or alcohol use (Tomasetti, Li, & Vogelstein, 2017). For all that is now known about cancer, there are still important knowledge gaps. One of these gaps is specific data on how long a carcinogenic exposure must last (exposure duration) to begin the cancer process.

None of the cancer studies reviewed for this report directly addressed the exposure duration question. However, the research gathered does offer indirect evidence that exposure durations less than 12 years can result in increased risk. Of the 19 studies summarized in the Phase 2 cancer report, 9 had a minimum length of service to be included in the research study ranging from 1 day to 1 – 6 months to 1 year. Other studies reviewed had broader inclusion criteria such as any active service. All 19 of these studies reported increased risk for one or more types or sites of cancer.

Cancer latency

The term "latency" refers to the time between an exposure of concern and the appearance of symptoms of the disease and clinical diagnosis. The development of cancer happens over years but the latency varies by site or type of cancer. For the cancers of interest to JLARC, a recent analysis by Nadler and Zurbenko calculated average latency periods for the general population ranging from 8 to 52 years; testicular cancer latency was not found (Haas, Delongchamps, Brawley, Wang, & de la Roza, 2008) (Nadler & Zurbenko, 2014).

The World Trade Center Health Program reviewed the scant scientific and expert panel literature on minimum cancer latency to determine guidelines for implementation of its follow-up and care for 9/11 first responders (CDC, 2014). This information from the World Trade Center Health Program is relevant because it was developed from peer-reviewed reports and is not directly linked to WTC exposure conditions. Because specific data on minimum latency for each cancer site or type is very limited, the World Trade Center Health Program created five cancer categories (mesothelioma, solid cancers, lymph and blood cell cancers, thyroid cancer, childhood cancer) and determined minimum latency for these categories. For the cancers of interest to JLARC, most are solid cancers with the exception of leukemia (a blood cell cancer). Data on minimum and average latency from the World Trade Center Health Program and Nadler and Zurbenko research are presented in the table below.

Cancer site or type of interest to JLARC	Minimum Latency[a] (years)	Average Latency[b] (years)
Colon (proposed)	4	52
Brain (proposed)	4	22
Testicular (proposed)	4	n/a
Leukemia	0.4	26
Pancreatic	4	8
Prostate	4	15-20
Rectal	4	30
Throat (esophagus or pharynx)	4	9-12
Ovarian	4	44
Breast	4	16

a CDC 2014 World Trade Center Health Program

b Nadler and Zurbenko 2014

Conclusions:

- No data identified by the consultants supports a 12-year length of service requirement.
- There is indirect evidence from the cancer epidemiology literature that exposure durations less than 12 years can result in increased cancer risk.
- Although data are limited, most cancers of interest to JLARC could have a minimum latency of as few as 4 years.
- These data on exposure duration and minimum cancer latency may also inform statute of limitations timeframes.

Recommendation on years of service requirement:

- **The data summarized on exposure duration and minimum cancer latency indicates scientific support to lower or reduce Virginia's length of service requirement.**

Bibliography and Quality Evaluation

For outcomes included in the search of electronic databases: Cancer, Cardiovascular, Respiratory, PTSD and Suicide

CANCER – ALL STUDIES CONTRIBUTED INFORMATION TO THE PHASE 2 ANALYSIS AS DESCRIBED IN THE REPORT

CANCER: All studies found to be of good quality, no evidence of outside influences found.

Study Number*	Full Citation
241c	Glass, D. C., et al. (2016). "Mortality and cancer incidence in a cohort of male paid Australian firefighters." Occup Environ Med **73**(11): 761-771.
212	Paget-Bailly, S., et al. (2013). "Occupation and head and neck cancer risk in men: results from the ICARE study, a French population-based case-control study." J Occup Environ Med **55**(9): 1065-1073.
217	Ahn, Y. S., et al. (2012). "Cancer morbidity of professional emergency responders in Korea." Am J Ind Med **55**(9): 768-778.
213	Tsai, R. J., et al. (2015). "Risk of cancer among firefighters in California, 1988-2007." Am J Ind Med **58**(7): 715-729.
250a	Sritharan, J., et al. (2017). "Prostate cancer in firefighting and police work: a systematic review and meta-analysis of epidemiologic studies." Environ Health **16**(1): 124.
223	Pukkala, E., et al. (2014). "Cancer incidence among firefighters: 45 years of follow-up in five Nordic countries." Occup Environ Med **71**(6): 398-404.
230b	Ahn, Y. S. and K. S. Jeong (2015). "Mortality due to malignant and non-malignant diseases in Korean professional emergency responders." PLoS One **10**(3): e0120305.
249	Barry, K. H., et al. (2017). "Risk of early-onset prostate cancer associated with occupation in the Nordic countries." Eur J Cancer **87**: 92-100.
222a	Daniels, R. D., et al. (2014). "Mortality and cancer incidence in a pooled cohort of US firefighters from San Francisco, Chicago and Philadelphia (1950-2009)." Occup Environ Med **71**(6): 388-397.
228	Daniels, R. D., et al. (2015). "Exposure-response relationships for select cancer and non-cancer health outcomes in a cohort of U.S. firefighters from San Francisco, Chicago and Philadelphia (1950-2009)." Occup Environ Med **72**(10): 699-706.
2091	Kirstine Ugelvig Petersen, K., et al. "Long-term follow-up for cancer incidence in a cohort of Danish firefighters." 263-269.
244b	Glass, D. C., et al. (2017). "Mortality and cancer incidence among male volunteer Australian firefighters." Occup Environ Med **74**(9): 628-638.
255a	Harris, M. A., et al. (2018). "Surveillance of cancer risks for firefighters, police, and armed forces among men in a Canadian census cohort." Am J Ind Med **61**(10): 815-823.
251	Kullberg, C., et al. (2018). "Cancer incidence in Stockholm firefighters 1958-2012: an updated cohort study." Int Arch Occup Environ Health **91**(3): 285-291.

226a	Ide, C. W. (2014). "Cancer incidence and mortality in serving whole-time Scottish firefighters 1984-2005." Occup Med (Lond) **64**(6): 421-427.
229	Brice, A., et al. (2015). "French firefighter mortality: analysis over a 30-year period." Am J Ind Med **58**(4): 437-443.
2093a	Jalilian, H., et al. (2019). "Cancer incidence and mortality among firefighters." Int J Cancer.
999a	Glass, D. C., et al. (2019). "Mortality and cancer incidence among female Australian firefighters." Occup Environ Med **76**(4): 215-221.
410	Muegge, C. M., et al. (2018). "Excess mortality among Indiana firefighters, 1985-2013." Am J Ind Med **61**(12): 961-967.

*Study number for internal reference

CARDIOVASCULAR

Top Quality

Clear independence of funding and authorship. Sample size large (>= 100). Outcomes assessed clinically or from surveillance system.

Study Number	Full Citation
230a	Ahn, Y. S. and K. S. Jeong (2015). "Mortality due to malignant and non-malignant diseases in Korean professional emergency responders." PLoS One **10**(3): e0120305
244a	Glass, D. C., et al. (2017). "Mortality and cancer incidence among male volunteer Australian firefighters." Occup Environ Med **74**(9): 628-638.
254	Petersen, K. U., et al. (2018). "Mortality in a cohort of Danish firefighters; 1970-2014." Int Arch Occup Environ Health **91**(6): 759-766.
281	Soteriades, E. S., et al. (2011). "Cardiovascular disease in US firefighters: a systematic review." Cardiol Rev **19**(4): 202-215.
305	Crawford, J. O. and R. A. Graveling (2012). "Non-cancer occupational health risks in firefighters." Occup Med (Lond) **62**(7): 485-495.
323a	Wolkow, A., et al. (2014). "Coronary heart disease risk in volunteer firefighters in Victoria, Australia." Arch Environ Occup Health **69**(2): 112-120.
355	Farioli, A., et al. (2015). "Incidence of sudden cardiac death in a young active population." J Am Heart Assoc **4**(6): e001818.
368	Risavi, B. L. and J. Staszko (2016). "Prevalence of Risk Factors for Coronary Artery Disease in Pennsylvania (USA) Firefighters." Prehosp Disaster Med **31**(1): 102-107.
370	Yu, C. C., et al. (2015). "Association Between Leisure Time Physical Activity, Cardiopulmonary Fitness, Cardiovascular Risk Factors, and Cardiovascular Workload at Work in Firefighters." Saf Health Work **6**(3): 192-199.
378	Choi, B., et al. (2016). "Twenty-four-hour work shifts, increased job demands, and elevated blood pressure in professional firefighters." Int Arch Occup Environ Health **89**(7): 1111-1125
401	Pedersen, J. E., et al. (2018). "Incidence of cardiovascular disease in a historical cohort of Danish firefighters." Occup Environ Med **75**(5): 337-343.
402a	Han, M., et al. (2018). "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 **8**(1): e019987.
402b	Han, M., et al. (2018). "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 **8**(1): e019987.
637	Thayyil, J., et al. (2012). "Metabolic syndrome and other cardiovascular risk factors among police officers." N Am J Med Sci **4**(12): 630-635.

652	Ramakrishnan, J., et al. (2013). "High prevalence of cardiovascular risk factors among policemen in Puducherry, South India." J Cardiovasc Dis Res **4**(2): 112-115.
713	Janczura, M., et al. (2015). "The Relationship of Metabolic Syndrome with Stress, Coronary Heart Disease and Pulmonary Function--An Occupational Cohort-Based Study." PLoS One **10**(8): e0133750.
716	Ganesh, K. S., et al. (2014). "Prevalence and Risk Factors of Hypertension Among Male Police Personnel in Urban Puducherry, India." Kathmandu Univ Med J (KUMJ) **12**(48): 242-246.
751	Shiozaki, M., et al. (2017). "Job stress and behavioral characteristics in relation to coronary heart disease risk among Japanese police officers." Ind Health **55**(4): 369-380
770	Bhatia, K. M. and N. Pandit (2017). "Prevalence of Chronic Morbidity and Sociodemographic Profile of Police Personnel - A Study from Gujarat." J Clin Diagn Res **11**(9): LC06-LC09

CARDIOVASCULAR: Middle Quality

Missing 1 or 2 elements of the Top Quality requirements.

Study Number	Full Citation
1648 ***self-reported data**	Studnek, J. R., et al. (2010). "An assessment of key health indicators among emergency medical services professionals." Prehosp Emerg Care **14**(1): 14-20.
258b ***review paper; no discussion of sample sizes or data collection methods from included papers**	Kales, S. N., et al. (2009). "Blood pressure in firefighters, police officers, and other emergency responders." Am J Hypertens **22**(1): 11-20.
295 ***conducted by petroleum industry; unable to determine independence**	Mochtar, I. and R. W. Hooper (2012). "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 **18**(2): 127-131.
299 ***self-reported data**	Plat, M. J., et al. (2012). "Diminished health status in firefighters." Ergonomics **55**(9): 1119-1122.
369a ***self-reported data**	Semmens, E. O., et al. (2016). "A cross-sectional survey of occupational history as a wildland firefighter and health." Am J Ind Med **59**(4): 330-335.
403 ***self-reported data**	Gendron, P., et al. "Cardiovascular Disease Risk Factors in Québec Male Firefighters." e300-e306.
422 *small sample size; funding source not provided to determine independence	Martin, Z. T., et al. (2019). "Cardiovascular Disease Risk Factors and Physical Fitness in Volunteer Firefighters." Int J Exerc Sci **12**(2): 764-776.
575 ***self-reported data**	Wanahita, N., et al. (2010). "No evidence of increased prevalence of premature coronary artery disease in New York City police officers as predicted by coronary artery calcium scoring." J Occup Environ Med **52**(6): 661-665.
595 ***self-reported data**	Ramey, S. L., et al. (2011). "Relationship of cardiovascular disease to stress and vital exhaustion in an urban, midwestern police department." AAOHN J **59**(5): 221-227
600 *funding source not provided to determine independence	Wright, B. R., et al. (2011). "Law enforcement officer versus non-law enforcement officer status as a longitudinal predictor of traditional and emerging cardiovascular risk factors." J Occup Environ Med **53**(7): 730-734
610 *funding source not provided to determine independence	Zimmerman, F. H. (2012). "Cardiovascular disease and risk factors in law enforcement personnel: a comprehensive review." Cardiol Rev **20**(4): 159-166.

