Estimating a standardized incidence ratio (SIR) for malignant melanoma cases diagnosed from 2000-2017 among career firefighters in the state of Washington

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Abstract

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Objective: Firefighters are exposed to occupational hazards including carcinogens working in states like Washington with laws that provide line-of-duty benefits for certain cancers; however, research on exposure-disease relationships is inconsistent for covered cancers like malignant melanoma (MM). The goal of this study was to characterize MM among career firefighters (FF) in Washington by: (1) identifying and describing MM cases diagnosed from 2000-2017 in career FF across multiple state counties, and (2) calculating a standardized incidence ratio (SIR) with 95% confidence interval using a standard population based on local, county-level estimations and an indirect standardization approach. *Methods*: Linkage between the Cancer Surveillance System (CSS) and Law Enforcement Officers' and Firefighters' (LEOFF) Retirement System identified MM cases in the study population of career FF. The standard population with age-specific MM rates were calculated using annual observations per estimated population informed by the Washington State Cancer Registry (WSCR) restricted to the CSS 13-County region to adjust for age and the Multicounty 6 Region Scheme to adjust for age and sex. Total FF population and age distributions were furnished by the Office of the State Actuary. For the analysis, data were restricted to either a first or second primary melanoma diagnosis. Indirect standardization using age-specific MM rates in the standard population adjusted for age alone and adjusted for both age and sex was performed separately to estimate expected counts. *Results*: A total of 184 observed MM cases with 16 (8.7%) cases among women and 168 (91.3%) among men were identified with almost all cases—182 (98.9%)—occurring in white firefighters. Many cases—102 (55.4%)—were reported from either an all-urban or mostly urban environment and 103 (56.0%) were diagnosed after retirement from firefighting. The most common area affected was the skin of the trunk in 64 (35%) cases. Eighty-five (46.2%) were classified as non-invasive (i.e., in-situ or stage 0 disease). Of the 95 invasive cases, the majority—66 (69.5%)—were Stage I, or in SEER Summary Stage parlance, 84 (88.4%) were considered early-stage disease. The estimated SIR for MM in career FF was 1.28 [95% CI 1.09, 1.46] after age-adjustment only and 1.18 [95% CI 1.01, 1.35] after both age and male sex adjustment. *Conclusions*: A diagnosis of melanoma is expected to occur in excess of 18% among career FF in the state of Washington when compared to the standard population used. Limitations of this study include suppressed age-specific rates by sex when counts were less than 10 to maintain privacy, unaccounted for calendar time at-risk, and another defined occupational group for comparison. Future research considerations might compare risks with other occupations already known to have an increased risk of MM (e.g., commercial airline crew and pilots) or where the MM risk is unknown, understudied, or simply assumed (e.g., outdoor workers).

Keywords: career firefighter, standardized incidence ratio, malignant melanoma, occupational cancer, presumption legislation, workplace hazards, occupational exposures, firefighting

Background

Not only is fighting fires dangerous but an increased risk of cancer-related deaths among firefighters (FF), compared to the general U.S. population, has been previously reported by the National Institute for Occupational Safety & Health (NIOSH).[1,2] Firefighters are known to have potential exposures to a wide range of confirmed and suspected carcinogens through their various work-related tasks mostly on fire run responses to extinguish active structural fires, but also during training exercises. While the constituents of fire smoke vary according to combusted materials and other factors, benzene, formaldehyde, polycyclic aromatic hydrocarbons and fine particulates are common.[3,4] More recently, a group of research scientists led by Graham Peaslee, a professor of physics at the University of Notre Dame, published in *Environmental Science & Technology Letters* of firefighter turnout gear testing positive for the presence of per- and polyfluorinated alkyl substances (PFAS).[5]

In 2010, the International Agency for Research on Cancer (IARC) classified occupational exposure in firefighters as possibly carcinogenic to humans (Group 2B)[4] based on several supportive epidemiological studies. Many of these studies demonstrated increased risks of specific malignancies—esophageal, pulmonary, intestinal, and renal—in firefighters,[6] while others have produced evidence indicating greater risk of developing cancers like malignant melanoma (MM).[6–9] Since the IARC Monograph Volume 98 was published in 2010, more research has become available in the literature. Two additional large-scale studies provide greater evidence in support of the IARC Group 2B classification of firefighters but suggest that perhaps an upgraded classification to Group 2A is warranted.

MM is a potentially life-threatening form of skin cancer with an incidence that has steadily increased in the United States for the last three decades. Despite MM accounting for a minority of all skin cancer variants, it causes an overwhelming majority of skin cancer deaths,[10,11] so targeted education on prevention strategies are of paramount importance. MM displays a peculiar epidemiological behavior. Women are disproportionately affected before the age of 50, but by the age of 55, men become disproportionately affected in an incremental manner so that with each subsequent decade of life by the age of 80, men are diagnosed with MM at a rate three times greater than that in women.[10,12] A grim but harsh reality confirmed by forecasted projections provided by the American Cancer Society finding that new diagnoses of MM in 2021 are expected to climb to 106,110 cases (62,260 in men vs. 43,850 in women) with 7,180 people expected to die from their diagnosis (4,600 men vs. 2,580 women).[12]

Though active firefighters are typically not octogenarians, those with 20 years of dedicated fire service may still have an increased risk due to previous cumulative exposures in the workplace and from constant exposure to the fireground environment. Nevertheless, a clear trend has emerged for otherwise healthy (and oftentimes young) firefighters diagnosed with cancer at alarmingly high rates, generating enough concern that federal legislation was enacted to establish the National Firefighter Registry (NFR) to better understand the link between toxicant exposures unique to them and their subsequent risk of developing cancer.[13] To tackle the issue, Congress directed the Centers for Disease Control and Prevention (CDC) to create the National Firefighter Registry (NFR). As the CDC's research division, NIOSH has taken the lead in developing the database that aims to enroll all firefighters across the country including career, wildland, volunteer, and even FF retired from the fire service, which established the National Firefighter Registry Subcommittee to help meet this goal.[14] The NFR will be used to track and analyze cancer trends and risk factors among U.S. fire service members. The program is currently open and actively enrolling firefighters into the national registry and encourages all firefighters including ones who are cancer-free to enroll.[14] Preliminary results analyzed on data currently being collected will only become available as early as 2024. More information on the National Firefighter Registry with information on how to enroll or even to sign up for their quarterly newsletter can be found at (https://www.cdc.gov/niosh/firefighters/registry.html).

Upon meeting specific criteria, compensated, career firefighters in the state of Washington are eligible for a provision of benefits for one or more specific cancers, including MM, under workers' compensation (WC) through presumption legislation. Presumption is based upon the Latin *prima facie,* meaning that a firefighter's WC claim submitted for a diagnosis under Revised Code of Washington (RCW) 51.32.185 should be assumed to have occurred due to job exposures[15] provided other eligibility criteria are met. In comparison to the traditional WC model that requires demonstrable proof of a relationship between workplace exposure and disease, presumption may allow for faster access to line of duty benefits. Officially enacted by the state legislature in 2002 and updated twice since, presumption for career firefighters considers MM a coverable condition as long as the diagnosis is made after ten years of service and evidence and no language suggestive of any suspicious lesions presenting as 'rule-out melanoma' or 'resembling melanoma' identified on a firefighter's initial qualifying medical exam.

Many researchers focusing their work on firefighters agree that chronic exposures to smoke and hazardous byproducts released upon combustion of certain materials most likely contributes to the development of chronic diseases like cancers affecting FF at higher rates compared to the U.S. population as was the case in the largest NIOSH study.[4,6,7,9,14–19] However, more information is needed particularly for MM since a major modifiable, environmental factor affecting one's risk of developing MM is chronic, unprotected exposure to ultraviolet radiation (UVR). To claim that an increased risk of MM can be seen in firefighters logically implies that such increased rates are due to some other factor in their working environment outside of UVR, assuming such higher rates occurred in the setting of similar UVR exposure. To further convolute matters, policy decisions to include MM on the list of coverable occupational cancers in the state of Washington was primarily informed by a scientific review in 1990[20] and has not been reconsidered despite subsequent studies reporting inconsistencies.[16,21,22] The largest cohort study to date published by NIOSH examining firefighters lacked specific state rates for colon, testicular, and MM cancer outcomes to perform the intended sensitivity analyses planned.[2]

The purpose of this study was to describe characteristics of MM diagnosed among career firefighters in the state of Washington from 2000-2017. We aimed to advance the literature by providing more information about the risk of MM in firefighters, which could be used to inform policy decisions regarding presumption coverage of MM. The analysis itself was intended to supplement the knowledge base shared by the public safety community, scientists, researchers, and medical professionals that seek better ways to understand and protect workers responsible for extinguishing the fire hazards within our own communities and surrounding environments. The findings may also have implications for MM presumption considerations for other occupational groups known to have an increased risk of MM such as cabin crew and pilots on commercial airline flights[12,13] or open new research avenues to study occupational groups where the risk of MM is unknown, understudied, or simply assumed (e.g., outdoor workers in agriculture). Broadly speaking, this study has the potential to help reduce the morbidity and mortality associated with MM among firefighters by raising awareness in the larger community.

Materials & Methods

Study design, setting, data sources, and study subjects

This study was designed as a cases-only population-based investigation focused on a particular subpopulation of individuals defined by their occupation, namely career firefighters, who comprised the study group. Collaboration between researchers at the University of Washington (UW), the Washington Safety & Health Assessment & Research for Prevention (SHARP) Program at the Washington State Department of Labor & Industries, and Cancer Surveillance System (CSS) managed by the Fred Hutch Cancer Research Center was required to successfully identify the total observed cases in the study population of interest.