CARDIOVASCULAR: Limited Quality

Missing more than 2 of the elements of the Top Quality group.

Study Number	Full Citation
258a ***review paper; no discussion of sample sizes or data collection methods from included papers; no comparison group for police**	Kales, S. N., et al. (2009). "Blood pressure in firefighters, police officers, and other emergency responders." Am J Hypertens **22**(1): 11-20.
3340 ***small sample size; funding not provided to determine independence**	Lestrina, D., et al. "Obesity with metabolic syndrome to police in Polres Deli Serdang." 15109-15123.
405 *small sample size; self-reported data; did not compare to similar population (used male firefighters rather than female)	Gendron, P., et al. (2018). "Cardiovascular disease risk in female firefighters." Occup Med (Lond) **68**(6): 412-414.
574 *small sample size; self-reported data; funding not provided to determine independence	Yoo, H. and W. D. Franke (2011). "Stress and cardiovascular disease risk in female law enforcement officers." Int Arch Occup Environ Health **84**(3): 279-286.
783a *self-reported data; lack of adequate comparison groups – male officers compared to female officers and female officers not compared to women in occupations with similar exposures.	Gendron, P., et al. (2018). "Cardiovascular health profile among Quebec male and female police officers." Arch Environ Occup Health: 1-10

PTSD 17 Independent Studies

PTSD: Independent, good quality studies

Clear independence of funding and authorship. Sample size large (>= 100). Outcomes assessed using standardized assessment forms.

Study Number	Full Citation
411	Jones, S., et al. (2018). "Prevalence and correlates of psychiatric symptoms among first responders in a Southern State." Arch Psychiatr Nurs **32**(6): 828-835.
481	Harvey, S. B., et al. (2016). "The mental health of fire-fighters: An examination of the impact of repeated trauma exposure." Aust N Z J Psychiatry **50**(7): 649-658.
503	Carleton, R. N., et al. (2018). "Mental Disorder Symptoms among Public Safety Personnel in Canada." Can J Psychiatry **63**(1): 54-64.
509	Kim, J. E., et al. (2018). "Firefighters, posttraumatic stress disorder, and barriers to treatment: Results from a nationwide total population survey." PLoS One **13**(1): e0190630.
523	Milligan-Saville, J., et al. (2018). "The impact of trauma exposure on the development of PTSD and psychological distress in a volunteer fire service." Psychiatry Res **270**: 1110-1115.
869	Austin-Ketch TL et al. (2012). “Addictions and the criminal justice system, what happens on the other side? Post-traumatic stress symptoms and cortisol measures in a police cohort.” J Addict Nurs. 2012 Feb;23(1):22-9.
880	Fox, J., et al. (2012). "Mental-health conditions, barriers to care, and productivity loss among officers in an urban police department." Conn Med **76**(9): 525-531.
1998	Mishra, S., et al. (2010). "Trauma exposure and symptoms of post-traumatic stress disorder in emergency medical services personnel in Hawaii." Emerg Med J **27**(9): 708-711.
5392	Fjeldheim, C. B., et al. (2014). "Trauma exposure, posttraumatic stress disorder and the effect of explanatory variables in paramedic trainees." BMC Emerg Med **14**: 11.
402	Han, M., et al. (2018). "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 **8**(1): e019987.
997	Martin M et al. (2019). Traumatic events in the workplace: impact on psychopathology and healthcare use of police officers. Int J Emerg Ment Health. 2009 Summer;11(3):165-76.

2044	Petrie, K., et al. (2018). "Prevalence of PTSD and common mental disorders amongst ambulance personnel: a systematic review and meta-analysis." Soc Psychiatry Psychiatr Epidemiol **53**(9): 897-909.

PTSD: Studies with potential for bias or financial conflict of interest but generally good quality

Missing no more than 2 of the quality elements.

Study Number	Full Citation
504 *funding source not provided to determine independence	Psarros, C., et al. (2018). "Personality characteristics and individual factors associated with PTSD in firefighters one month after extended wildfires." Nord J Psychiatry **72**(1): 17-23.
525 *funding source not provided to determine independence	Khan, K., et al. (2018). "A Case Study of the Effects of Posttraumatic Stress Disorder on Operational Fire Service Personnel Within the Lancashire Fire and Rescue Service." Safety and Health at Work **9**(3): 277-289.
2050 *funding source not provided to determine independence	Bezabh, Y. H., et al. (2018). "Prevalence and associated factors of post-traumatic stress disorder among emergency responders of Addis Ababa Fire and Emergency Control and Prevention Service Authority, Ethiopia: institution-based, cross-sectional study." BMJ Open **8**(7): e020705.
5037 *funding source not provided to determine independence	Skeffington., et al. (2017)Trauma exposure and post-traumatic stress disorder within fire and emergency services in Western Australia. Australian Journal of Psychology 2017; 69: 20–28
5061 *funding source not provided to determine independence	Arbona, C. and J. P. Schwartz (2016). "Posttraumatic Stress Disorder Symptom Clusters, Depression, Alcohol Abuse, and General Stress Among Hispanic Male Firefighters." Hispanic Journal of Behavioral Sciences **38**(4): 507-522.

Suicide 14 Independent Studies

Suicide : Independent, good quality studies

Clear independence of funding and authorship. Sample size large (>= 100). Outcomes assessed using standardized assessment forms

Study Number	Full Citation
254	Petersen, K. U., et al. (2018). "Mortality in a cohort of Danish firefighters; 1970-2014." Int Arch Occup Environ Health **91**(6): 759-766.
8651	Carleton, R. N., et al. (2018). "Suicidal Ideation, Plans, and Attempts Among Public Safety Personnel in Canada." Canadian Psychology-Psychologie Canadienne **59**(3): 220-231.
8660	Stanley, I. H., et al. (2017). "Suicidal thoughts and behaviors among women firefighters: An examination of associated features and comparison of pre-career and career prevalence rates." J Affect Disord **221**: 107-114.
8713	Wild Stanley, I. H., et al. (2018). "Wildland firefighters and suicide risk: Examining the role of social disconnectedness." Psychiatry Res **266**: 269-274.
8591	Stanley, I. H., et al. (2015) “Career prevalence and correlates of suicidal thoughts and behaviors among firefighters.” J Affect Disord **187**: 163-171
11574	Violanti, J. M., et al. (2011). "Is suicide higher among separated/retired police officers? an epidemiological investigation." Int J Emerg Ment Health **13**(4): 221-228.
230	Ahn, Y. S. and K. S. Jeong (2015). "Mortality due to malignant and non-malignant diseases in Korean professional emergency responders." PLoS One **10**(3): e0120305.
241	Glass, D. C., et al. (2016). "Mortality and cancer incidence in a cohort of male paid Australian firefighters." Occup Environ Med **73**(11): 761-771.
244	Glass, D. C., et al. (2017). "Mortality and cancer incidence among male volunteer Australian firefighters." Occup Environ Med **74**(9): 628-638.
999	Glass, D. C., et al. (2019). “Mortality and cancer incidence among female Australian firefighters” Occup Environ Med 2019; 76 :215–221.
11747	Violanti, J. M., et al. (2013). "Law enforcement suicide: a national analysis." Int J Emerg Ment Health **15**(4): 289-297.

Suicide: Studies with potential for bias or financial conflict of interest but generally good quality

Missing no more than 2 quality elements.

Study Number	Full Citation
10724 *funding source not provided to determine independence	Violanti, J. M., et al. (2012). "Police suicide in small departments: a comparative analysis." Int J Emerg Ment Health **14**(3): 157-162.
12527 *funding source not provided to determine independence	Grassi, C., et al. (2019). "Suicide among Italian police officers from 1995 to 2017." Riv Psichiatr **54**(1): 18-23.

Suicide: Studies with limited quality

Missing more than 2 of the quality elements. This study (Costa 2019) did not contribute to determinations.

Study Number	Full Citation
12661 *small sample n=39, missing data, non-significant finding	Costa, T., et al. (2019). "Suicides of Male Portuguese Police Officers - 10 years of National Data." Crisis: 1-5.

RESPIRATORY

Top Quality

Clear independence of funding and authorship. Sample size large (>= 100). Outcomes assessed clinically or from surveillance system.

Study Number	Full Citation
254	Petersen, K. U., et al. (2018). "Mortality in a cohort of Danish firefighters; 1970-2014." Int Arch Occup Environ Health **91**(6): 759-766.
6294	Pedersen, J. E., et al. (2018). "Risk of asthma and chronic obstructive pulmonary disease in a large historical cohort of Danish firefighters." Occup Environ Med **75**(12): 871-876
230	Ahn, Y. S. and K. S. Jeong (2015). "Mortality due to malignant and non-malignant diseases in Korean professional emergency responders." PLoS One **10**(3): e0120305.
229	Brice, A., et al. (2015). "French firefighter mortality: analysis over a 30-year period." Am J Ind Med **58**(4): 437-443.
6079	Greven, F., et al. (2011). "Lung function, bronchial hyperresponsiveness, and atopy among firefighters." Scand J Work Environ Health **37**(4): 325-331.

RESPIRATORY: Middle Quality

Missing no more than 2 of the quality elements.

Study Number	Full Citation
244 ***conducted by fire industry; unable to determine independence**	Glass, D. C., et al. (2017). "Mortality and cancer incidence among male volunteer Australian firefighters." Occup Environ Med **74**(9): 628-638.
999 ***conducted by fire industry; unable to determine independence**	Glass, D. C., et al. (2019). "Mortality and cancer incidence among female Australian firefighters." Occup Environ Med **76**(4): 215-221.
369 ***self-reported data**	Semmens, E. O., et al. (2016). "A cross-sectional survey of occupational history as a wildland firefighter and health." Am J Ind Med **59**(4): 330-335.
241 ***conducted by fire industry; unable to determine independence**	Glass, D. C., et al. (2016). "Mortality and cancer incidence in a cohort of male paid Australian firefighters." Occup Environ Med **73**(11): 761-771.
6184 ***self-reported data**	Schermer, T. R., et al. (2014). "Chronic respiratory conditions in a cohort of metropolitan fire-fighters: associations with occupational exposure and quality of life." Int Arch Occup Environ Health **87**(8): 919-928.
410 ***funding source not provided to determine independence**	Muegge, C. M., et al. (2018). "Excess mortality among Indiana firefighters, 1985-2013." Am J Ind Med **61**(12): 961-967.

RESPIRATORY: Limited Quality

Missing more than 2 of the quality elements.

Study Number	Full Citation
405 *self-reported data; small sample size; did not compare to women in occupations with similar exposures	Gendron, P., et al. (2018). "Cardiovascular disease risk in female firefighters." Occup Med (Lond) **68**(6): 412-414.
6056 (b) *self-reported data; no funding source provided; did not compare to other firefighters	Ribeiro, M., et al. (2009). "Prevalence and risk of asthma symptoms among firefighters in Sao Paulo, Brazil: a population-based study." Am J Ind Med **52**(3): 261-269

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Appendix A: Methods

Literature search strategy and outcome selection

Following the workplan outlined by JHU in response to the Statement of Work, we conducted an electronic literature search of the PubMed, Embase, and PsycINFO databases for articles published between January 1, 2009 and May 31, 2019. Our search terms included those listed in the Statement of Work as well as those suggested by JHU medical librarian (see Supplemental information pages 96-99). The populations of interest were structural and wildland firefighters, hazardous materials officers (if identified separately), and police/law enforcement officers. Search strategies were run in all three databases simultaneously with duplicates eliminated (see Supplemental Appendix 2). We also included works recommended by JLARC constituents if they met the date and topical criteria. Selected other articles were included based on examination of reference lists and relevant systematic reviews.

Cardiovascular and respiratory outcome selection: Selection of cardiovascular and respiratory disease outcomes was based on frequency of their occurrence in the US adult population (CDC, 2011b, 2017a, 2017b, 2017c, 2019a).

Pneumoconiosis: Pneumoconiosis was not included in the 10-year literature search due to the very large numbers of articles available on that outcome alone. The pneumoconiosis section includes an overview and an examination of the various types of jobs at risk of pneumoconiosis informed by several recent reviews and a NIOSH database as key resources.

Inclusion and exclusion criteria

We searched for articles meeting the following criteria: (1) date range as described above; (2) were human epidemiological studies; (3) assessed exposure-disease or occupation-disease association; (4) specified the worker populations of interest; (5) specified diseases only; and (6) were published in English. Articles were excluded if they were: (1) not published in English; (2) reported only therapy or treatment; (3) were focused on exposures or risk factors only; (4) were hypothesis-generating or mechanism studies (animal toxicology, cell-culture); or (5) were popular press or news articles.

A multi-step screening process began with title and abstract review and then proceeded to full-text review. Articles meeting all inclusion criteria were retained for quality assessment and data extraction. Questions about inclusion or exclusion of articles were resolved by team consensus.

Search summary:

- Approximately 13,000 papers found
- ~8000 unique publications (5000 duplicates removed)
- ~7900 excluded as irrelevant
- ~100 included from literature search
- Some additional references retrieved from systematic reviews, etc.
- A very small number of references could not be found/retrieved to date but it is unlikely that any particular study would influence the results presented below.
- Final total of papers included/summarized:
    - Cancer papers: 19
    - Cardiovascular (CVD): 35
    - Post-traumatic stress disorder (PTSD): 17
    - Respiratory: 14
    - Suicide: 14
    - Pneumoconiosis: 12

<u>Choices regarding populations of interest (made in consultation with JLARC)</u>

Hazardous materials (HazMat) officers are typically firefighters too. Findings for HazMat officers will be identified when available. In a few studies data on wildland firefighters, dispatchers and emergency medical service workers were reported and included. Our search found studies following the health of 9/11 World Trade Center rescue and recovery workers; however, we excluded those studies because the nature of exposures during the World Trade Center rescue and response were substantially different from typical first responder work.

<u>Study quality assessment</u>

Quality assessment was determined based on study quality and conduct and independence of funding source and authorship. Studies were divided into three tiers Top Quality, Middle Quality, and Limited

Quality. Studies of Top Quality had clear independence between funding source and authorship, had sample sizes greater than or equal to 100, and did not collect health outcome data by self-report (except for PTSD research, as discussed below). Those of Middle Quality had no more than two of the assessment elements (independence, sample size, outcome assessment) missing. Finally, studies of Limited Quality had more than two of the assessment elements (independence, sample size, outcome assessment) missing. However, due to the limited number of studies for each outcome, all studies were considered in the evaluation of evidence for each outcome (unless otherwise noted). Further discussion on use of data in making determinations appears below, see "Other considerations in evaluating epidemiological data".

Evaluation process

In assessing study quality and evaluating the dataset developed from the literature search, a standard framework similar to that applied by committees of the National Academies of Science, Engineering and Medicine, e.g., in the Veterans and Agent Orange and other reports was adapted and applied. The evaluation process required an assessment of each study individually and then collectively as group, as follows: (1) the quality of the data in each study; (2) appropriateness of methods used in each study; and (3) putting the findings of each study in the context of the larger dataset of other studies on each outcome. The assessment of data collection addresses several key areas of scientific concern ranging from the identification of study participants and controls and their representativeness to the population of concern in the policy matter, whether exposures and outcomes are correctly defined, and whether the data collected is free from potential bias. Assessing the methods addresses how well the results actually inform the questions asked in the study. An overall summary of the evaluation process is presented in Table M1.

Following the quality review, the evaluation of the included studies continued with consideration of how each study contributed to the dataset[3] as a whole to define the overall "strength of evidence" and make determinations, summarized in Table M2. The five categories in Table M2 are similar to those used in other expert reviews but were tailored to this task and developed in consultation with JLARC. Categorizing a diverse scientific dataset is always a challenging task requiring scientific judgments.

[3] Dataset refers to the group of articles gathered and included for each health outcome.

The main criteria used to assess the dataset and inform the categorization judgments for each outcome were: 1) strength of association including statistical significance; 2) replication; and 3) consistency. Strength of association means measures of association of 2 or greater – indicating at least of doubling of risk[4]; replication means multiple studies in different settings; and consistency means generally similar quantitative results.

Table M1. Description of study quality and dataset evaluation process

Evaluation Areas	Scientific concerns
1) Data collection	Well-defined populations (exposed and unexposed) Sample size or number of participants (if small the study may not be representative of the population of concern) Data free of potential bias (over-reporting or under-reporting)
2) Analytical methods applied	Appropriate statistical methods Control for known risk factors and potential confounders Adequate follow-up time (cancer)
3) Contribution to overall dataset	Statistically significant findings Consistent findings Replicated in different places Similar magnitude of risk Similar direction of increase or decrease

Table M2. Guide for determinations

"Strength of Evidence" Category	Features of the dataset (strength of association, replication, consistency)
Sufficient evidence	Several (5 or more) consistent studies with statistically significant positive associations and one or more studies finding relative risk/SMR/SIR more than 2; few (2-3) studies finding decreased risk
Supportive evidence	At least 3 studies with statistically significant positive associations with one or more studies finding relative risk/SMR/SIR more than 2; one or no studies finding statistically significant decreased risk
Suggestive evidence	Few (2-3) studies with statistically significant increased risk or positive associations with risks less than 2; one or no studies with statistically significant decreased risk
Insufficient evidence	Three (3) or fewer studies with: No statistically significant findings of increased and/or decreased risk; OR Statistically significant findings of both increased and decreased risk
No evidence	No data found

4 A risk measure of 2 or greater is a commonly used indicator of strength of association.

Other considerations in evaluating epidemiological data

Utility of different sources of data (surveys, clinic visits, surveillance systems)

There is stronger potential for bias when data are gathered by self-reported survey. For example, study participants may under-report risky behaviors such as smoking or alcohol use. Participants without illness may have less recollection of past exposures, while those who are ill may be more sensitive to past exposures and be more likely to over-report them. Study findings based on self-reports should be interpreted with caution. Data gathered at a clinic visit including the medical record or by a formal surveillance system (vital statistics or cancer registries) are generally less prone to bias in comparison to self-report.

Definitions of incidence and prevalence and their utility for assessing risk

Incidence data identifies the new cases of a disease over a specific time period in a defined population. Prevalence data includes new and existing cases of disease in a defined population. These differences become important in the context of epidemiological investigation because identifying a causal agent requires an understanding of the timing of exposure, i.e., exposure must precede the disease development. Incidence data is considered the best indicator for evaluating risk because relating new disease to a particular exposure is more easily done. Prevalence data gives an understanding of the overall burden of disease in a population of interest but it may not be possible to identify whether cases of disease occurred before or after a particular exposure (or whether the disease is controlled by treatment). Mortality data is informative for risk analyses but mortality is also influenced by the availability and effectiveness of treatment.

Use of prevalence data in this report

The literature gathered included self-reported surveys with prevalence data for several outcomes, notably hypertension, asthma, emphysema, chronic obstructive pulmonary disease and also PTSD. The prevalence data for these outcomes was used differently within each section. The prevalence data for hypertension, asthma, emphysema, chronic obstructive pulmonary disease are discussed in each section but are not used in making strength-of-evidence determinations because the “gold standard” assessments for these outcomes are clinical measurements (blood pressure measurements, pulmonary function tests), and because of the potential for bias as described above.

The prevalence data for PTSD was used in making strength-of-evidence determinations. PTSD is assessed by self-reported survey instruments designed to provide a diagnosis aligned with current mental health diagnostic criteria (Diagnostic and Statistical Manual of Mental Disorders [DSM-5]). All studies included in this report used a survey instrument of this type so the PTSD prevalence data are equivalent to clinical assessments.

Healthy Worker Effect

The healthy worker effect (HWE) is defined as "a phenomenon where workers often exhibit lower overall death rates than the general population, because persons who are severely ill and chronically disabled are ordinarily excluded from employment or leave employment early"(Green-McKenzie, 2017). The HWE was not part of the literature search conducted so no new data were gathered on this topic. However in 2011, overall mortality in firefighters was examined by the Institute of Medicine (IOM) Committee on the Long-term Health consequences of Exposure to Burn Pits in Iraq and Afganistan. (Due to lack of research on military personnel, firefighters and other surrogate populations with similar exposures to smoke and combustion by-products were examined (IOM, 2011).) The IOM committee summarized twelve studies that assessed all-cause mortality in firefighters with publication dates ranging from 1990 - 2005. All twelve studies reported lower all-cause mortality in firefighters as compared to the general population; eight of the studies had statistically significant results including one with SMR of 0.52[5], four did not. Applying the strength of evidence guidance developed for this work (Table M2 above), the studies summarized by IOM provide sufficient evidence that as an occupational group firefighters are healthy workers.

In the context of the current analyses of cancer and other chronic conditions in first responders, it is important to consider the HWE when evaluating comparative health risk data. Given the HWE, it is not surprising to find evidence of decreased risk or that the increased risks that are found are often

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5 A SMR of 0.52 represents a risk of death one-half that of the comparison population; a strong indicator of decreased risk.

considered small to moderate particularly in comparison to the health experience of the general population.

Given an understanding of HWE, there are two implications related to the present task:

- Small to moderate increased risks are an important signal of health concern;
- Evidence of decreased risk compared with the general population is not surprising in the context of a healthy working population; therefore, no evidence of decreased risk is a finding of note.

Conclusion on methods: A relatively small number of studies were identified for the outcomes of interest in firefighters and police. The process and considerations reviewed above provide a useful framework to make informed determinations of risk from the literature identified.

Common Measures in Epidemiology Studies

Measure	Interpretation	
Measures of Frequency		
Incidence Risk (R)	Proportion of the population who develop the outcome over a set time.	
Incidence Rate (IR)	Proportion of the population who develop the outcome per unit time as risk.	
Prevalence (P)	Proportion of the population with an outcome/condition at a specific point in time.	
Odds (O)	Ratio of cases to non-cases.	
Measures of Association		
Risk Ratio (RR)	Those **exposed** were **RR times** as likely to have **the outcome** compared to those who were **not exposed** over **the time period**.	Null value of 1. If the result is less than 1, there is *decreased* risk associated with the exposure. It is also said that the exposure is a *protective factor* against the outcome. If the result is greater than 1, there is an increased risk of developing the associated with the exposure.
Incidence Rate Ratio (IRR)	Those **exposed** had **IRR times** the rate of **the outcome** compared to those who were **not exposed.**	
Odds Ratio (OR)	Those **with the outcome** are **OR times** as likely to have been **exposed** than those **without the outcome**.	