Identification of career FF with MM was achieved through linkage analysis between the requested bank of data on malignant melanoma cases stored in the CSS database and the Law Enforcement Officers' and Firefighters' (LEOFF) Retirement Pension System database. Such linkage was performed by a third-party participant at the SHARP Program who was then tasked with deidentification protocols of the linked data before sending the data in an encrypted, electronic format using a secure file transfer protocol (SFTP). As a result, exempt approval for the study was granted by the Washington State IRB and reciprocal approval fell under "not human subject based," according to the predefined criteria of research necessitating IRB review by the UW Research Human Subjects Division. Data sharing agreements detailing the SFTP process were signed and in-place by all involved parties before transmission.

It should be noted that while CSS follows the available recommendations and guidelines as provided by the North American Association of Central Cancer Registries regarding cancer data standards, collection procedures, and certifications[23], the CSS captures only a portion of cancer cases in the state of Washington responsible for overseeing the collection of cancer surveillance statistics in just 13 of 39 state counties. The data collected by this system feeds directly into the Washington State Cancer Registry maintained by the Washington State Department of Health. CSS may represent just one-third of the state counties, however, taking into account population density per county, the 13 counties under CSS oversight—Clallam, Grays Harbor, Island, Jefferson, King, Kitsap, Mason, Pierce, San Juan, Skagit, Snohomish, Thurston, and Whatcom—collectively reflect 5.4 million people in a state of approximately 7.8 million based on 2021 population estimates as presented by "World Population Review."[24] This amounts to nearly 70% of cancer surveillance data actually handled by CSS for the state thereby justifying its use in this study but also providing a defensible reason for using it as a surrogate, for all intents and purposes, as a statewide standard population.

To find the total number of observed melanoma cases in the study population, the following criteria were applied to the coded cancer registry information:

<u>Inclusion Criteria</u>	<u>Exclusion Criteria</u>
- Reported MM linked to unique Case ID	- MM records linked to same Case ID*
- Age at diagnosis at least 20 years-old	- Age at diagnosis 19 years-old or younger

*The decision was made to include up to a second primary melanoma in any given individual or Case ID with how relatively uncommon malignant melanoma is in general and taking into account a relatively rare diagnosis in an already small subpopulation. Restricting to a maximum of a second primary melanoma in any individual also limits the possibility of including anyone with an underlying genetic condition or genetic predisposition such as BRCA1 associated protein-1 (ubiquitin carboxy-terminal hydrolase shortened to BAP1)[25] that increases the risk of malignant melanoma as can be seen in familial atypical multiple mole melanoma (FAMMM) syndrome or melanoma-pancreatic cancer syndrome; otherwise, it was impossible to exclude or identify potential hereditary cancer syndromes from simply deciphering the registry code alone. The age cutoff was placed to avoid including what experts refer to as juvenile melanoma because of how different it tends to behave in comparison to MM diagnosed in an individual at least 20 years old.[26] The overall intent for placing the criteria was aimed at avoiding introduction of misclassification bias by erroneously inflating either the observed number of melanomas in the study population or the melanoma rate in the standard population used with inadvertent downstream effects when calculating the expected case count.

Basic demographic information and tumor information was described using R Studio and Microsoft Excel was used to generate the SIR. Using an indirect standardization approach requires a study population with a total observed melanoma case count in addition to the age structure and distributions within the population of interest. The total FF population at-risk was determined and identified from the Office of the State Actuary. Total population number of FF with age distributions were collected from publicly available data based on the 2019 Annual Actuarial Report. (See *Supplemental Materials Appendix Figures A3a, A3b* for FF age distribution charts). 2019 was in closest proximity to the study period with available data.

The total estimated study population of firefighters from 2019 was used for three reasons. Firstly, the actuarial data were elegantly assembled by age structure making translatability simpler. Secondly, the actuarial data included not only active firefighters but those retired from service and since some occupational cancers can result from hazardous exposures that exhibit an accumulation effect from chronic exposure over time, we felt including retired FF as part of the study population was appropriate. Lastly, according to the National Firefighter Protection Association (NFPA), the fire service workforce has on average grown a mere 1.63% each year since the late 1980s[17]; therefore, any overestimation of total FF population using the 2019 data was considered negligible at a rate of 1.63%. Furthermore, incorrectly using a much larger FF population at each age-specific stratum would increase the denominator in the SIR calculation for expected number of cases and mask or minimize any truly increased SIR result, which is arguably more acceptable than the alternative in this context.

The standard population and age-specific malignant melanoma incident rates

Using an indirect standardization approach requires a standard population with case rates for the diagnosis of interest. The standard population and melanoma incident rates were obtained by the WSCR web application (See *Supplemental Materials Appendix Figures A4a, A4b*), which allowed age-specific rate calculations at the county-level even beyond the study period of interest. The total annual observations of melanomas across the CSS 13-County region for each year from 2000-2017 stratified by age-category in addition to the total county-level population estimations for the year in question were identified. A summation of the data made it possible to calculate the age-specific melanoma case rates in this defined standard population. All melanomas diagnosed each year from 2000-2017 were added together by age-specific stratum and used to calculate the melanoma case rates in the standard population. The total age-specific population used to create the standard rates was defined by the 2009 total population estimations across all 13 counties. The year 2009 was chosen since it represented the midpoint year of the range provided by the study years 2000-2017. Given how many times cancer staging manuals and coding guidelines have changed over the years, the chosen years to include in the study helped minimize the number of times manuals and coding schema had changed leaving less room for interpretation and less confusion when determinations on melanoma staging were required. The only caveat with using the WSCR to calculate melanoma case rates in the standard population using county-level population estimations was that in the event that less than 10 MM diagnoses were made for any given age-specific group in any given year, the observed case count was suppressed thereby rendering sex-specific rates unavailable. An alternative perhaps would have been to calculate the expected fraction if one sex-specific data point was available; however, this was not always available and the resultant imprecision in using this method outweighed the decision to actually pursue it. Therefore, only age-specific rates were used in the determination of standard rates applied to the FF population in calculating the SIR.

Upon closer inspection of how data were available and assembled through the WSCR web application and understanding the importance of defining a standardized population with melanoma incident rates adjusted for age and male given its peculiar predilection for older men and the predominantly male firefighter population, a second estimation of the summary measure was planned. Instead of using the CSS 13-County region rampant with sex-specific melanoma case count suppressions, the next aggregated level of county data was available in the 'Washington State Multicounty Six Region Scheme.'[27] The entire CSS catchment area was captured in the following multicounty regions—North, King, Kitsap-Pierce, and West. (See *Supplemental Materials Appendix Figure A1* for designated geographic boundaries). The only caveat in using these data was that the 'West' region included six additional counties—Clark, Cowlitz, Lewis, Pacific, Skamania, and Wahkiakum—that were not included in the original CSS 13-County catchment area. Where appropriate, available melanoma counts from the six additional counties were removed for consistency. Fortunately, southwestern Washington is simply not as populated; therefore, manual adjustments were minimal and hardly required.

To recapitulate, the first estimation of the SIR used an age-only standardized population without accounting for sex from the exact same geographic region the observed melanomas were sampled among the career FF. This was because at the granular county-level, too many suppressed data points made it impossible to calculate standardized melanoma rates adjusted for both age and male sex. Recognizing the importance of the standard population adjusting for both age and sex, especially in the context of malignant melanoma, a second estimation of the SIR successfully calculated a standard population adjusted for both age and male sex, but from a slightly larger catchment area with six additional counties. All attempts were made to remove MM case counts for these six counties for consistency.

Descriptive statistics, SIR calculation and 95% CI of the summary measure

Demographics, marital status, urban rural indication, primary insurer at time of diagnosis, date of diagnosis relative to retirement date, primary anatomical site involved, and clinical stage of melanoma at time of diagnosis were described for the total number of included MM cases. While no direct comparison group was included in this study, similar characteristics were determined and described for all other melanoma cases that were not uniquely linked to a firefighter in the LEOFF system, subject to the restrictions of the study period (2000-2017). Twenty-five cases that initially matched to a unique LEOFF identification marker during linkage analysis were excluded as it was impossible to determine whether these cases belonged in the total observed MM count among FF.

The SIR calculation was achieved in six steps:

1. Standard population estimations, *P*, were calculated for each age-specific stratum by summation of the 13 county estimates for 2009.

2. For each year in the study period, 2000-2017, annual observed MM cases, *E*, across the 13 counties were added together for each age-specific stratum.

3. For each age category, an age-specific standardized rate, *R*, was calculated using the values determined for *P* and *E* with the following equation:

$$R = E/P$$

4. The resultant rate, *R*, for each age-specific stratum was then applied to the number of total firefighters found in that age-specific stratum with the following equation:

$$e_i = R \cdot p_i$$

5. Summation of the values determined for e_i in each age-specific stratum resulted in the expected number of events, *EE*. This can be thought of as the number of MM cases expected among FF if they had the same age structure and distribution as the standard population. Mathematical expression of this concept was obtained with the following:

$$EE = \sum_{i=1}^{k} p_i \cdot R_i$$

   where *i* is the first age-specific stratum and *k* is the number of total age-specific strata across which to perform the summation.

6. The SIR was then calculated by simply taking the total observed melanoma cases among the study population of FF identified through the CSS cancer registry and dividing it by the value determined for the expected number of events, *EE*. The quotient of the ratio "observed/expected" represents the SIR.

SIR calculations are shown in a tabular format presented as Figure 1a and 1b in the **Results** section. In addition, the *Supplemental Materials Appendix* has the original Microsoft Excel sheets with SIR calculations, the landing page of the WSCR web application mined for data, and the FF age structure with distribution pulled from the 2019 Annual Actuarial Report. A 95% confidence interval (CI) about the estimated value was performed under the assumption that when the observed number of cases is greater than 25, the approximate 95% CI can be obtained by using the standard error (SE) of the estimated SIR, where the defined SE(SIR) is the square root of the observed value divided by the expected value:[28,29]

$$\mathbf{SE_{SIR}} = \frac{\sqrt{observed}}{\sum_{i=1}^{k} p_i \cdot R_i}$$

The value obtained here was then applied to estimate both the upper and lower limits of the 95% CI using the following equation[28,29]:

$$SIR \pm 1.96 \times SE(SIR)$$

If the 95% CI excluded 1.0 indicating the expected number of diagnoses exactly equaled the observed number of diagnoses, then this could be considered statistically significant.

Results

A data quality check accompanied receipt of the pre-linked and deidentified dataset, which indicated a match between CSS and LEOFF in 402 cases with unique Case IDs. From the 402 cases identified in the pre-linkage analysis, applying the inclusion and exclusion criteria, study period limits, and restricting to a maximum of a second primary melanoma in any given record, 184 cases were determined to be associated with a firefighter, while 193 were attributed to police officers. For 25 cases, it was unknown and indeterminable whether the case belonged to an officer or firefighter. After putting all other melanoma cases that were not firefighters (non-FF) through the same criteria, the total MM case count for this group was 41,208 MM cases.

Table 1 was created to organize and help present descriptive statistics of malignant melanoma diagnoses among firefighters and for all non-FF (i.e., everyone else captured by CSS) in Washington State from 2000-2017 in a visually appealing format. Malignant melanoma case characteristics for career firefighters and for everyone else diagnosed with melanoma during the same time period are summarized in Table 1. Most notable for career FF was that the majority of cases were diagnosed in white (99%), non-Hispanic (99%) men (91%), aged 55 years or older (64%), and reported in areas considered to be completely or mostly urban (55%). As the most common anatomical site for melanoma in men is on the back,[30] it is not surprising that most cases involved skin of the trunk (35%), and were classified as early-stage disease at diagnosis in 46% of all cases diagnosed in career FF or 88% of cases when considering just the invasive fraction of cases. Lastly, one final data point of interest to highlight specific to firefighters was that 56% of cases overall or 77% of cases with a known retirement date had a date of diagnosis that occurred after their listed retirement date.

Table 1. Characteristics of MM cases from CSS 13 Co. Region in WA, 2000-2017 – n (%)

Sex	Career FF	Non-FF
Male	168 (91)	21,990 (53)
Female	16 (8.7)	19,217 (47)
Transexual, Natal XX (FTM)	-	1 (<0.1)

Age Groups	Career FF	Non-FF
Under 24	5 (2.7)	6,405 (16)
25-34	10 (5.4)	
35-44	18 (9.8)	3,803 (9.2)
45-54	33 (18)	6,339 (15)
55-64	49 (27)	8,745 (21)
65+	69 (38)	15,916 (39)

Urban Rural Indicator	Career FF	Non-FF
All (100%) or most (>50%) surrounding pop. in urban area	102 (55)	35,196 (85)
All (100%) or most (>50%) surrounding pop. in rural area	82 (45)	6,005 (15)
Unknown	-	7 (<0.1)

Marital Status	Career FF	Non-FF
Single (Never Married), Separated, Widowed, Divorced	14 (7.6)	5,112 (12)
Married (Incl. Comm. Law), Domestic Part. (Opp.+ Same Sex)	72 (39)	13,971 (34)
Unknown	98 (53)	22,125 (54)

Ethnicity – Hispanic Origin	Career FF	Non-FF
Non-Hispanic	182 (99)	40,619 (99)
Mexican	-	55 (0.1)
Puerto Rican	-	20 (<0.1)
Cuban	-	4 (<0.1)
South or Central American Excluding Brazil	-	21 (0.1)
Other Specified Spanish/Hispanic Incl. Euro Excl. D.R.	-	6 (<0.1)
Spanish NOS, Hispanic NOS, Latino NOS	2 (1.1)	123 (0.3)
Surname Match Only	-	93 (0.2)
Dominican Republic (D.R.)	-	10 (<0.1)
Unknown	-	257 (0.6)

Race			Career FF	Non-FF
White			182 (99)	40,158 (97)
Black			-	35 (0.1)
American Indian, Aleutian, Alaskan Native, Eskimo (AIAANE)			-	58 (0.1)
Asian			-	114 (0.3)
Chinese			-	8 (<0.1)
Japanese			-	6 (<0.1)
Filipino			-	11 (<0.1)
Korean			-	6 (<0.1)
Vietnamese			-	7 (<0.1)
Thai			-	2 (<0.1)
Kampuchean			-	1 (<0.1)
Indian			-	3 (<0.1)
Other Asian, NOS			-	70 (0.2)
Pacific Islander			-	10 (<0.1)
Hawaii'an			-	5 (<0.1)
Guamanian			-	1 (<0.1)
Samoan			-	3 (<0.1)
Pacific Islander NOS			-	1 (<0.1)
Biracial				
Black	White		-	6 (<0.1)
AIAANE	White		-	108 (0.3)
Japanese	White		-	2 (<0.1)
Filipino	White		-	2 (<0.1)
Hawaii'an	White		-	1 (<0.1)
Korean	White		-	5 (<0.1)
Samoan	White		-	1 (<0.1)
Other Asian NOS	White		-	9 (<0.1)
Pacific Islander NOS	White		-	2 (<0.1)
AIAANE	Black		-	1 (<0.1)
Hawaii'an	Samoan		-	1 (<0.1)
Hawaii'an	Chinese		-	1 (<0.1)
Multiracial				
AIAANE	Filipino	White	-	1 (<0.1)
AIAANE	Other Asian	White	-	2 (<0.1)
Chinese	Japanese	Other Asian	-	1 (<0.1)
Asian Indian	Chinese	Other Asian	-	1 (<0.1)
Unknown			2 (1.1)	689 (1.7)

Primary Payer at Diagnosis	**Career FF**	**Non-FF**
Uninsured		
Self-Pay	1 (0.5)	108 (0.3)
Charity | Write-Off | Bad Debt	-	98 (0.2)
Commercial/Private Insurance		
Managed Care, HMO, or PPO	25 (14)	5,126 (12)
Fee-for-Service	1 (0.5)	298 (0.7)
Medicare | Medicaid		
Managed Care Administered	3 (1.6)	2,148 (5.2)
+ Secondary Insurance, Supplemental Coverage	16 (8.7)	2.781 (6.7)
- Secondary Insurance, Supplemental Coverage	4 (2.2)	1,387 (3.4)
Military, TRICARE, Veterans Affairs	-	396 (1.0)
Insurance, NOS	13 (7.1)	2,932 (7.1)
Unknown	121 (66)	25,793 (63)
Primary Anatomical Site Involved**	**Career FF**	**Non-FF**
Skin of lip	-	101 (0.2)
Skin of eyelid	1 (0.5)	186 (0.5)
Skin of external ear	5 (2.7)	1,084 (2.6)
Skin of face, other or unspecified	32 (17)	5,436 (13)
Skin of scalp and neck	22 (12)	3,049 (7.4)
Skin of trunk	64 (35)	13,051 (32)
Skin of upper limb including shoulder	40 (22)	9,962 (24)
Skin of lower limb including hip	16 (8.7)	6,919 (17)
Skin of overlapping area of skin	1 (0.5)	21 (0.1)
Skin, NOS	2 (1.1)	846 (2.1)
Ocular – choroid	1 (0.5)	371 (0.9)
Clinical Stage at Initial Diagnosis	**Career FF**	**Non-FF**
Stage 0 (Melanoma in-situ | Noninvasive)	85 (46)	18,920 (46)
Early-Stage Disease		
Stage I	66 (36)	15,919 (39)
Stage II	18 (9.8)	2,053 (5.0)
Late-Stage Disease		
Stage III	4 (2.2)	2,610 (6.3)
Stage IV	7 (3.8)	1,264 (3.1)
Unknown	4 (2.2)	442 (1.1)
Diagnosis (Dx) Date Relative to Retirement Date	**Career FF**	**Non-FF**
Dx Made PRIOR TO or SAME YEAR as Retirement Date	31 (17)	-
Dx Made AFTER Retirement Date	103 (56)	-
Retirement Date Not Set	50 (27)	-

*FTM- female-to-male; Pop- population; Incl- including; Comm- common; Part- partnership; Opp- opposite; NOS- not otherwise specified; Excl- excluding; HMO- health maintenance organization; PPO- preferred provider organization; **1,082 MM in non-FF involved anatomical sites not seen among FF so were not included in this table

Dashed outline box draws attention to indicate this value did not contribute to the total expected count calculation because this age-specific group stratum fell under exclusion criteria

Figure 1a. SIR Calculation: Age Adjusted Only

SIR CALCULATION - AGE ADJUSTMENT ONLY - INDIRECT STANDARDIZATION						
	New MM Cases Both Men & Women	Standard Pop. Estimates	Age Specific MM Incident Rate	Study Group Total FF Population	Total Observed MM Cases in FF	Expected MM in FF Applying Std. Pop. Age Specific Rates
Age Cat	E	P	R = E/P	pi	ei	EE = R x pi
< 1-14	-	852,748	NA	NA	-	NA
15-19	10	303,496	0.00003295	43	-	0.00140270
20-24	181	319,221	0.00056701	106	-	0.06034556
25-34	1,821	656,374	0.00277433	1,909	-	5.29620156
35-44	3,581	652,220	0.00549048	2,738	-	15.03293061
45-54	6,388	695,519	0.00918451	3,012	-	27.66373888
55-64	9,061	544,740	0.01663362	2,514	-	41.81692918
65-69	4,837	169,549	0.02852863	780	-	22.25232824
70+	12,421	363,146	0.03420387	925	-	31.63858338
			TOTAL :	12027	184	143.76105740
			SIR = observed/expected = 184/143.76105740 -->			SIR = 1.28