Supplemental to Appendix A. Search Terms for the Electronic Literature Search of the PubMed, Embase, and PsycINFO Databases (2009 – 2019)

Database	Concept	Search Terms
PubMed	1: Occupation Type	
	1a: Firefighters	firefighter [mesh] OR firefighter* [tw]
	1b: Police	police [mesh] OR law enforcement officer* [tw] OR police [tw] OR police* [tw]
	1c: Emergency responders	emergency responders [mesh] OR emergency responder* [tw] *NOTE: emergency responders are personnel trained to provide the initial services, care, and support in EMERGENCIES or DISASTERS* [1]
	1d. Hazardous materials officer	hazardous materials officer* OR hazmat officer* OR hazardous materials safety officer* OR hazmat safety officer* OR safety officer* OR fire safety officer *NOTE: hazardous materials safety officer (HMSO): NFPA title for the person that will work under the Incident Commander or Safety Officer at a HazMat incident and is responsible to ensure that recognized safe practices are followed for all operations involving hazardous materials/WMD* [2] *NOTE: hazmat: an abbreviated term for hazardous materials* [3] *NOTE: fire / safety officer: senior member of the responding fire department who manages the risks that emergency personnel (firefighters, police, EMTs, etc.) take at emergencies including but not limited to: structure fires, hazmat incidents, water rescues, extrications, and confined space incidents* [4, 5]
	2: Cancer	
	2a: Cancers covered by VA	leukemia [mesh] OR neoplasms [mesh] OR pancreatic neoplasms [mesh] OR prostatic neoplasms [mesh] OR rectal neoplasms [mesh] OR pharyngeal neoplasms [mesh] OR laryngeal neoplasms [mesh] OR tonsillar neoplasms [mesh] OR esophageal neoplasms [mesh] OR head and neck neoplasms [mesh] OR ovarian neoplasms [mesh] OR breast neoplasms [mesh] OR leukemia [tw] OR neoplasm* [tw] OR pancreatic neoplasm* [tw] OR prostatic neoplasm* [tw] OR rectal neoplasm* [tw] OR pharyngeal neoplasm* [tw] OR laryngeal neoplasm* [tw] OR tonsillar neoplasm* [tw] esophageal neoplasm* [tw] OR head and neck neoplasm* [tw] OR ovarian neoplasm* [tw] OR breast neoplasm* [tw]
	2b: Proposed cancers to be covered by VA	leukemia [mesh] OR neoplasms [mesh] OR pancreatic neoplasms [mesh] OR prostatic neoplasms [mesh] OR rectal neoplasms [mesh] OR pharyngeal neoplasms [mesh] OR laryngeal neoplasms [mesh] OR tonsillar neoplasms [mesh] OR ovarian neoplasms [mesh] OR breast neoplasms [mesh] OR colonic neoplasms [mesh] OR brain neoplasms [mesh] OR testicular neoplasms [mesh] OR leukemia [tw] OR neoplasm* [tw] OR pancreatic neoplasm* [tw] OR prostatic neoplasm* [tw] OR rectal neoplasm* [tw] OR pharyngeal neoplasm* [tw] OR laryngeal neoplasm* [tw] OR tonsillar neoplasm* [tw] OR ovarian neoplasm* [tw] OR breast neoplasm* [tw] OR colonic neoplasms [tw] OR brain neoplasms [tw] OR testicular neoplasms [tw]
	3: Cardiovascular disease	
		cardiovascular diseases [mesh] OR hypertension [mesh] OR heart diseases [mesh] OR cardiovascular disease* [tw] OR hypertension* [tw] OR heart disease* [tw]
	4: Mental health	
		trauma and stressor related disorders [mesh] OR post-traumatic stress disorder [mesh] OR acute stress disorder [mesh] OR trauma and stressor related disorder* [tw] OR post-traumatic stress disorder* [tw] OR acute stress disorder* [tw] OR PTSD [mesh] OR PTSD [tw] OR complex PTSD [tw] OR depression [mesh] OR depression [tw] OR depressive disorder [mesh] OR depressive disorder [tw] OR suicide [mesh] OR suicide [tw]
	5: Occupational pneumoconiosis	
	5a: Occupation	work [mesh] OR occupations [mesh] OR work* [tw] OR occupation* [tw]
	5b: Pneumoconiosis	pneumoconiosis [mesh] OR asbestosis [mesh] OR silicosis [mesh] OR anthracosis [mesh] OR pneumoconiosis* [tw] OR asbestosis* [tw] OR silicosis* [tw] OR anthracosis
	6: Respiratory diseases	
	6a: Disease location	respiratory track diseases [mesh] or respiratory track disease* [tw]
	6b: Disease type	respiratory physiological phenomena [mesh] respiratory physiological phenomena [tw]

10 Fire Engineering Magazine. https://www.fireengineering.com/articles/print/volume-161/issue-6/departments/roundtable/the-role-of-the-safety-officer.html.

Embase	1: Occupation Type	
	1a: Firefighters	fire fighters OR fire man OR firefighter OR firefighters OR firefighting OR fireman
	1b: Police	police OR law enforcement officer* OR police officer OR police officer* OR police*
	1c: Emergency responders [1]	emergency responders OR emergency responder*
	1d. Hazardous materials officer [2-5]	hazardous materials officer* OR hazmat officer* OR hazardous materials safety officer* OR hazmat safety officer* OR safety officer* OR fire safety officer
	2: Cancer	
	2a: Cancers covered by VA	leukemia OR neoplasm OR pancreas cancer OR prostate cancer OR rectum cancer OR pharynx cancer OR larynx cancer OR tonsil cancer OR esophageal cancer OR head and neck cancer OR ovary cancer OR breast cancer OR leukemia* OR neoplasm* OR pancreas cancer* OR prostate cancer* OR rectum cancer* OR pharynx cancer* OR larynx cancer* OR tonsil cancer* OR esophageal cancer* OR head and neck cancer* OR ovary cancer* OR breast cancer*
	2b: Proposed cancers to be covered by VA	leukemia OR neoplasm OR pancreas cancer OR prostate cancer OR rectum cancer OR pharynx cancer OR larynx cancer OR tonsil cancer OR esophageal cancer OR head and neck cancer OR ovary cancer OR breast cancer OR colon cancer OR brain cancer OR testis cancer OR leukemia* OR neoplasm* OR pancreas cancer* OR prostate cancer* OR rectum cancer* OR pharynx cancer* OR larynx cancer* OR tonsil cancer* OR esophageal cancer* OR head and neck cancer* OR ovary cancer* OR breast cancer* OR colon cancer* OR brain cancer* OR testis cancer*
	3: Cardiovascular disease	
		hypertension OR heart diseases OR hypertension* OR heart disease*
	4: Mental health	
		trauma and stressor related disorders OR posttraumatic stress disorder OR acute stress disorder OR PTSD OR complex PTSD OR depression OR depressive disorder OR suicide OR trauma and stressor related disorder* OR posttraumatic stress disorder* OR acute stress disorder* OR PTSD* OR complex PTSD* OR depression* OR depressive disorder* OR suicide*
	5: Occupational pneumoconiosis	
	5a: Occupation	occupations OR profession OR occupation* OR profession*
	5b: Pneumoconiosis	pneumoconiosis OR lung disease OR occupational lung disease OR lung fibrosis OR Caplan OR Caplan disease OR Caplan syndrome OR pneumoconiosis* OR lung disease* OR occupational lung disease* OR lung fibrosis* OR Caplan* OR Caplan disease* OR Caplan syndrome*
	6: Respiratory diseases	
		respiratory track disease OR lung function OR total lung capacity OR respiratory function

Database	Concept	Search Terms
PsycINFO	1: Occupation Type	
	1a: Firefighters	fire fighters OR fire man OR firefighter OR firefighters OR firefighting OR fireman
	1b: Police	police OR law enforcement officer* OR police officer OR police officer* OR police*
	1c: Emergency responders [1]	emergency responders OR emergency responder* OR rescue personnel* OR emergency medical technician*
	1d. Hazardous materials officer [2 - 5]	hazardous materials officer* OR hazmat officer* OR hazardous materials safety officer* OR hazmat safety officer* OR safety officer* OR fire safety officer
	4: Mental health	
		trauma and stressor related disorders OR posttraumatic stress disorder OR acute stress disorder OR PTSD OR complex PTSD OR depression OR depressive disorder OR suicide OR trauma and stressor related disorder* OR posttraumatic stress disorder* OR acute stress disorder* OR PTSD* OR complex PTSD* OR depression* OR depressive disorder* OR suicide*

Supplemental to Appendix A. Search Strategies for the Electronic Literature Search of the PubMed, Embase, and PsycINFO Databases (2009 – 2019)

Paired Concepts for Search Strategy – PubMed and Embase			Health Outcome Concepts						
			2: Cancer		3: Cardiovascular disease	4: Mental health	5: Occupational pneumoconiosis	6: Respiratory diseases	
			2a: Cancers covered by Virginia	2b: Proposed cancers to be covered by Virginia			5b: Pneumoconiosis	6a: Disease location	6b: Disease type
Occupation Concepts	1: Occupation Type	1a: Firefighter	X	X	X	X		X	X
		1b: Police			X	X		X	X
		1c: Emergency responder	X	X	X	X		X	X
		1d. Hazardous materials officer	X	X	X	X			
	5: Occupational pneumoconiosis	5a: Occupation					X		

Paired Concepts for Search Strategy - PsycINFO			Health Outcome Concepts
			4: Mental health
Occupation Concepts	1: Occupation Type	1a: Firefighter	X
		1b: Police	X
		1c: Emergency responder	X
		1d. Hazardous materials officer	X

Appendix B. Glossary of terms

Carcinogen. An agent capable of inducing a cancer response.

Dose. The amount of a substance available for interactions with metabolic processes or biologically significant receptors after crossing the outer boundary of an organism.

Dose-response evaluation. A component of risk assessment that describes the quantitative relationship between the amount of exposure to a substance (or condition such as a certain occupation) and the extent of toxic injury or disease.

Dose-response relationship. The quantitative relationship between the amount of exposure to a substance (or condition such as a certain occupation) and the extent of toxic injury produced.

Epidemiological study. Study of human populations to identify causes of disease. Such studies often compare the health status of a group of persons who have been exposed to a suspect agent with that of a comparable non-exposed group.

Exposure. Exposure is any type of contact. Typically, an exposure is contact made between a chemical, physical, or biological object and the outer boundary of an organism. However, exposures can also be an occupation. In some occupational health studies, exposure can be a specifically defined as a certain job. Exposure is quantified as the amount of an agent available at the exchange boundaries of the organism (e.g., skin, lungs, gut).

Healthy-worker effect (HWE). A type of bias that occurs in occupational epidemiology studies. While the general population consists of both healthy people and unhealthy people, the workforce tends to have fewer sick people. Moreover, those with severe illnesses would be most likely to be excluded from employment, but not from the general population. As a result, comparisons of disease rates between an employed group and the general population will be biased.

Human health risk. The likelihood (or probability) that a given exposure or series of exposures (or type of work) may have or will damage the health of individuals experiencing the exposures.

Incidence rate (IR). A measure of disease frequency in epidemiology studies; this is a measure of incidence that incorporates time (as person-time) directly into the measure. It is the ratio of the number of cases to the total time the population is at risk of disease.

Incidence risk (R). A measure of disease frequency in epidemiology studies; this is the proportion of an initially disease-free population that develops disease, becomes injured, or dies during a specified (usually limited) period of time. Synonyms include attack rate, risk, cumulative incidence, incidence proportion.

Incidence rate ratio (IRR). A measure of disease-exposure association in epidemiology studies; it compares the incidence rates, person-time rates, or mortality rates of two groups. These groups typically have all characteristics in common except exposure to an agent of interest. Interpretation is based on 1.0. An IRR of 1.0 indicates equal rates of the outcome in the two groups, an IRR greater than 1.0 indicates an increased rate of the outcome for the group in the numerator (typically the exposed group), and an IRR less than 1.0 indicates a decreased rate of the outcome for the group in the numerator (typically the exposed group).

Measure of association. Quantifies the relationship between exposure and disease among the two groups.

Measures of frequency. Characterize the occurrence of health events in a population.

Meta-analysis. A type of systematic review that uses statistical analyses to combine and analyze the data from single scientific studies on a specific topic and uses these combined findings to generate a single estimate or effect size to make more conclusive statements about the topic.

Neoplasm. An abnormal growth of tissue, as a tumor.

Odds (O). A measure of disease frequency *rarely used* in epidemiology studies; it is the probability of the outcome occurring divided by the probability that the outcome will not occur.

Odds ratio (OR). A measure of disease-exposure association in epidemiology studies; it quantifies the relationship between an exposure with two categories and one health outcome. The OR represents the odds that an outcome will occur given a particular exposure, compared to the odds of the outcome occurring in the absence of that exposure. Interpretation is based on 1.0. An OR of 1.0 indicates equal odds of the outcome in the two groups, an OR greater than 1.0 indicates an increased odds of the outcome for the group in the numerator (typically the exposed group), and an OR less than 1.0 indicates a decreased odds of the outcome for the group in the numerator (typically the exposed group).

Person-time. An estimate of the actual time-at-risk – in years, months, or days – that all participants contributed to a study.

Potency. A level of adverse effect produced by a unit amount of material.

ppb. Parts per billion.

ppm. Parts per million (equivalent to mg/kg or mg/m^3 or mg/L).

Prevalence (P). A measure of disease frequency in epidemiology studies; it is the proportion of persons in a population who have a particular disease at a specified point in time or over a specified period of time. It differs from incidence in that prevalence includes all cases, both new and preexisting, in the population at the specified time, whereas incidence is limited to new cases only.

Proportionate mortality ratio (PMR). Used to understand how a particular cause of death is distributed within a population of interest such as by age group or by occupation. PMR is calculated as the observed number of cause-specific deaths within a certain job divided by the expected number of deaths by that cause within that worker group. A PMR greater than 1 indicates more deaths than expected.