Study Years 2000-2017
Midpoint = 2009
Avg. Pop For 2009
Both Male & Female
Standard Population
CSS 13-County Region

The 95% CI for the estimated summary measure of SIR 1.28 had a standard error of SE(SIR) = 0.094 x 1.96, defining the upper and lower bounds in the following manner: SIR 1.28 ± 0.1849

SIR 1.28 [95% CI 1.09, 1.46]

Dashed outline box draws attention to indicate this value did not contribute to the total expected count calculation because this age-specific group stratum fell within the exclusion criteria

Figure 1b. SIR Calculation: Both Age & Male Adjusted

SIR CALCULATION - BOTH AGE AND SEX ADJUSTED - INDIRECT STANDARDIZATION						
	New MM Cases Only Men Included	Standard Pop. Estimates	Age & Male-Specific MM Incident Rate	Study Group Male FF Population	Total Observed MM Cases in FF	Expected MM in FF Applying Std. Pop. Age Specific Rates
Age Cat	E	P	R = E/P	pi	ei	
< 1-14	-	436,423	NA	NA	-	NA
15-19	5	155,805	0.00003209	40	-	0.00128366
20-24	29	163,408	0.00017747	100	-	0.01774699
25-34	327	336,245	0.00097251	1,794	-	1.74467427
35-44	1,306	332,967	0.00392231	2,572	-	10.08818291
45-54	2,994	347,538	0.00861489	2,830	-	24.38012534
55-64	5,263	265,639	0.01981260	2,362	-	46.79736786
65-69	3,207	82,049	0.03908640	733	-	28.65033090
70+	7,881	153,666	0.05128656	869	-	44.56801765
			TOTAL:	11,300	184	156.24644592
			SIR = observed/expected = 184/156.24672744 -->			SIR = 1.18

Study Years 2000-2017
Midpoint = 2009
Male Only
Standard Population
Six Region Multi-County

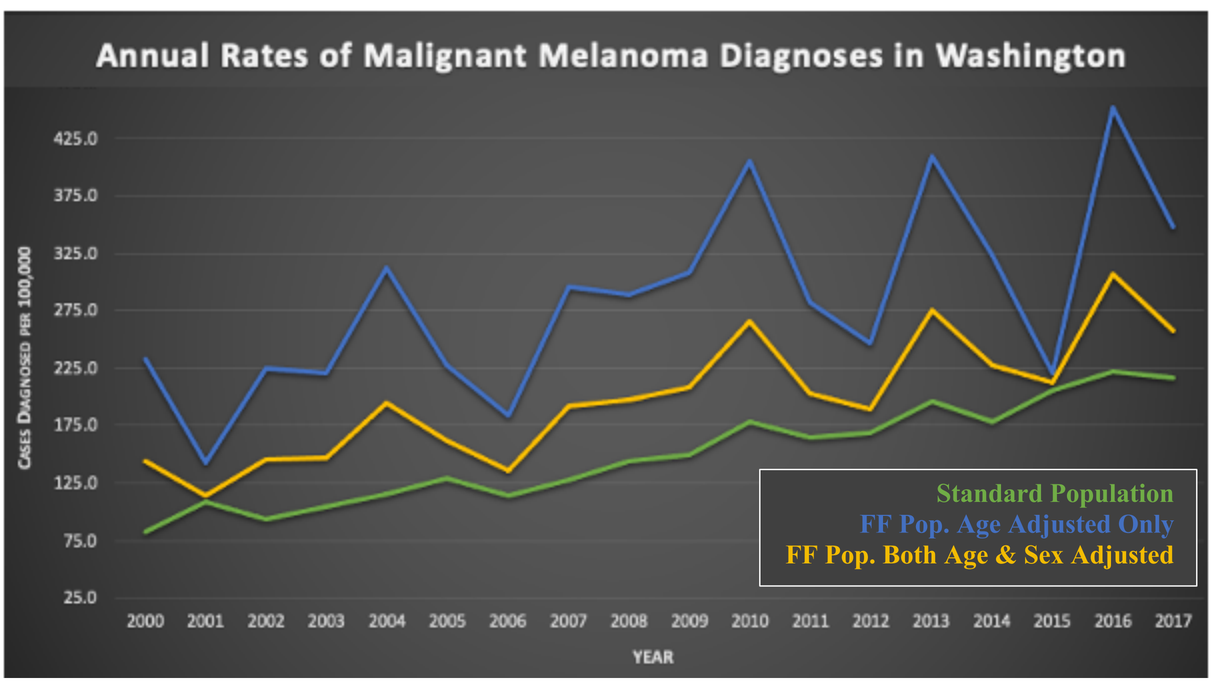
The 95% CI for the estimated summary measure of SIR 1.18 had a standard error of SE(SIR) = 0.087 x 1.96, defining the upper and and lower bounds in the following manner: SIR 1.18 ± 0.1705

SIR 1.18 [95% CI 1.01, 1.35]

The SIR calculations in both circumstances were found to be statistically significant in comparison to the standard and indicates that melanoma diagnoses would occur in career FF most likely at a rate that is 18% more excessive than the current rate within the standard population. To help visualize this concept and appreciate the steadily increasing incidence rate of malignant melanoma over time in general, a graph of the melanoma case rates from 2000-2017 in Washington are shown in Figure 2. The stable, less variable with the least amount of rate fluctuations over time in green represents the CSS 13-County catchment standard population's MM rates for both men and women combined. The variability of the rates (i.e., high fluctuations) seen in both the blue and yellowish orange lines is usually reflective of uncommon, relatively rare, or generally smaller case count totals in an already small subpopulation.

The lines with variability represent unstable rates seen in career firefighters supporting why indirect standardization for unstable rates in a study population is the preferred approach when estimating a summary measure like SIR to understand how specific diseases may affect specific populations of interest differently within a particular time period of interest. The blue line is clearly the most unstable and reflects MM rates in career FF adjusted only based on age compared to the standard. The yellowish-orange line represents rates of MM cases in FF after adjusting for both age and male sex, clearly indicating the importance of adjusting for both variables, especially in the context of malignant melanoma. Confirmation of this can be gleaned from the graph itself with the yellowish orange line exhibiting a tendency toward rate stability more aligned with the stable rate portrayed by the standard yet still different enough to remain statistically significant. All lines display and confirm the claim that melanoma incidence rates continue to increase even in the state of Washington and have had the tendency to continue increasing for at least the last two decades based on the interpretation of this graph alone.

Figure 2. MM case rates in career FF and standard population over the study period*



*Note, the annual MM rate in the standard population (green) is here just for referential purposes. It should not be used for direct comparisons but rather as a visual effect exhibiting stability but gradually increasing incident rates of MM over time. The high variation and fluctuations seen in standardized FF group adjusted for age only (blue) is the result of unstable counts of a relatively rare condition in an already small subpopulation of individuals. The standardized FF group adjusted for both age and male sex (yellowish orange) shows improved stability in MM incident rates, but still not quite at the level of stability exhibited by the standard.

Discussion

While policy decisions about presumption covered conditions are informed by science, the complex decision-making process and myriad factors considered extend far beyond any statistically significant summary measure. What the calculated SIRs do provide is evidence of an 18% excess risk estimate for career FF to be diagnosed with MM compared to the standard population used. Beyond this, additional findings of interest surfaced as a result of this study, or at the very least, we hope sparked interest in designing additional investigations. For instance, excluding unknowns, at least three quarters of career FF received a MM diagnosis after their retirement date. One of the eligibility criteria to fall under presumption is a time limit on when a diagnosis will be considered coverable beyond a firefighter's separation date. One could investigate perhaps the interplay between date of diagnosis, retirement date, and how eligibility under presumption was affected by the relationship of these two dates. The immediate question that comes to mind for further exploration is, "What fraction of FF with diagnosis dates that occurred after their retirement fell outside of the window of eligibility and by how long?" Equipped with this nuanced insight, a relook at how benefits are accessible under presumption given the additional criteria that are prerequisites for eligibility might suggest the need to consider being more flexible with respect to the rate of benefits access as a result of the window of opportunity an occupational cancer diagnosis is considered coverable under presumption.

Briefly mentioned in the **Introduction**, PFAS and turnout gear has recently resurfaced as a point of contention with respect to how safe safety gear truly is. As the PFAS finding suggests, firefighters should add yet another concerning toxic chemical to their list of potential exposures; however, some firefighter educational websites such as FireRescue1 have spoken out against PFAS in the past and have described it as causing, "relatively volatile dialogue in the fire service revolving around the potential hazards of wearing firefighter turnout gear including assertions that the gear…off gasses fluorooctanoic acid (PFOA)." The website further points out that such dialogue has, "unnecessarily created anxiety over the safety of firefighter gear…and are creating distractions from other areas far more deserving of attention."[5,18] While the educational site ultimately agrees that further study may be needed, they contend that the fireground environment is the primary source of carcinogen risk exposure for the majority of active firefighters in the current workforce and the reason for the increased rates of cancers found in this occupation.

Although the risk of PFAS in firefighters due to their old, frayed turnout gear remains debatable, the finding should still encourage research in the area to get a sense of the magnitude of this potential source of exposure risk. With respect to the professional garment, uniform attire industry, there are no national guidelines or standards by which manufacturers are required to comply. Nearly all flame-resistant (FR) fabrics will claim to be National Fire Protection Association (NFPA) certified. NFPA 2112 is the standard protecting workers from flash fire exposure and injury by specifying performance requirements and test methods for flame-resistant fabric and garments[31]; however, not all NFPA 2112 certified garments are created equal.

FR fabrics come in two major forms—inherent and treated. As the name suggests, inherent-FR are engineered to be flame-resistant for life, having the FR properties literally built into the very core of the fabric's fiber.[32] The protection does not wash or wear out over time and the garment will always be FR no matter how long the use[32] unless severely compromised with rips, excessive fraying, and synthetic fiber breakdown. Treated FR fabrics go through a chemical application process that makes them FR. Over time, the FR properties begin to degrade and become less and less protective as the wear life of the garment continues. Wear, abrasion, UV exposure, and laundering will shorten the useful life of a treated FR fabric.[32] Add to this the fact that the chemical FR treatments applied to fabrics such as cotton often present significant environmental concerns about the effluents of such processes[32] and lack standard guidelines with respect to the amount of treatment application that can be applied.

During the summer of 2019, breakouts of contact dermatitis cases among flight attendants employed by a very popular commercial airline—Delta Air—were observed following the launch of the company's new brand uniform.[33] It was discovered that the procurement of the uniform was outsourced through the global supply chain market and most likely fell under the treated type of FR attire. Each time the uniform was laundered, exposed to ultraviolet and to a lesser degree cosmic radiation while working on the planes, most likely contributed to an expedited degradation of the chemical treatment applied to the uniform fabric used to create its FR properties, resulting in the clinical presentation in the dozen or so workers seen in our clinic.

Based in anecdotes such as Delta's mini-epidemic, additional questions should be asked such as: "Are there safety standards in the manufacturing and processing of firefighter turnout gear beyond NFPA 2112? Are there consensus guidelines on how often turnout gear should be thrown out and new items purchased to replace older ones?" Irrespective of what such research studies would find, equipped with an increased awareness of the myriad paths of exposure to hazardous compounds that exists for firefighters, it becomes clear why standardized safety measures in the creation of uniform attire is important. Furthermore, it should be encouraged that fire departments invest in the oftentimes much more expensive inherent type of FR fabric given its longevity and most likely its safety profile in comparison to attire or garments sewn with treated type FR fabric. While the latter may be acceptable in commercial airline flight attendants, it does not seem like the practical solution for an occupation such as firefighting.

It was interesting to observe that when considering just the fraction of invasive cases among FF, 88% of cases were found to meet the definition of early-stage disease. The practice of dividing cancer cases according to so-called stages arose from the fact that survival rates were higher for cases in which the disease was localized than for those in which the disease had extended beyond the organ of origin.[34] These groups were often referred to as "early" cases and "late" cases, implying some regular progression with time. In fact, the stage of disease at the time of diagnosis may be a reflection not only of the rate of growth and extension of the neoplasm but also of the type of tumor and of the tumor-host relationship.[34] There are some experts who argue the increasing incidence in melanoma is largely attributable to increases in diagnosis and cite the high percentage of diagnosed melanoma in-situ as the primary driver.[30,35,36] In the United States, the annual incidence of melanoma in-situ was 9.5% in 2016. These experts suggest that including melanoma in-situ in the numbers should be reconsidered as it falsely inflates melanoma incidence.[30,35,36] On the other hand, and likely the more correct assessment, are experts who contend that increased screening and biopsy alone cannot account for the dramatic changes observed in incidence as increasing numbers have been demonstrated across all staging classifications independent of socioeconomic status, which some suggest is a surrogate marker for health care access and screening.[30,37,38]

Taken altogether, perhaps the high case percentage seen among both melanoma in-situ disease and early-stage disease among FF reflects truly increased incidence from not only an increased number of performed biopsies and better technologies detecting the cancer from increased screening efforts in addition to a laundry list of other reasons: greater awareness for melanoma and its attributable risk factors, societal impositions (e.g., legislation in some states that have banned the use of tanning beds by minors), increased individual acceptance of implementing modifiable lifestyle and behavioral changes (e.g., daily sunscreen application). The latter two examples may seem counterintuitive as additive effects to the incidence rate of melanoma but think of them as processes that can affect an individual already destined to develop melanoma. By engaging in safety practices and prevention strategies the destined melanoma diagnosis may be caught at an earlier stage thereby increasing the fraction of melanoma in-situ or early-stage disease cases within the population. An interesting follow up to this is to try and determine how much of these cases are the result of a very proactive, pro-awareness and pro-education "right to know" FF union representation potentially contributes to the values seen in this study. Robust, proactive, union representation among the fire service workforce likely translates to a decreased threshold of having concerning spots or other skin lesions on their bodies examined and evaluated by qualified healthcare professionals.

The findings highlighted in this study are hardly the first to estimate SIR or other summary measures specifically looking at malignant melanoma in FF. Several other studies[39–42] that historically looked at melanoma cases in firefighters as referenced by the IARC Monograph Volume 98[4] showed no statistically significant SIRs or standardized morbidity ratios (SMR). However, three more recent studies are consistent with the findings in this one. These studies reported an increased SIR involving a 45-year follow-up study in five Nordic countries[3], an increased meta-relative risk (mRR) measure that examined 32 studies in a review and meta-analysis[43], and an increased adjusted odds ratio (aOR) among male firefighters demonstrating an increased odds of malignant melanoma diagnoses in firefighters using cancer registry data from Florida[44]. While the latter study is exciting as it validates use of cancer registry data to support evidence of an increased risk of MM in FF, it still required some scrutiny given that ultraviolet radiation (UVR) exposure was not fully accounted for, but perhaps the authors assumed that being in an environment like Florida simply raises the risk for everyone.

Limitations and modifications that might alter interpretation of results

This study has several potential limitations. At first, sex-specific rates were not used as they were unavailable until deeper exploration of the WSCR web application provided aggregated multicounty case counts removing the sex-specific melanoma rates stratified by age that were suppressed due to counts less than ten. Sex-specific rates may not seem so obvious if one was unaware of particular epidemiological predilection expressed by malignant melanoma, but considering the subpopulation of interest has an overwhelming representation of a certain sex in the workforce (i.e., men firefighters in Washington State comprise up to 95% of the fire service workforce), it's clear that adjusting for sex in the context of malignant melanoma specifically, especially when the study population is dominated by men is of value. Consideration of including a third variable to adjust for would be to limit the standard population to the Non-Hispanic White fraction given the higher prevalence of malignant melanoma among this particular demographic group and that the majority of career FF at least in the state of Washington fall within this higher risk group. Begrudgingly, we were unable to execute this particular adjustment since the distribution of specific races and ethnicities among the career FF study population was unknown.

Second, although sufficient, the standard population used in this study was not ideal. If the standard population does not reflect the population at large with relatively stable case rates (or at the very least, a stabler one) then a falsely elevated SIR can be observed. This is why choice of standard population is extremely important. Poor choice of standard translates to an indefensible or poorly justifiable result. When a standard population similar to one that represents a statewide population—like the one used in this study—is chosen, the results can be viewed with a lesser degree of skepticism; however, temptation to make a comparison of the summary measure in a different context should be avoided where interpretation is only applicable insofar as to the standard population used. Choosing a standard population that accurately reflects the study population will help adjust or in a way control for glaring and obvious differences between them such as was the case of not having sex-specific rates initially available until realizing that aggregated multicounty data rendered suppressed counts a nonissue. According to the Association of Public Health Epidemiologists in Ontario (APHEO), "for indirect standardization, the standard population for calculating an SMR [or SIR] should be chosen depending on the study population being examined [and] it is best to use a standard that is similar to the years of data available for the study population.[45]" This is precisely why the standard population chosen was the midpoint (i.e., 2009 population) for the defined study period.

Another limitation in this study was not accounting for time at-risk among the study population. Someone working on the fire service for 10 years, of which 8 of those years were spent at the active fireground environment, responding to fire service emergencies to put out structural building fires with myriad exposures to burning materials and combustion byproducts, will have a much greater risk profile than someone who joined the fire service workforce just two years ago. Both of their risk profiles would be different when compared to another firefighter who has been in the service for 15 years, but for the last 8 years has served in a primarily educational leadership and administrative role. Since information about length of employment as a career FF was unavailable in this particular investigation, access to such information would most certainly provide a more accurate summary measure. Consideration of creating a case-control study design with specified risk categories might help mitigate this limitation by providing a different approach to estimate measures of association that reflect the defined risk exposure and disease relationship of firefighters and malignant melanoma.

When calendar time can be adjusted by the researcher, even if it's as simple as including only firefighters that have been employed on the fire service workforce for at least one year, the possibility of being able to stratify by the calendar time at-risk permits risk estimations for stratified groups of workers within the study population itself. Subgroups within the study population can be compared to each other, separated based on calendar time exposed to hazardous situations while employed or even based on other criteria of interest. For example, first pass criteria could be limited to those employed with the fire service for at least one year. Then this subgroup with at least one year of work in the fire service can be separated even deeper based on exposure risk (e.g., at least 1 year of work in the fire service and at least 6 months of assigned duties responding to structural and active fire response calls). Another example may be to look at various fire department practices such as those departments that practice decontamination procedures on site prior to returning to the fire station compared to other fire departments performing decontamination upon returning to their station.