Risk. Probability of injury, disease, or death under specific circumstances.

Risk assessment. The process of evaluating scientific evidence of the toxic properties of a chemical and the conditions of human exposure to it both to ascertain the likelihood that exposed humans will be adversely affected, and to characterize the nature of the effects they may experience.

Risk characterization. Final component of risk assessment that involves integration of the data and analysis involved in hazard evaluation, dose-response evaluation, and human exposure evaluation to determine the likelihood that humans will experience any of the various forms of toxicity associated with a substance.

Risk management. Decisions about whether an assessed risk is sufficiently high to present a public health concern and about the appropriate means for control of a risk judged to be significant.

Risk ratio (RR). A measure of disease-exposure association in epidemiology studies; it compares the risk of a health event (disease, injury, risk factor, or death) among one group with the risk among another group. These groups typically have all characteristics in common except exposure to an agent of interest. Interpretation is based on 1.0. An RR of 1.0 indicates equal risk of the outcome in the two groups, an RR greater than 1.0 indicates an increased risk of the outcome for the group in the numerator (typically the exposed group), and an RR less than 1.0 indicates a decreased risk of the outcome for the group in the numerator (typically the exposed group). Also called relative risk.

Route of exposure. Method by which the chemical is introduced into the biological organism.

Scientifically plausible. An approach or concept having substantial scientific support but that is without complete empirical verification.

Standardized incidence ratios (SIR). The ratio of the observed number of cases to the expected number of cases.

Standardized mortality ratio (SMR). The ratio between the observed number of deaths in a study population and the number of deaths that would be expected, based on the age- and sex-specific rates in a standard population and the population size of the study population by the same age/sex groups.

Statistically significant. The difference in disease outcome between the exposed and unexposed workers that is probably not due to chance. Usually set at less than 0.05, indicating that there is less than a 5% probability that the difference is due to chance.

Threshold dose. The dose that has to be exceeded to produce a toxic response.

Total dose. Sum of doses received by all routes of exposure.

Upper bound estimate. Estimate not likely to be lower than the true risk.

Weight of evidence. The extent to which the available biomedical data support the hypothesis that a substance causes cancer in humans.

Methods and Glossary References

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Appendix C. Data Tables

NOTES:

Statistically significant results are presented in **Bold**.

The data tables are arranged in columns as listed and defined below:

Study ID Number: Internal study team tracking number for journal articles.

Type of study: Study design

Sample size: Number of participants in the study

How outcome data was collected: Main source of exposure and outcome data used in the study

Measure of occurrence: Type/definition of occurrence data, e.g., prevalence or incidence rates

Measure of occurrence value: The numerical value of the occurrence data

Measure of association: Type/definition of the measure of association, e.g., Hazard or Odds Ratio, Standardized Mortality or Incidence Ratio, etc.

Measure of association value: The numerical value of the measure of association

Variables controlled in analysis: Potential confounders addressed in the analysis

Cancer Data Tables

Colon Cancer								
Study ID Number	**Type of study**	**Sample size**	**How outcome data was collected**	**Measure of occurrence**	**Measure of occurrence value****	**Measure of association**	**Measure of association value****	**Variables controlled in analysis**
213	Case control	3996	Surveillance system	n/a	n/a	Odds ratio	1.1 (0.93, 1.31)	age, year of diagnosis, race
217	Retrospective cohort	29438	Surveillance system	n/a	n/a	Standardized incidence ratio	**1.27 (1.01, 1.59)**	age, calendar year
223	Retrospective cohort	16422	Surveillance system	n/a	n/a	Standardized incidence ratio	1.14 (0.99, 1.31)	age
229	Retrospective cohort	10829	Surveillance system	n/a	n/a	Standardized mortality ratio	0.73 (0.44, 1.04)	age
251	Retrospective cohort	1080	Surveillance system	n/a	n/a	Standardized incidence ratio	0.83 (0.43, 1.46)	age, calendar year
2091	Retrospective cohort	9061	Surveillance system	n/a	n/a	Standardized incidence ratio	**0.73 (0.57, 0.95)**	age
2093a	Systematic Review	999	Surveillance system	n/a	n/a	Summary incidence risk	**1.14 (1.06, 1.21)**	Underlying studies controlled: age, gender, smoking, race, others
2093b	Systematic Review	999	Surveillance system	Hazard	n/a	Summary mortality risk	1.1 (0.91, 1.34)	Underlying studies controlled: age, gender, smoking, race, others
226a	Prospective cohort	2213	Surveillance system	Incidence rate	0.000138 ($p < 0.01$)	n/a	n/a	age
226b	Prospective cohort	2213	Surveillance system	Mortality rate	0.000045 ($p > 0.05$)	n/a	n/a	age
230b	Prospective cohort	33442	Surveillance system	n/a	n/a	Standardized mortality ratio	0.65 (0.34, 1.14)	age
230c	Prospective cohort	33442	Surveillance system	n/a	n/a	Relative Risk (10 yrs service)	1.4 (0.33, 5.87)	age
230d	Prospective cohort	33442	Surveillance system	n/a	n/a	Relative Risk (20 yrs service)	1.29 (0.27, 6.08)	age
241c	Retrospective cohort	30057	Surveillance system	n/a	n/a	Standardized incidence ratio	1.07 (0.89, 1.28)	age group, calendar year
244b	Retrospective cohort	163094	Surveillance system	n/a	n/a	Standardized incidence ratio	**0.87 (0.78, 0.97)**	age
255a	Retrospective cohort	4535	Surveillance system	n/a	n/a	Hazard ratio	0.9 (0.67, 1.22)	age group, region, education
999a	Retrospective cohort	16320	Surveillance system	n/a	n/a	Standardized incidence ratio	1.12 (0.76, 1.59)	age, calendar year

Brain Cancer

Study ID Number	Type of study	Sample size	How outcome data was collected	Measure of occurrence	Measure of occurrence value**	Measure of association	Measure of association value**	Variables controlled in analysis
213	Case control	3996	Surveillance system	n/a	n/a	Odds ratio	**1.54 (1.19, 2.00)**	age, year of diagnosis, race
217	Retrospective cohort	29438	Surveillance system	n/a	n/a	Standardized incidence ratio	0.53 (0.14, 1.36)	age, calendar year
223	Retrospective cohort	16422	Surveillance system	n/a	n/a	Standardized incidence ratio	0.86 (0.66, 1.10)	age
251	Retrospective cohort	1080	Surveillance system	n/a	n/a	Standardized incidence ratio	0.6 (0.07, 2.15)	age, calendar year
2091	Retrospective cohort	9061	Surveillance system	n/a	n/a	Standardized incidence ratio	0.94 (0.67, 1.33)	age
2093a	Systematic Review	n/a	Surveillance system	n/a	n/a	Summary incidence risk	1.07 (0.87, 1.33)	Underlying studies controlled: age, gender, smoking, race, others
2093b	Systematic Review	n/a	Surveillance system	n/a	n/a	Summary mortality risk	1.25 (0.96, 1.63)	Underlying studies controlled: age, gender, smoking, race, others
222a	Retrospective cohort	29993	Surveillance system	n/a	n/a	Standardized mortality ratio	1.01 (0.79, 1.27)	age, gender, race, year
222b	Retrospective cohort	29993	Surveillance system	n/a	n/a	Standardized incidence ratio	1.02 (0.76, 1.34)	age, gender, race, calendar year
226a	Prospective cohort	2213	Surveillance system	Incidence rate	0.000048 (p > 0.05)	n/a	n/a	age
238a	Retrospective cohort	95	Surveillance system	n/a	n/a	Standardized incidence ratio	3.63 (0.09, 20.3)	age, calendar period (High risk group: fire training operators)
238b	Retrospective cohort	256	Surveillance system	n/a	n/a	Standardized incidence ratio	**5.74 (1.56, 14.7)**	age, calendar period (Medium exposure group: fire training instructors)
241c	Retrospective cohort	30057	Surveillance system	n/a	n/a	Standardized incidence ratio	0.93 (0.62, 1.35)	age group, calendar year
244b	Retrospective cohort	163094	Surveillance system	n/a	n/a	Standardized incidence ratio	0.94 (0.74, 1.17)	age
255a	Retrospective cohort	4535	Surveillance system	n/a	n/a	Hazard ratio	1.11 (0.61, 2.01)	age group, region, education
999a	Retrospective cohort	16320	Surveillance system	n/a	n/a	Standardized incidence ratio	0.84 (0.27, 1.97)	age, calendar year

Testicular Cancer

Study ID Number	Type of study	Sample size	How outcome data was collected	Measure of occurrence	Measure of occurrence value**	Measure of association	Measure of association value**	Variables controlled in analysis
213	Case control	3996	Surveillance system	n/a	n/a	Odds ratio	1.1 (0.73, 1.66)	age, year of diagnosis, race
223	Retrospective cohort	16422	Surveillance system	n/a	n/a	Standardized incidence ratio	**0.51 (0.23, 0.98)**	age
410	Case control	2818	Surveillance system	cause of death	0.027	N/A	999	year of death, age at time of death, sex, race, ethnicity,industry code, occupation code, and
2091	Retrospective cohort	9061	Surveillance system	n/a	n/a	Standardized incidence ratio	1.3 (0.95, 1.73)	age
2093a	Systematic Review	999	Surveillance system	n/a	n/a	Summary incidence risk	**1.34 (1.08, 1.68)**	Underlying studies controlled: age, gender, smoking, race, others
222a	Retrospective cohort	29993	Surveillance system	n/a	n/a	Standardized mortality ratio	0.73 (0.15, 2.14)	age, gender, race, year
222b	Retrospective cohort	29993	Surveillance system	n/a	n/a	Standardized incidence ratio	0.75 (0.43, 2.42)	age, gender, race, calendar year
226a	Prospective cohort	2213	Surveillance system	Incidence rate	0.000091 (p > 0.05)	N/A	999	age
238a	Retrospective cohort	95	Surveillance system	n/a	n/a	Standardized incidence ratio	**11.9 (1.44, 42.9)**	age, calendar period (High risk group: fire training operators)
238b	Retrospective cohort	256	Surveillance system	n/a	n/a	N/A	999	age, calendar period (Medium exposure group: fire training instructors)
241c	Retrospective cohort	30057	Surveillance system	n/a	n/a	Standardized incidence ratio	1.25 (0.91, 1.89)	age group, calendar year
244b	Retrospective cohort	163094	Surveillance system	n/a	n/a	Standardized incidence ratio	1.1 (0.88, 1.37)	age
255a	Retrospective cohort	4535	Surveillance system	n/a	n/a	Hazard ratio	1.8 (0.85, 3.78)	age group, region, education

Leukemia

Study ID Number	Type of study	Sample size	How outcome data was collected	Measure of occurrence	Measure of occurrence value	Measure of association	Measure of association value	Variables controlled in analysis
213	Case control	3996	Surveillance system	n/a	n/a	Odds ratio	**1.32 (1.05, 1.66)**	age, year of diagnosis, race
217	Retrospective cohort	29438	Surveillance system	n/a	n/a	Standardized incidence ratio	1.05 (0.56, 1.79)	age, calendar year
223	Retrospective cohort	16422	Surveillance system	n/a	n/a	Standardized incidence ratio	0.94 (0.71, 1.22)	age
228	Case control	19309	Surveillance system	n/a	n/a	Hazard ratio	**1.45 (1.00, 2.35)**	age
229	Prospective cohort	10829	Surveillance system	n/a	n/a	Standardized mortality ratio	0.89 (0.64, 1.20)	age
251	Retrospective cohort	1080	Surveillance system	n/a	n/a	Standardized incidence ratio	0.43 (0.05, 1.59)	age, calendar year
2091	Retrospective cohort	9061	Surveillance system	n/a	n/a	Standardized incidence ratio	0.76 (0.40, 1.46)	age
2093a	Other	999	Surveillance system	n/a	n/a	Summary incidence risk	0.97 (0.85, 1.11)	Underlying studies controlled: age, gender, smoking, race, others
2093b	Other	999	Surveillance system	n/a	n/a	Summary mortality risk	1.06 (0.93, 1.22)	Underlying studies controlled: age, gender, smoking, race, others
222a	Retrospective cohort	29993	Surveillance system	n/a	n/a	Standardized mortality ratio	1.1 (0.91, 1.31)	age, gender, race, calendar year
222b	Retrospective cohort	29993	Surveillance system	n/a	n/a	Standardized incidence ratio	0.94 (0.77, 1.15)	age, gender, race, calendar year
230b	Prospective cohort	33442	Surveillance system	n/a	n/a	Standardized mortality ratio	0.66 (0.24, 1.44)	age
230c	Prospective cohort	33442	Surveillance system	n/a	n/a	Relative Risk	6.54 (0.50, 85.12)	age
230d	Prospective cohort	33442	Surveillance system	n/a	n/a	Relative Risk	**83.65 (2.21, 3166.29)**	age
241c	Retrospective cohort	30057	Surveillance system	n/a	n/a	Standardized incidence ratio	1 (0.73, 1.35)	age group, calendar year
244b	Retrospective cohort	163094	Surveillance system	n/a	n/a	Standardized incidence ratio	**0.78 (0.64, 0.94)**	age
255a	Retrospective cohort	4535	Surveillance system	n/a	n/a	Hazard ratio	0.93 (0.55, 1.58)	age group, region, education
999a	Retrospective cohort	16320	Surveillance system	n/a	n/a	Standardized incidence ratio	0.71 (0.26, 1.55)	age, calendar year