The final limitation that merits discussion is the potential of introducing bias into the study with misclassification bias—differential and nondifferential—arguably being the most relevant in the context of this study. Some degree of nondifferential misclassification has inevitably occurred in this study. The exposure is the firefighter occupation but this particular study only isolated career firefighters in the study group primarily because there was a mechanism to identify this type of firefighter by crosslinking with the LEOFF retirement pension system. Some degree of nondifferential misclassification bias undoubtedly occurred because it's very likely that other non-career firefighters (e.g., wildland or volunteer fire service workers) diagnosed with melanoma were either (a) not included in the firefighter exposure study group and/or (b) not excluded from analysis and lumped in the non-firefighter group ultimately contributing to the standard population. The magnitude of effect from nondifferential misclassification would result in a bias toward the null with an SIR much closer to 1.0 and/or the associated 95% CI inclusive of 1.0, which was not observed in this study.

If differential misclassification bias were introduced, it would hypothetically require that a systematic over- or under-identification of malignant melanoma cases among FF in comparison to the standard population be observed. If this hypothetical systematic error led to over-identification of MM cases among FF compared to the standard population, we might expect erroneously inflated "total expected counts" in the denominator. For the hypothetical situation resulting in systematic under-identification, we might expect small "total number of observed cases," in the numerator. In both cases, the estimated SIR would be 1.0 or considerably lesser than 1.0. For the findings in this study, the magnitude of effect from non-differential misclassification bias was diluted enough among the standard population that bias toward the null was not observed. The discussion regarding differential misclassification was technically not possible to introduce in our study since there was no true unexposed group for direct comparison plus all the data was already classified and determined in a sense by the cancer registry itself. Its inclusion as a potential source of bias and limitation are more for demonstrable purposes.

A third bias for consideration that could influence this particular investigation is a concept commonly referred to as the healthy worker effect (HWE). Estimating the SIR in this study roughly parallels studies aimed at estimating the SMR in others. Whether SIR or SMR, both calculations rely on the overall, general population estimations among individuals with cancer, which can be quite vulnerable to healthy worker effects since workers, on average, are healthier than the general population which necessarily includes employed, unemployed, and retired individuals.[43,44] As a result, the HWE bias is likely much more amplified in studies on firefighters given the stringent fitness and health requirements those in the fire service must meet in order to maintain employment in the profession.[44,46] In fact, a paper published in 2013 provided definitive evidence that the HWE bias plays a strong role when estimating cancer risk in the working population, but also suggested that the extent of this bias varies across cancer subtype and worker gender.[44,47] Based on these findings, a case-control approach to estimate cancer risk might reduce the HWE bias when the controls are defined as all other cancers in the state except for the cancer of interest.[44,48] A very creative and thoughtful study design detail for which these authors should be commended.[44]

The last mentionable bias with respect to this study is confounding, which can cause either an over- or under-estimation of the summary measure. Addressing confounding can be achieved either at the design stage of a study or during the analysis phase. Since this investigation relied on data that was already collected, classified, and codified, the available options to correct for confounding through modifications of the study design were extremely limited. Previously collected and classified data essentially makes unmeasured, missing data on confounders the investigator considers important (e.g., blistering sunburns in childhood, overall nevi burden—two data points not included in cancer registry data capture) are an unfortunate inevitability. Potential confounders that would not otherwise be considered, (e.g., different behaviors and practices chosen by different people—artificial tanning bed use, daily sunscreen application, avoidance of outdoor sun exposure during the hottest part of the day, etc.) resulting in unexpected findings after analysis is sometimes referred to as residual confounding.[49] The most common way to correct for confounding in the analysis phase, is to adjust based on factors believed to be important and potentially affect relationship of the outcome being measured.

Expected benefits and future directions

Several expected benefits can be attributed to the findings from this study including the provision of supplemental evidence about a coverable condition under presumption legislation in the state of Washington for career firefighters. The supportive evidence based on the findings in this investigation were found in a current climate where the majority of available literature on this specific cancer in this specific occupational worker population has been relatively scarce and where the conclusions of the studies published and available have been contradictory and conflicting at worst, though not statistically significant at best. This seemingly began to change when more recently published data from five Nordic countries over a 45-year follow period and researchers using the FL cancer registry began to give credence again to the claim that career FF have an increased risk of developing malignant melanoma. Despite the statistically significant SIR estimations in our study, it should be noted that follow-up studies to verify the findings in this study are encouraged as a means of achieving reliable and reproducible work.

The obvious and most direct benefit from doing this study is at the level of the individual beneficiary who falls under legislation for coverable conditions as defined by the stipulations and eligibility criteria outlined in the Revised Code of Washington (RCW) 51.32.185 state legislation.[20] While most of the benefits will be realized by covered FF, other individuals that might benefit from the findings in this study include other participants, associates, and agencies directly engaged with this project. One major benefit we hope comes to fruition as a result of this study is an increased awareness in the 18% excess melanoma diagnoses expected among career firefighters in comparison to the standard population used. Aside from just simply raising the broader community's awareness about MM and career firefighters, we truly hope that the findings and this study pique the interest of other researchers and perhaps inspire continued research endeavors investigating occupational cancer risks.

Yet another benefit from participating in this study was the creation of an educational platform that encouraged ongoing and continual collaborations with state research agencies like Labor & Industries (L&I) with intentions to continue research-related work in this particular area or discuss opportunities to work on any future projects in the pipeline that could use some additional help. Establishment of this professional working relationship should hopefully make it quite simple to jump onboard another project or maintain open lines of communication with respect to finalizing projects regarding any potential publication opportunities that may arise. Some examples that could help guide any future research work that aims to verify the findings in this study, may consider doing a data verification but with alternative study design approaches similar to some of the modifications discussed in the aforementioned section. For example, considering a case-control design approach to limit the HWE bias, securing Non-Hispanic white distributions among firefighters and the counts of melanoma that are diagnosed in this particular demographic in Washington allowing to adjust for age, sex, race, and ethnicity would be insanely powerful. If specific melanoma incidence rates among FF can be obtained then a direct standardization approach that estimates comparative morbidity ratios (CMR) such that direct comparisons between seemingly different groups can be made more readily given the inherent limitation of indirect standardization's inability to make any comparisons except the standard.

Future research directions should focus on verifying the findings of this study but at the same time consider pursuing alternative summary or risk factors to measure. Modifications to the study design, including how to measure or define various levels of risk within the firefighter population should be entertained. In addition, exploring the multivariable logistic regression model built as part of this project's initial conception and research proposal to assess associations between occupation as an exposure variable and the outcome of interest defined as stage of melanoma at diagnosis. The model used to define this association could be tested with moderators and potential confounders including age, sex, marital status, primary anatomical site involved, urban/rural residential indicator, etc. Any future projects related to the findings in this project should also seriously consider including a direct comparison group that could involve workers in occupational roles with known increased risk of malignant melanoma (e.g., pilots and air cabin crew of commercial airlines) and/or make direct comparisons to a third group of occupational roles with an unknown, understudied, or simply assumed risk of malignant melanoma (e.g., outdoor workers in agricultural workers).

This particular opportunity was quite unique in that it allowed an outsider to push forward a state agency's research agenda but at the same provide an educational opportunity while simultaneously gaining some professional experience, and the chance to develop some new research skills that will eventually contribute to a skill set that can be used in clinical research endeavors in the future. The level of impact this particular study can impart goes well behind the intended individual benefits. Finally, we remain committed to maintaining open lines of communication through this professional working relationship forged with L&I as a result of this project with the intention of continuing more clinical research with a slight shift in focus after starting a new position at Sea Mar Community Health Clinics, where access to different worker groups such as agricultural and outdoor workers might be more readily available if this happens to be an interest shared by L&I.

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Supplemental Materials Appendix

Figure A1. Washington Multi-County Regions: Six Region Scheme[27]
Six additional counties were included in the standard pop. when adjusting for age *and* sex. These six additional counties are encircled with the dashed lines in the southwest part of Washington

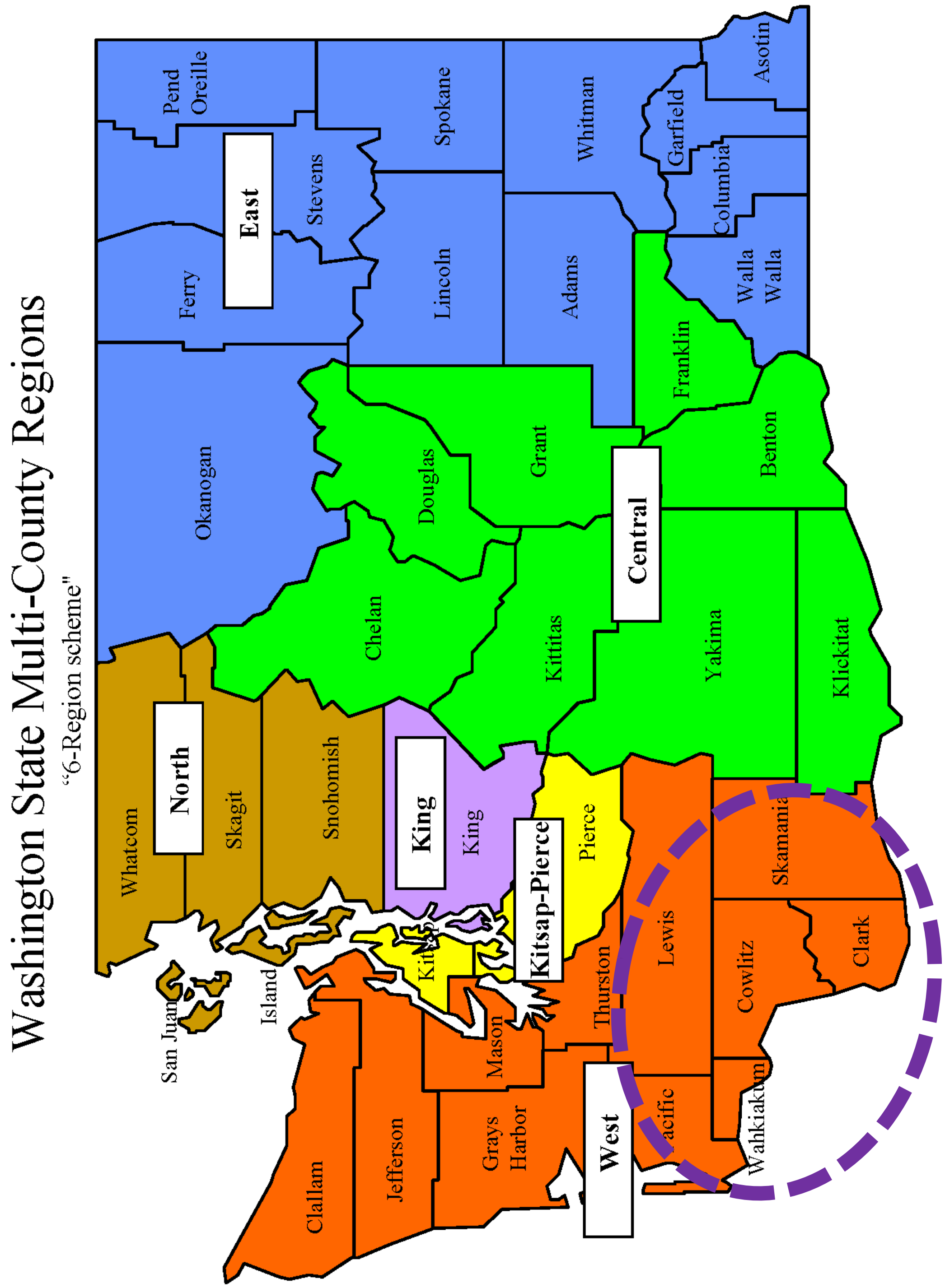

Figure A2. SIR Calculations Adjusted for Age (Top) and Both Age and Male Sex (Bottom)

Column:		*E*	*F*	*G*	*H*	*I*	*J*
Study Years 2000-2017 Standard Pop. Estimates from Midpoint Year = 2009 **Both Men and Women** Standard Pop. Used **CSS 13 County Region***		New MM Cases Both Men & Women	Std. Pop. Estimates	Age Specific MM Incidence Rate	Study Population Career FF	Total **Observed** MM Cases in Career FF	Total **Expected** MM Cases in FF Applying Std. Pop. Age Specific Rates
	Age Cat	**E**	**P**	**R = E/P**	**p_i**	**e_i**	**EE = R x p_i**
	< 1-14	-	852,748	NA	NA	-	NA
	15-19	10	303,496	0.00003295	43	-	0.00140270
	20-24	181	319,221	0.00056701	106	-	0.06034556
	25-34	1,821	656,374	=((E8/F8))	1,909	-	5.29620156
	35-44	3,581	652,220	0.00549048	2,738	-	=(H9*G9)
	45-54	6,388	695,519	0.00918451	3,012	-	27.66373888
	55-64	9,061	544,740	0.01663362	2,514	-	41.81692918
	65-69	4,837	169,549	0.02852863	780	-	22.25232824
	70+	12,421	363,146	0.03420387	925	-	31.63858338
				TOTAL :	12027	184	=SUM(J7:J13)

*Age Cat- age categories; Std.- standard; Pop.- population

SMR = observed/expected = 184/143.76105740 --> SMR = =I14/J14

Column:		*E*	*F*	*G*	*H*	*I*	*J*
Study Years 2000-2017 Standard Pop. Estimates from Midpoint Year = 2009 **Men Only** Standard Pop. Used **Multicounty Six Region***		New MM Cases Both Men & Women	Std. Pop. Estimates	Age Specific MM Incidence Rate	Study Population Career FF	Total **Observed** MM Cases in Career FF	Total **Expected** MM Cases in FF Applying Std. Pop. Age Specific Rates
	Age Cat	**E**	**P**	**R = E/P**	**p_i**	**e_i**	**EE = R x p_i**
	< 1-14	-	436,423	NA	NA	-	
	15-19	5	155,805	0.00003209	40	-	0.00128359
	20-24	29	163,408	0.00017747	100	-	0.01774615
	25-34	327	336,245	0.00097251	1,794	-	1.74429115
	35-44	1,306	332,967	0.00392231	2,572	-	10.09012532
	45-54	2,994	347,538	0.00861489	2,830	-	24.37954514
	55-64	5,263	265,639	=((E29/F29))	2,362	-	46.79806962
	65-69	3,207	82,049	0.03908640	733	-	=(H30*G30)
	70+	7,881	153,666	0.05128656	869	-	44.57243971
				TOTAL:	11,300	184	156.24672744

*Age Cat- age categories; Std.- standard; Pop.- population

SMR = observed/expected = 184/156.24672744 --> SMR = =I32/J32

Figure A3a. Total FF Pop. by Age Group LEOFF 1 and LEOFF 2 – Active FF Members

Formula Bar Service Distribution of Active Fire Fighters
(Number of Actives and Average Annual Salary)
LEOFF Plan 1

Attained Age	Attained Years of Service: 0	1	2	3	4	5-9	10-14	15-19	20-24	25-29	30-34	35-39	40 & Over	Total
Under 25	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	**$0**
25-29	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	**$0**
30-34	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	**$0**
35-39	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	**$0**
40-44	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	**$0**
45-49	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	**$0**
50-54	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	**$0**
55-59	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	**$0**
60-64	0	0	0	0	0	0	0	0	0	0	0	0	3	**3**
	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$125,277	**$125,277**
65-69	0	0	0	0	0	0	0	0	0	0	0	0	4	**4**
	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$102,496	**$102,496**
70 & Over	0	0	0	0	0	0	0	0	0	0	0	0	3	**3**
	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$111,899	**$111,899**
Total	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**10**	**10**
	$0	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$112,151**	**$112,151**

Average:	Age	67.4	**Number of Participants:**	Vested	10	Males	10	**Early Retirement Eligible:**	N/A
	Service	45.3		Not Vested	0	Females	0	**Normal Retirement Eligible:**	10

Annual Salary omitted for privacy reasons.

Age and Service Distribution of Active Fire Fighters
(Number of Actives and Average Annual Salary)
LEOFF Plan 2

Attained Age	Attained Years of Service: 0	1	2	3	4	5-9	10-14	15-19	20-24	25-29	30-34	35-39	40 & Over	Total
Under 25	35	76	27	10	1	0	0	0	0	0	0	0	0	**149**
	$66,803	$67,953	$76,826	$90,900	*	$0	$0	$0	$0	$0	$0	$0	$0	**$71,096**
25-29	79	177	167	117	79	99	0	0	0	0	0	0	0	**718**
	$68,311	$73,754	$85,285	$93,981	$101,947	$105,519	$0	$0	$0	$0	$0	$0	$0	**$86,615**
30-34	73	173	168	122	141	355	158	1	0	0	0	0	0	**1,191**
	$68,847	$73,499	$85,937	$95,695	$104,184	$109,568	$114,578	*	$0	$0	$0	$0	$0	**$97,137**
35-39	43	91	105	87	81	347	536	89	0	0	0	0	0	**1,379**
	$71,970	$74,038	$86,152	$92,140	$103,012	$111,142	$119,822	$130,441	$0	$0	$0	$0	$0	**$108,512**
40-44	15	36	42	35	39	168	431	478	115	0	0	0	0	**1,359**
	$74,190	$70,734	$87,615	$93,506	$101,040	$109,438	$119,600	$127,126	$134,640	$0	$0	$0	$0	
45-49	7	15	29	12	17	70	238	452	544	135	0	0	0	**1,519**
	$80,722	$87,192	$82,490	$86,313	$90,356	$107,772	$117,682	$130,421	$138,158	$148,372	$0	$0	$0	**$129,380**
50-54	2	9	10	4	12	42	125	222	421	476	98	0	0	**1,421**
	$68,947	$80,794	$95,258	$112,308	$106,106	$102,937	$119,206	$126,564	$137,915	$146,691	$159,129	$0	$0	**$136,765**
55-59	0	7	8	6	6	15	28	86	167	275	211	51	0	**860**
	$0	$76,439	$108,872	$107,919	$110,870	$123,704	$117,170	$123,550	$131,849	$149,138	$151,816	$167,166	$0	**$141,943**
60-64	1	3	2	2	3	6	19	29	39	93	75	51	8	**331**
	*	$93,376	$82,121	$144,879	$99,041	$153,634	$120,548	$111,539	$121,411	$139,593	$152,040	$156,097	$175,267	**$139,069**
65-69	1	0	0	1	0	2	10	6	3	11	15	8	2	**59**
	*	$0	$0	*	$0	$72,555	$109,703	$122,452	$116,647	$140,235	$129,739	$172,784	$234,563	**$133,456**
70 & Over	0	0	0	0	0	0	1	1	1	0	0	2	0	**5**
	$0	$0	$0	$0	$0	$0	*	*	*	$0	$0	$139,442	$0	**$124,262**
Total	**256**	**587**	**558**	**396**	**379**	**1,104**	**1,546**	**1,364**	**1,290**	**990**	**399**	**112**	**10**	**8,991**
	$69,576	**$73,370**	**$85,771**	**$94,515**	**$102,658**	**$109,678**	**$118,716**	**$127,768**	**$136,401**	**$146,862**	**$152,824**	**$162,032**	**$187,126**	**$118,598**

Average:	Age	43.1	**Number of Participants:**	Vested	6,647	Males	8,420	**Early Retirement Eligible:**	662
	Service	14.0		Not Vested	2,344	Females	571	**Normal Retirement Eligible:**	1,689

Annual Salary omitted for privacy reasons.
Numbers of participants eligible for early and normal retirement are estimates only.