Pancreatic Cancer

Study ID Number	Type of study	Sample size	How outcome data was collected	Measure of occurrence	Measure of occurrence value**	Measure of association	Measure of association value**	Variables controlled in analysis
213	Case control	3996	Surveillance system	n/a	n/a	Odds ratio	1.1 (0.83, 1.46)	age, year of diagnosis, race
217	Retrospective cohort	29438	Surveillance system	n/a	n/a	Standardized incidence ratio	0.95 (0.44, 1.81)	age, calendar year
223	Retrospective cohort	16422	Surveillance system	n/a	n/a	Standardized incidence ratio	1.17 (0.94, 1.45)	age
229	Retrospective cohort	10829	Surveillance system	n/a	n/a	Standardized mortality ratio	1.27 (0.92, 1.72)	age
251	Retrospective cohort	1080	Surveillance system	n/a	n/a	Standardized incidence ratio	0.87 (0.24, 2.23)	age, calendar year
2091	Retrospective cohort	9061	Surveillance system	n/a	n/a	Standardized incidence ratio	1.2 (0.86, 1.68)	age
2093a	Systematic Review	999	Surveillance system	n/a	n/a	Summary incidence risk	1.05 (0.94, 1.18)	Underlying studies controlled: age, gender, smoking, race, others
2093b	Systematic Review	999	Surveillance system	n/a	n/a	Summary mortality risk	1.13 (0.99, 1.29)	Underlying studies controlled: age, gender, smoking, race, others
241c	Retrospective cohort	30057	Surveillance system	n/a	n/a	Standardized incidence ratio	1.03 (0.69, 1.48)	age group, calendar year
244b	Retrospective cohort	163094	Surveillance system	n/a	n/a	Standardized incidence ratio	**0.77 (0.61, 0.97)**	age
255a	Retrospective cohort	4535	Surveillance system	n/a	n/a	Hazard ratio	1.38 (0.83, 2.29)	age group, region, education
410	Case control	2818	Surveillance system			Odds ratio	**1.45 (1.01, 2.06)**	year of death, age at time of death, sex, race, ethnicity,industry code, occupation code, and underlying cause of death

Prostate Cancer

Study ID Number	Type of study	Sample size	How outcome data was collected	Measure of occurrence	Measure of occurrence value**	Measure of association	Measure of association value**	Variables controlled in analysis
213	Case control	3996	Surveillance system	n/a	n/a	Odds ratio	**1.45 (1.25, 1.69)**	age, year of diagnosis, race
217	Retrospective cohort	29438	Surveillance system	n/a	n/a	Standardized incidence ratio	1.32 (0.60, 2.51)	age, calendar year
223	Retrospective cohort	16422	Surveillance system	n/a	n/a	Standardized incidence ratio	**1.13 (1.05, 1.22)**	age
229	Prospective cohort	10829	Surveillance system	n/a	n/a	Standardized mortality ratio	**0.54 (0.31, 0.86)**	age
249	Prospective cohort	7400000	Surveillance system	n/a	n/a	Standardized incidence ratio	**2.59 (1.34, 4.52)**	age, sex
251	Retrospective cohort	1080	Surveillance system	n/a	n/a	Standardized incidence ratio	**0.48 (0.33, 0.69)**	age, calendar year
2091	Retrospective cohort	9061	Surveillance system	n/a	n/a	Standardized incidence ratio	1.1 (0.95, 1.26)	age
2093a	Systematic Review	999	Surveillance system	n/a	n/a	Summary incidence risk	**1.15 (1.05, 1.27)**	Underlying studies controlled: age, gender, smoking, race, others
2093b	Systematic Review	999	Surveillance system	n/a	n/a	Summary mortality risk	1.08 (0.92, 1.27)	Underlying studies controlled: age, gender, smoking, race, others
222a	Retrospective cohort	29993	Surveillance system	n/a	n/a	Standardized mortality ratio	1.09 (0.96, 1.22)	age, gender, race, year
222b	Retrospective cohort	29993	Surveillance system	n/a	n/a	Standardized incidence ratio	1.03 (0.98, 1.09)	age, gender, race, calendar year
238a	Retrospective cohort	95	Surveillance system	n/a	n/a	Standardized incidence ratio	1.43 (0.46, 3.34)	age, calendar period (High risk group: fire training operators)
238b	Retrospective cohort	256	Surveillance system	n/a	n/a	Standardized incidence ratio	0.79 (0.32, 1.62)	age, calendar period (Medium exposure group: fire training instructors)
241c	Retrospective cohort	30057	Surveillance system	n/a	n/a	Standardized incidence ratio	**1.31 (1.19, 1.43)**	age group, calendar year
244b	Retrospective cohort	163094	Surveillance system	n/a	n/a	Standardized incidence ratio	**1.13 (1.08, 1.19)**	age
250a	Systematic Review	540767	meta analysis	n/a	n/a	Summary risk estimate (Incidence)	**1.17 (1.08, 1.28)**	Underlying studies controlled: age, ethnicity, others
250c	Systematic Review	40849	meta analysis	n/a	n/a	Summary risk estimate (Mortality)	1.12 (0.92, 1.36)	Underlying studies controlled: age, ethnicity, others
255a	Retrospective cohort	4535	Surveillance system	n/a	n/a	Hazard ratio	**1.18 (1.01, 1.37)**	age group, region, education

Rectal Cancer

Study ID Number	Type of study	Sample size	How outcome data was collected	Measure of occurrence	Measure of occurrence value**	Measure of association	Measure of association value**	Variables controlled in analysis
223	Retrospective cohort	16422	Surveillance system	n/a	n/a	n/a	0.99 (0.82, 1.19)	age
229	Prospective cohort	10829	Surveillance system	n/a	n/a	Standardized mortality ratio	1.36 (0.86, 2.04)	age
2091	Retrospective cohort	9061	Surveillance system	n/a	n/a	Standardized incidence ratio	1.22 (0.95, 1.55)	age
2093a	Systematic Review	999	Surveillance system	n/a	n/a	Summary incidence risk	**1.09 (1.00, 1.2)**	Underlying studies controlled: age, gender, smoking, race, others
2093b	Systematic Review	999	Surveillance system	n/a	n/a	Summary mortality risk	**1.36 (1.18, 1.57)**	Underlying studies controlled: age, gender, smoking, race, others
222a	Retrospective cohort	29993	Surveillance system	n/a	n/a	Standardized mortality ratio	**1.45 (1.16, 1.78)**	age, gender, race, year
222b	Retrospective cohort	29993	Surveillance system	n/a	n/a	Standardized incidence ratio	1.11 (0.95, 1.30)	age, gender, race, calendar year
230b	Prospective cohort	33442	Surveillance system	n/a	n/a	Standardized mortality ratio	0.65 (0.34, 1.14)	age
230c	Prospective cohort	33442	Surveillance system	n/a	n/a	Relative Risk	1.4 (0.33, 5.87)	age
230d	Prospective cohort	33442	Surveillance system	n/a	n/a	Relative Risk	1.29 (0.27, 6.08)	age
241c	Retrospective cohort	30057	Surveillance system	n/a	n/a	Standardized incidence ratio	1.18 (0.93, 1.48)	age group, calendar year
244b	Retrospective cohort	163094	Surveillance system	n/a	n/a	Standardized incidence ratio	0.84 (0.72, 0.97)	age
255a	Retrospective cohort	4535	Surveillance system	n/a	n/a	Hazard ratio	0.88 (0.61, 1.27)	age group, region, education
999a	Retrospective cohort	16320	Surveillance system	n/a	n/a	Standardized incidence ratio	1.26 (0.69, 2.12)	age, calendar year

Throat Cancer

Study ID Number	Type of study	Sample size	How outcome data was collected	Measure of occurrence	Measure of occurrence value**	Measure of association	Measure of association value**	Variables controlled in analysis
212	Case control	4620	Surveillance system	n/a	n/a	Odds ratio	**3.9 (1.4, 11.2)**	age, study center, alcohol, smoking
213	Case control	3996	Surveillance system	n/a	n/a	Odds ratio	**1.59 (1.2, 2.1)**	age, year of diagnosis, race
217	Retrospective cohort	29438	Surveillance system	n/a	n/a	Standardized incidence ratio	0.75 (0.28, 1.64)	age, calendar year
223	Retrospective cohort	16422	Surveillance system	n/a	n/a	Standardized incidence ratio	1 (0.60, 1.57)	age
229	Retrospective cohort	10829	Surveillance system	n/a	n/a	Standardized mortality ratio	0.93 (0.67, 1.27)	age
251	Retrospective cohort	1080	Surveillance system	n/a	n/a	Standardized incidence ratio	1.46 (0.40, 3.75)	age, calendar year
410	Case control	2818	Surveillance system	cause of death	0.007	Odds ratio	**2.26 (1.05, 4.65)**	year of death, age at time of death, sex, race, ethnicity,industry code, occupation code, and underlying cause of death
2091	Retrospective cohort	9061	Surveillance system	n/a	n/a	Standardized incidence ratio	0.91 (0.59, 1.41)	age
2093a	Systematic Review	999	Surveillance system	n/a	n/a	Summary incidence risk	1.15 (0.91, 1.44)	Underlying studies controlled: age, gender, smoking, race, others
2093b	Systematic Review	999	Surveillance system	n/a	n/a	Summary mortality risk	1.21 (0.95, 1.55)	Underlying studies controlled: age, gender, smoking, race, others
222a	Retrospective cohort	29993	Surveillance system	n/a	n/a	Standardized mortality ratio	**1.39 (1.14, 1.67)**	age, gender, race, year
222b	Retrospective cohort	29993	Surveillance system	n/a	n/a	Standardized incidence ratio	**1.62 (1.31, 2.00)**	age, gender, race, calendar year
241c	Retrospective cohort	30057	Surveillance system	n/a	n/a	Standardized incidence ratio	0.78 (0.46, 1.26)	age group, calendar year
244b	Retrospective cohort	163094	Surveillance system	n/a	n/a	Standardized incidence ratio	0.76 (0.57, 0.98)	age
255a	Retrospective cohort	4535	Surveillance system	n/a	n/a	Hazard ratio	1.31 (0.68, 2.51)	age group, region, education