Figure A3b. Total FF by Age Group LEOFF 1 and LEOFF 2 – Retired FF Members

Age and Years Retired Distribution of Service Retired Fire Fighters

(Number of Service Retired Members and Average Monthly Benefit)

LEOFF Plan 1

Attained Age	0	1	2	3	4	5-9	10-14	15-19	20-24	25-29	30-34	35-39	40 & Over	Total
	Attained Years Retired													
Under 50	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	**$0**
50-54	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	**$0**
55-59	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	**$0**
60-64	0	1	4	2	3	20	7	0	0	0	0	0	0	**37**
	$0	*	$9,111	$8,750	$8,058	$8,745	$7,111	$0	$0	$0	$0	$0	$0	**$8,457**
65-69	1	5	7	6	12	51	76	27	0	0	0	0	0	**185**
	*	$9,670	$9,138	$9,532	$10,050	$8,641	$6,698	$5,374	$0	$0	$0	$0	$0	**$7,536**
70-74	0	0	2	4	2	44	83	99	65	0	0	0	0	**299**
	$0	$0	$11,739	$11,320	$8,125	$8,173	$7,284	$5,489	$4,371	$0	$0	$0	$0	**$6,277**
75-79	0	0	0	0	0	7	14	38	57	47	1	0	0	**164**
	$0	$0	$0	$0	$0	$10,447	$7,438	$6,147	$4,950	$3,823	*	$0	$0	**$5,357**
80-84	0	0	0	0	1	1	2	5	29	29	32	0	0	**99**
	$0	$0	$0	$0	*	*	$8,868	$7,462	$5,430	$5,821	$3,273	$0	$0	**$5,062**
85-89	0	0	0	0	0	0	0	1	4	10	26	13	0	**54**
	$0	$0	$0	$0	$0	$0	$0	*	$6,467	$5,830	$4,545	$3,262	$0	**$4,640**
90-94	0	0	0	0	0	0	0	0	0	3	12	14	8	**37**
	$0	$0	$0	$0	$0	$0	$0	$0	$0	$4,372	$5,436	$4,629	$4,037	**$4,742**
95 & Over	0	0	0	0	0	0	0	0	0	0	1	0	4	**5**
	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	*	$0	$4,329	**$4,434**
Total	**1**	**6**	**13**	**12**	**18**	**123**	**182**	**170**	**155**	**89**	**72**	**27**	**12**	**880**
	*****	**$9,744**	**$9,530**	**$9,998**	**$9,356**	**$8,585**	**$7,062**	**$5,678**	**$4,836**	**$4,718**	**$4,151**	**$3,971**	**$4,135**	**$6,149**

Average:	Age	74.5	Males	875
	Years Retired	18.0	Females	5

**Monthly benefit omitted for privacy reasons.*

Age and Years Retired Distribution of Service Retired Fire Fighters

(Number of Service Retired Members and Average Monthly Benefit)

LEOFF Plan 2

Attained Age	0	1	2	3	4	5-9	10-14	15-19	20-24	25-29	30-34	35-39	40 & Over	Total
	Attained Years Retired													
Under 50	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	**$0**
50-54	19	36	10	4	3	0	0	0	0	0	0	0	0	**72**
	$4,449	$4,127	$4,914	$3,774	$4,917	$0	$0	$0	$0	$0	$0	$0	$0	**$4,335**
55-59	63	109	105	70	63	81	0	0	0	0	0	0	0	**491**
	$6,247	$5,500	$5,221	$5,008	$4,778	$4,477	$0	$0	$0	$0	$0	$0	$0	**$5,205**
60-64	29	93	96	86	92	326	70	0	0	0	0	0	0	**792**
	$6,117	$5,548	$6,180	$5,943	$5,978	$5,290	$3,610	$0	$0	$0	$0	$0	$0	**$5,461**
65-69	10	20	37	42	40	231	127	25	0	0	0	0	0	**532**
	$6,648	$5,402	$5,473	$6,054	$5,416	$5,079	$3,497	$2,506	$0	$0	$0	$0	$0	**$4,752**
70-74	1	3	6	5	7	63	55	41	0	0	0	0	0	**181**
	*	$6,690	$4,460	$4,107	$5,463	$4,463	$3,860	$2,692	$0	$0	$0	$0	$0	**$3,937**
75-79	0	0	1	0	1	12	21	15	2	0	0	0	0	**52**
	$0	$0	*	$0	*	$2,719	$3,084	$2,254	$2,876	$0	$0	$0	$0	**$2,867**
80-84	0	0	0	0	0	1	1	7	5	5	0	0	0	**19**
	$0	$0	$0	$0	$0	*	*	$2,666	$1,045	$1,068	$0	$0	$0	**$1,731**
85-89	0	0	0	0	0	0	0	1	3	2	0	0	0	**6**
	$0	$0	$0	$0	$0	$0	$0	*	$2,099	$1,129	$0	$0	$0	**$1,883**
90-94	0	0	0	0	0	0	0	0	0	0	1	0	0	**1**
	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	*	$0	$0	*****
95 & Over	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	**$0**
Total	**122**	**261**	**255**	**207**	**206**	**714**	**274**	**89**	**10**	**7**	**1**	**0**	**0**	**2,146**
	$5,944	**$5,334**	**$5,596**	**$5,563**	**$5,464**	**$5,009**	**$3,560**	**$2,564**	**$1,727**	**$1,086**	*****	**$0**	**$0**	**$4,952**

Average:	Age	63.3	Males	1,995
	Years Retired	5.7	Females	151

Monthly benefit omitted for privacy reasons.

Figure A4a. WSCR Filter to Define Standard Pop. CSS 13-County MM Incident Rates

Used when estimating the SIR for MM in career FF with age adjustment only

WA Stat https://fortress.wa.gov/wscr

Results June 22, 2021 1:57:28 AM Pacific Daylight Time

Cancer Incidence Codes ICD-0-3

Melano C44.0-C44.9, including only histology codes 8720-8790

Data	Cancer Site	Stage At D	Geography	Year	Age Group	Gen	Race	Annual Population	Annual Observations	Age-Spec.	95% CI
Inciden	Melanoma of the Skin	All	Clallam	2009	65-69	All	All	4960	NR	NR	NR
Inciden	Melanoma of the Skin	All	Grays Harbor	2009	65-69	All	All	3724	NR	NR	NR
Inciden	Melanoma of the Skin	All	Island	2009	65-69	All	All	4709	NR	NR	NR
Inciden	Melanoma of the Skin	All	Jefferson	2009	65-69	All	All	2672	NR	NR	NR
Inciden	Melanoma of the Skin	All	King	2009	65-69	All	All	63138	100	158.4	[128.9, 192.6]
Inciden	Melanoma of the Skin	All	Kitsap	2009	65-69	All	All	10875	18	165.5	[98.1, 261.6]
Inciden	Melanoma of the Skin	All	Mason	2009	65-69	All	All	3538	NR	NR	NR
Inciden	Melanoma of the Skin	All	Pierce	2009	65-69	All	All	27590	33	119.6	[82.3, 168.0]
Inciden	Melanoma of the Skin	All	San Juan	2009	65-69	All	All	1302	NR	NR	NR
Inciden	Melanoma of the Skin	All	Skagit	2009	65-69	All	All	5632	10	177.6	[85.1, 326.5]
Inciden	Melanoma of the Skin	All	Snohomish	2009	65-69	All	All	22922	38	165.8	[117.3, 227.5]
Inciden	Melanoma of the Skin	All	Thurston	2009	65-69	All	All	10282	20	194.5	[118.8, 300.4]
Inciden	Melanoma of the Skin	All	Whatcom	2009	65-69	All	All	8205	16	195	[111.5, 316.7]

Washington State Cancer Incidence Data: Washington State Department of Health, Washington State Cancer Registry, released in March 2020

Figure A4b. WSCR Filter for Standard Pop. 6 Region Multi-County MM Incident Rates

Used when estimating the SIR for MM in career FF when adjusting for *both* age and sex

WA Sta	https://fortress.wa.gov/wscr										
Results	June 22, 2021 12:36:10 AM Pacific Daylight Time										
Cancer	Incidence Codes ICD-0-3										
Melanc	C44.0-C44.9, including only histology codes 8720-8790										
Data	Cancer Site	Stage At D	Geography	Year	Age Group	Gender	Race	Annual Population	Annual Observations	Age-Spec.	95% CI
Inciden	Melanoma of the Skin	All	King	2009	65-69	Male	All	30352	62	204.3	[156.6, 261.9]
Inciden	Melanoma of the Skin	All	Kitsap-Pierce	2009	65-69	Male	All	18605	39	209.6	[149.1, 286.6]
Inciden	Melanoma of the Skin	All	North	2009	65-69	Male	All	20806	46	221.1	[161.9, 294.9]
Inciden	Melanoma of the Skin	All	West	2009	65-69	Male	All	25681	33	128.5	[88.5, 180.5]
Washington State Cancer Incidence Data: Washington State Department of Health, Washington State Cancer Registry, released in March 2020											