Ovarian Cancer – no data

Breast Cancer

Study ID Number	Type of study	Sample size	How outcome data was collected	Measure of occurrence	Measure of occurrence value**	Measure of association	Measure of association value**	Variables controlled in analysis
229	Retrospective cohort	10829	Surveillance system	n/a	n/a	Standardized mortality ratio	0.76 (0.02, 4.23)	age
410	Case control	2818	Surveillance system	cause of death	0.001	n/a	n/a	ethnicity,industry code, occupation code, and underlying cause of death
2093a	Systematic Review	n/a	Surveillance system	n/a	n/a	Summary incidence risk	1.02 (0.47, 2.25)	Underlying studies controlled: age, gender, smoking, race, others
2093b	Systematic Review	n/a	Surveillance system	n/a	n/a	Summary mortality risk	2.47 (0.65, 9.48)	Underlying studies controlled: age, gender, smoking, race, others
222a	Retrospective cohort	29993	Surveillance system	n/a	n/a	Standardized mortality ratio	0.39 (0.60, 2.73)	age, gender, race, year
222b	Retrospective cohort	29993	Surveillance system	n/a	n/a	Standardized incidence ratio	1.26 (0.82, 1.85)	age, gender, race, calendar year
241c	Retrospective cohort	30057	Surveillance system	n/a	n/a	Standardized incidence ratio	2.17 (0.80, 4.72)	age group, calendar year
244b	Retrospective cohort	163094	Surveillance system	n/a	n/a	Standardized incidence ratio	1.29 (0.67, 2.26)	age
255a	Retrospective cohort	4535	Surveillance system	n/a	n/a	n/a	n/a	age group, region, education
999a	Retrospective cohort	16320	Surveillance system	n/a	n/a	Standardized incidence ratio	0.93 (0.78, 1.09)	age, calendar year

Cardiovascular Data Tables

Hypertension

Study ID Number	Type of study	Sample Size	How outcome data was collected	Measure of occurrence type for hypertension	Measure of occurrence value**	Measure of association type for hypertension	Measure of association value**	Other Variables Controlled or Measured in Analysis
Firefighter								
370	Cross sectional	387	Clinically assessed	Prevalence	33.9	n/a	n/a	age; BMI; waist circumference; history of hypertension; diabetes; high cholesterol; smokers and ex-smokers; history of heart disease; family history of heart disease
299	Cross sectional	278	Self-report	Prevalence	29	n/a	n/a	age; sex; volunteer or professional; BMI; hypertension; smoking
403	Cross sectional	756	Self-report	Prevalence	12.2	n/a	n/a	age; sex; height; body weight; years of employment; estimated maximal oxygen consumption; CVD history (heart attack, stroke, heart failure, etc.); modifiable CVD risk factors (smoking, physical inactivity, diagnosed hypertension, dyslipidemia, and diagnosed T2D); family history of CVD; CVD symptoms; psychological stress; nutrition (vegetable, fruit, and soft drink consumption)
422	Cross sectional	74	Clinically assessed	Prevalence	27	n/a	n/a	age; family history of CVD; smoking; sedentary lifestyle; obesity; hypertension; dyslipidemia; prediabetes
295	Cross sectional	369	Clinically assessed	Prevalence	26.7	n/a	n/a	age; sex; lipid and sugar profiles; smoking status; history of hypertension; diabetes
1648	Cross sectional	19960	Self-report	Prevalence	10.2	n/a	n/a	age; sex; pre-existing health conditions (diabetes, asthma, hypertension, myocardial infarction, angina, stroke, and/or high blood cholesterol level); general health; physical activity; smoking status; work-life balance
281*	Other	n/a	N/A, review paper	Prevalence	20 to 30	n/a	n/a	n/a systematic review
378	Cross sectional	330	Self-report, clinically assessed	Prevalence	11 (p < 0.01)	n/a	n/a	psychosocial working conditions; sociodemographic variables; health-related behaviors; sleep; mental health variables; and BMI
368*	Cross sectional	160	Clinically assessed	Prevalence	45 (33, 47)	n/a	n/a	height; weight; BMI; waist circumference; blood pressure (SBP and DBP); physical activity; department affiliation; age; gender; experience; marital status; race; smoking; history of hypertension
258a*	Other	n/a	Not provided or not available	Prevalence	23	n/a	n/a	lack of regular exercise; poor nutrition; shift work; noise exposure; PTSD; imbalance between job demands and decisional latitude
405*	Cross sectional	41	Self-report	Prevalence	5 (1, 19)	n/a	n/a	age; career level (rank); BMI; history of CVD and/or hypertension; smoking; physical activity
402b†	Retrospective cohort	272	Surveillance system	Incidence rate	1924.2	Hazard ratio	**0.85 (0.82, 0.88)**	smoking; alcohol consumption; history of hypertension; obesity; dyslipidemia; work-related factors such as night duties, high job stress, workplace violence and long work shifts
378	Cross sectional	330	Self-report, clinically assessed	Prevalence	11 (p < 0.01)	n/a	n/a	age; race; education; job title; worksite
244a$^{\delta}$	Retrospective cohort	163094	Surveillance system	n/a	n/a	Standardized mortality ratio	**0.46 (0.41, 0.5)**	age
254*	Cross sectional	11775	Surveillance system	n/a	n/a	Standardized mortality ratio	0.96 (0.54, 1.69)	employment types, periods, places, titles and functions; the unique Danish personal identification number; full time, part time, volunteer status; duration of employment
369a$^{\delta}$	Cross sectional	499	Self-report	n/a	n/a	Odds ratio	**4.2 (1.3, 14.0)**	age; sex; race; socio-economic status
369b$^{\delta}$	Cross sectional	499	Self-report	n/a	n/a	Odds ratio	**5 (1.3, 20.2)**	age; sex; race; socio-economic status

Hypertension – continued

Police								
716	Cross sectional	296	Clinically assessed	Prevalence	34.5	n/a	n/a	age; sex; blood pressure; anthropometric measurements; demographic factors; smoking; alcohol intake; physical activity; stress level; obesity; dietary factors
783a	Cross sectional	2099	Self-report	Prevalence	14.3	n/a	n/a	gender; age; height; body weight; years of employment; estimated maximal oxygen consumption; smoking; physical inactivity; diagnosed hypertension; diagnosed dyslipidemia; diagnosed type-2 diabetes; family history of CVD; history of CVD events (heart attack, stroke, heart failure, etc.); perceived stress; health and physical fitness; self-perception; and nutrition (vegetable, fruit and soft drink consumption)
783b	Cross sectional	806	Self-report	Prevalence	4.1	n/a	n/a	gender; age; height; body weight; years of employment; estimated maximal oxygen consumption; smoking; physical inactivity; diagnosed hypertension; diagnosed dyslipidemia; diagnosed type-2 diabetes; family history of CVD; history of CVD events (heart attack, stroke, heart failure, etc.); perceived stress; health and physical fitness; self-perception; and nutrition (vegetable, fruit and soft drink consumption)
610	Other	n/a	N/A, review paper	Prevalence	15.3 to 38.5	n/a	n/a	n/a systematic review
637	Cross sectional	900	Clinically assessed	Prevalence	41.4	n/a	n/a	socio-demographic characteristics; anthropometric and biochemical parameters; medical history; diet; regular physical exercise; smoking status; alcohol use.
652	Cross sectional	256	Clinically assessed	Prevalence	**30.5 (24.9, 36.5)**	n/a	n/a	Socio-demographic details; alcohol intake; smoking; stress; blood pressure; waist circumference and hip circumference were measured by standard methods; fasting blood sugar; serum cholesterol; lipid profile
3340	Cross sectional	82	Clinically assessed	Prevalence	52.4	n/a	n/a	obesity; KDL and HDL cholesterol; sex; age; duty unit activity
770	Cross sectional	982	Clinically assessed	Prevalence	51.06	n/a	n/a	sex; age, religion; diet; alcohol use; tobacco chewing or smoking use; diagnosed chronic morbidities; BMI; blood sugar; exercise; yoga
574	Cross sectional	65	Self-report	Prevalence	**12.3 (p > 0.05)**	n/a	n/a	history or family history of CVD obesity, diabetes, hypertension, hypercholesterolemia; physical activity; tobacco use; psychological stress and included the measures of perceived stress, job strain, vital exhaustion, effort–reward imbalance and social support; years of experience as a LEO; frequency of shift work and overtime work; perception of their CVD risk relative to other public safety personnel and male LEOs.
595	Cross sectional	336	Self-report	Prevalence	28	n/a	n/a	level of physical activity; duration of service; age; sex; BMI race; job rank; history of CVD
258b	Other	n/a	N/A; review paper	Prevalence	24	n/a	n/a	lack of regular exercise; poor nutrition; shift work; noise exposure; PTSD; imbalance between job demands and decisional latitude
575	Cross sectional	2064	Self-report	Prevalence	11	n/a	n/a	age; sex
713	Cross sectional	216	Clinically assessed	n/a	n/a	Odds ratio	**1.05 (1.01, 1.09)**	age; BMI; blood pressure (SBP and DBP); cholesterol levels; diabetes; smoking; psychosocial or work stress; lack of regular physical activity
402a	Retrospective cohort	1073	Surveillance system	Incidence rate	2329.6	Hazard ratio	**1.05 (1.03, 1.07)**	smoking; alcohol consumption; history of hypertension; obesity; dyslipidemia; and work-related factors such as night duties, high job stress, workplace violence and long work shifts
600	Prospective cohort	170	Clinically assessed	Incidence rate	**0 (p > 0.05)**	n/a	n/a	sex; age; occupation (law enforcement, firefighting, health care, education, and business)

Coronary Heart Disease (CHD)

Study ID Number	Type of study	Sample Size	How outcome data was collected	Measure of occurrence type for CHD	Measure of occurrence	Measure of association type for CHD	Measure of association value**	Other Variables Controlled or Measured in Analysis
Firefighter								
368	Cross sectional	160	Clinically assessed	Prevalence	11 (6, 16)	n/a	n/a	height; weight; BMI; waist circumference; blood pressure (SBP and DBP); physical activity; department affiliation; age; gender; experience; marital status; race; smoking; history of hypertension
281	Other	n/a	N/A; review paper	Prevalence	1 to 9	n/a	n/a	n/a systematic review
258a	Other	n/a	Not provided or not available	n/a	n/a	Odds ratio	**5.5 (2.1, 14.2)**	lack of regular exercise; poor nutrition; shift work; noise exposure; PTSD; imbalance between job demands and decisional latitude
254	Cross sectional	11775	Surveillance system	n/a	n/a	Standardized mortality ratio	0.72 (0.44, 1.17)	employment types, periods, places, titles and functions; the unique Danish personal identification number; full time, part time, volunteer status; duration of employment
305	Retrospective cohort	171	Surveillance system	n/a	n/a	Incidence rate ratio	0.5 (0.2, 1.4)	n/a systematic review
323a	Cross sectional	2943	Clinically assessed	n/a	n/a	Incidence risk ratio	**3.2 (3.1, 3.3)**	age; sex; blood pressure (SBP and DBP); smoking, fasting levels of HDL-C, LDL-C, and blood glucose
323b	Cross sectional	2943	Clinically assessed	n/a	n/a	Incidence risk ratio	**1.3 (1.19, 1.32)**	age; sex; blood pressure (SBP and DBP); smoking, fasting levels of HDL-C, LDL-C, and blood glucose
401	Cross sectional	11691	Surveillance system	n/a	n/a	Incidence rate ratio	1.02 (0.88, 1.18)	age; length of employment
Police								
575	Cross sectional	2064	Self-report	Prevalence	0	n/a	n/a	age; sex
751	Cross sectional	1196	Clinically assessed	Prevalence	4.27 (p <0.05)	n/a	n/a	age; sex; length of employment; no chronic illnesses impacting job duties; could provide complete history of own CVD
258b	Other	n/a	N/A; review paper	n/a	n/a	Odds ratio	**1.19 (1.03, 1.38)**	lack of regular exercise; poor nutrition; shift work; noise exposure; PTSD; imbalance between job demands and decisional latitude

Ischemic Heart Disease (IHD)

Study ID Number	Type of study	Sample Size	How outcome data was collected	Measure of occurrence type for IHD	Measure of occurrence value**	Measure of association type for IHD	Measure of association value**	Other Variables Controlled or Measured in Analysis
Firefighter								
254	Cross sectional	11775	Surveillance system	n/a	n/a	Standardized mortality ratio	0.86 (0.73, 1.02)	employment types, periods, places, titles and functions; the unique Danish personal identification number; full time, part time, volunteer status; duration of employment
401	Cross sectional	11691	Surveillance system	n/a	n/a	Incidence rate ratio	**1.15 (1.06, 1.24)**	age; length of employment

Myocardial Infarction (MI)

Study ID Number	Type of study	Sample Size	How outcome data was collected	Measure of occurrence type for MI	Measure of occurrence value**	Measure of association type for MI	Measure of association value**	Other Variables Controlled or Measured in Analysis
Firefighter								
405	Cross sectional	41	Self-report	Prevalence	3	n/a	n/a	age; career level (rank); BMI; history of CVD and/or hypertension; smoking; physical activity
402b	Retrospective cohort	272	Surveillance system	Incidence rate	216.8	Hazard ratio	**1.21 (1.10, 1.32)**	smoking; alcohol consumption; history of hypertension; obesity; dyslipidemia; and work-related factors such as night duties, high job stress, workplace violence and long work shifts
401	Cross sectional	11691	Surveillance system	n/a	n/a	Incident rate ratio	**1.16 (1.06, 1.26)**	age; length of employment
Police								
402a	Retrospective cohort	1073	Surveillance system	Incidence rate	342.2	Hazard ratio	**1.84 (1.77, 1.92)**	smoking; alcohol consumption; history of hypertension; obesity; dyslipidemia; and work-related factors such as night duties, high job stress, workplace violence and long work shifts
258b	Other	n/a	N/A, review paper	n/a	n/a	Odds ratio	**2.2 (1.6, 3.2)**	lack of regular exercise; poor nutrition; shift work; noise exposure; PTSD; imbalance between job demands and decisional latitude

Heart Disease Mortality and Sudden Cardiac Death

Study ID Number	Type of study	Sample Size	How outcome data was collected	HD Mortality				Sudden Cardiac Death (SCD)				Other Variables Controlled or Measured in Analysis
				Measure of occurrence type for HD mortality	Measure of HD mortality occurrence value**	Measure of HD mortality association	Measure of association HD mortality value**	Measure of occurrence type for SCD mortality	Measure of SCD mortality occurrence value**	Measure of SCD mortality association	Measure of association SCD value**	
Firefighter												
281	Other	999	N/A; review paper	Prevalence	35	n/a	n/a	n/a	n/a	n/a	n/a	n/a systematic review
230a	Prospective cohort	33442	Surveillance system	n/a	n/a	Standardized mortality ratio	**0.42 (0.25, 0.66)**	n/a	n/a	n/a	n/a	age
254	Cross sectional	11775	Surveillance system	n/a	n/a	Standardized mortality ratio	**0.64 (0.46, 0.89)**	n/a	n/a	n/a	n/a	employment types, periods, places, titles and functions; the unique Danish personal identification number; full time, part time, volunteer status; duration of employment
258a	Other	999	N/A; review paper	n/a	n/a	n/a	n/a	n/a	n/a	Odds ratio	**4.7 (2.0, 11.1)**	lack of regular exercise; poor nutrition; shift work; noise exposure; PTSD; imbalance between job demands and decisional latitude
355	Prospective cohort	182	Surveillance system	n/a	n/a	n/a	n/a	Incidence rate	**18.1 (15.7, 21.0)**	Obs/Exp	Military comparison: 0.9 (0.33, 5.26) General popn: 0.65 (0.41, 1.07)	age

Respiratory Disease Data Tables

Asthma

Study ID Number	Type of study	Sample Size	How outcome data was collected	Measure of occurrence type for asthma	Measure of occurrence value**	Measure of association type for asthma	Measure of association value**	Variables controlled in analysis
Firefighter								
6184	Cross sectional	570	Self-report	Prevalence	4	Score	-5.54 (7.95, 3.13)	age, employment duration, BMI, smoking
6056b	Cross sectional	1235	Self-report	Prevalence	9.3	Odds ratio	**1.23 (1.01, 1.56)**	n/a
6079	Cross sectional	402	Self-report;Clinically assessed	Prevalence	16.1	N/A	n/a	n/a
254	Cross sectional	11775	Surveillance system	n/a	n/a	Standardized mortality ratio	**0.71 (0.52, 0.98)**	n/a
6294	Retrospective cohort	11968	Surveillance system	n/a	n/a	Incidence rate ratio	**1.58 (1.32, 1.88)**	age, employment duration, location of employment, SES, physical activity
369a	Cross sectional	499	Self-report	n/a	n/a	Odds ratio	1.4 (0.5, 3.5)	age; sex; race; SES
369b	Cross sectional	499	Self-report	n/a	n/a	Odds ratio	2 (0.5, 8.3)	age; sex; race; SES

Chronic Obstructive Pulmonary Disease (COPD)

Study ID Number	Type of study	Sample Size	How outcome data was collected	Measure of occurrence type for COPD	Measure of occurrence value**	Measure of association type for COPD	Measure of association value**	Variables controlled in analysis
Firefighter								
405	Cross sectional	41	Self-report	Prevalence	16	n/a	n/a	age, rank, BMI, history of CVD, smoking, physical activity, hypertension
6184	Cross sectional	570	Self-report	Prevalence	6	Incidence risk ratio	-5.54 (7.95, 3.13)	age, employment duration, BMI, smoking
241a	Retrospective cohort	30057	Surveillance system	n/a	n/a	Standardized mortality ratio	**0.54 (0.35, 0.8)**	age group, calendar year
6294	Retrospective cohort	11968	Surveillance system	n/a	n/a	Incidence rate ratio	1.14 (0.98, 1.32)	age, employment duration, location of employment, SES, physical activity
244a	Retrospective cohort	163094	Surveillance system	n/a	n/a	Standardized mortality ratio	**0.34 (0.26, 0.43)**	age
999a	Retrospective cohort	16320	Surveillance system	n/a	n/a	Standardized mortality ratio	**0.11 (0.01, 0.61)**	age, calendar year

Emphysema

Study ID Number	Type of study	Sample Size	How outcome data was collected	Measure of occurrence type for emphysema	Measure of occurrence value**	Measure of association type for emphysema	Measure of association value**	Variables controlled in analysis
Firefighter								
6184	Cross sectional	570	Self-report	Prevalence	6	Score	-5.54 (7.95, 3.13)	age, employment duration, BMI, smoking
254	Cross sectional	11775	Surveillance system	n/a	n/a	Standardized mortality ratio	**0.71 (0.52, 0.98)**	n/a

Respiratory Mortality

Study ID Number	Type of study	Sample Size	How outcome data was collected	Measure of occurrence type for respiratory mortality	Measure of occurrence value**	Measure of association type for respiratory mortality	Measure of association value**	Variables controlled in analysis
Firefighter								
410	Case control	2818	Surveillance system	cause of death	9.9	n/a	n/a	year of death, age at time of death, sex, race, ethnicity,industry code, occupation code, and underlying cause of death
254	Cross sectional	11775	Surveillance system	n/a	n/a	Standardized mortality ratio	0.51 (0.21, 1.22)	n/a
230a	Prospective cohort	33442	Surveillance system	n/a	n/a	Standardized mortality ratio	**0.13 (0.03, 0.37)**	age
230d	Prospective cohort	33442	Surveillance system	n/a	n/a	Relative Risk	5.89 (0.34, 101.13)	age
244a	Retrospective cohort	163094	Surveillance system	n/a	n/a	Standardized mortality ratio	**0.36 (0.30, 0.43)**	age
999a	Retrospective cohort	16320	Surveillance system	n/a	n/a	Standardized mortality ratio	**0.17 (0.03, 0.50)**	age, calendar year
229	Retrospective cohort	10829	Surveillance system	n/a	n/a	Standardized mortality ratio	**0.54 (0.39, 0.73)**	age

PTSD and Suicide Data Tables

PTSD

Study ID	Type of Study	Population	Sample Size	Data collection	Measure of Occurrence	Measure of Occurrence Value	Measure of Association	Measure of Association Value	Variables controlled in analysis
411	Cross sectional	Fire Fighter/EMT	220	Self-Report	Prevalence	26%	n/a	n/a	relationship status, military status rank (firehouses only), shift structure, age at which he/she started as a FR, years of service, history of responses to suicide attempts/deaths, and history of medical and mental health diagnoses
481	Cross sectional	Fire Fighter	753	Self-Report	Prevalence	8%	n/a	n/a	Hazardous alcohol consumption, Poor subjective wellbeing
503	Cross sectional	Police, Fire Fighter, EMS, 911 Operator	459	Self-Report	Prevalence	P= 19-25%; FF=17%, EMS =22%, 911 oper=19%			examined association social support, and coping strategy to PTSD symptoms
509	Cross sectional	Fire Fighter	37093	Self-Report	Prevalence	5.40%	n/a	n/a	n/a
523	Cross sectional	Fire Fighter	459	Self-Report	Prevalence	5.40%	n/a	n/a	number of traumatic events
869	Cross sectional	Police	100	Self-Report	Prevalence	35%	n/a	n/a	n/a
880	Cross sectional	Police	150	Self-Report	Prevalence	24%	n/a	n/a	n/a
1998	Cross sectional	EMS	105	Self-Report	Prevalence	4%	n/a	n/a	n/a
5392	Cross sectional	EMS	131	Self-Report	Prevalence	16%	n/a	n/a	number of trauma exposures
402	Retro Cohort	Police/Fire Fighter	1073(P) 272(FF)	Surveillance System	n/a	n/a	Hazard Ratio	FF HR: **1.40,(1.26, 1.5)** Police HR: 1.00(0.93 to 1.07)	smoking, alcohol consumption, hyper-tension, obesity, DM or dyslipidaemia, and work-related factors
997	Cross sectional	Police	132	Self-Report	Prevalence	8%	n/a	n/a	n/a
2044	Systematic Review	EMS	30878	Self-Report	Prevalence	11%	n/a	n/a	n/a
504	Cross sectional	Firefighter	102	Self-Report	Prevalence	18.6%	n/a	n/a	employment status full time vs. seasonal
525	Cross sectional	Firefighter	100	Self-Report	Prevalence	4%	n/a	n/a	n/a
2050	Cross sectional	Firefighter	603	Self-Report	Prevalence	19%	n/a	n/a	exposure to traumatic events
5031	Cross sectional	Firefighter	210	Self-Report	Prevalence	5%	n/a	n/a	examined association social support, and coping strategy to PTSD symptoms
5061	Cross sectional	Firefighter	551	Self-Report	Prevalence	11%	n/a	n/a	n/a

Suicide (Excluding Costa et al. 2019)

Study ID	Type of Study	Population	Sample Size	Data Source	Measure of Occurrence	Measure of Occurrence Value	Measure of Association	Measure of Association Value	Variables controlled in analysis
254	Retrospective Cohort	Fire Fighter	11775	Surveillance System	n/a	n/a	Standardized mortality ratios	**0.65 (0.48–0.87)**	n/a
8651	Cross sectional	Fire Fighter Police	999	Self-Report	Prevalence of Suicide Attempts	2.1% POLICE, 3.3% FF			n/a
8660	Cross sectional	Fire Fighter	313	Self-Report Survey	Prevalence Suicide Attempts	3.5			active vs. retired
11574	Retrospective Cohort	Police	3228	Mortality Surveillance Analysis	Yearly Crude Rate	(8.76/100,000 vs. 11/100,000 respectively)			separated/retired risk relative to currently working
230	Prospective Cohort	Fire Fighter	33442	Surveillance System			Adjusted relative risk of suicide	**2.57 (1.01-6.64)**	age
241	Retrospective Cohort	Fire Fighter	30057	Surveillance System			Standardized Mortality Ratios	**0.70 (0.55 to 0.88**)	age group, calendar year
244	Retrospective Cohort	Fire Fighter	163094	Surveillance System			Standardized Mortality Ratios	**0.60 (0.52 to 0.69)**	age
999	Retrospective Cohort	Fire Fighter	16320	Surveillance System			Standardized Mortality Ratios	0.73 (0.40 to 1.23)	age, calendar year
11747	Retrospective Cohort	Police	146240	Death Certificate			PROPORTIONATE SUICIDE RATIO	**169 (150-191)**	n/a
10724	Cross sectional	Police	119624	Self-Report	Annual Suicide Rate	15.3/100,000			n/a
12527	Cross sectional	Police	271	Death Certificate	Mean Suicide Rate	11.78 per 100,000 per year			n/a
8713	Cross sectional	Fire Fighter	1131	Self-Report	Suicide Attempt Prevalence Rate	4.2 ALL FF; 15% for wildland FF			n/a
8591	Cross sectional	Fire Fighter	1027	Self-Report	Suicide Attempt Prevalence Rate	15.5			n/a