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Office of the City Manager

CONSENT CALENDAR
March 22, 2022

To: Honorable Mayor and Members of the City Council

From: Dee Williams-Ridley, City Manager

Submitted by: Abraham Roman, Fire Chief

Subject: Contract: Pinnacle for Occupational Physicals

RECOMMENDATION

Adopt a Resolution authorizing the City Manager to execute a contract and any amendments with Pinnacle Training Systems, LLC (Contractor) for occupational health and pre-employment medical examinations including cancer and cardiac screening for firefighters, paramedics, emergency medical technicians, police officers and other designated staff through March 22, 2026 in an amount not to exceed $325,000 per fiscal year with an option to extend for three additional two-year terms, for a total ten-year potential contract not to exceed $3,250,000.

FISCAL IMPACTS OF RECOMMENDATION

The base term of this contract runs for four (4) years from March 23, 2022 through March 22, 2026 not to exceed $325,000 per year. There is an option to extend for three additional two-year terms for a total term of ten years with cost increases in year three (2.5%), five (3.0%), seven (3.0%) and nine (3.0%). Funding for the annual physical program is already budgeted annually in the Fire Department budget: 147-72-742-835-0000-000-422-612410.

CURRENT SITUATION AND ITS EFFECTS

There is an existing contractor in place that is supposed to be delivering services. This existing contractor has demonstrated an inability to provide services meeting contact and city of Berkeley requirements. This includes frequently being unresponsive to staff communications via phone and email, conducting incomplete physical examinations that do not adhere to the City's specifications, and providing inaccurate or incomplete medical results to City employees. The current contractor also does not specialize in providing public safety physical examinations.

The City conducted a competitive bid process and Pinnacle Training Systems, LLC successfully met the bid requirements and ranked highest for annual physicals and cancer prevention among all bidders. The pricing is deemed to be fair and reasonable. The proposed Contractor is a woman-owned, California small business and has a long history of providing occupational physicals for first responders in California. Current agencies utilizing this contractor include; Clovis, Union City, Citrus Heights, Menifee, Placer County, Roseville, Alhambra, Fresno, Cosumnes, Novato, Healdsburg, Sanger, San Gabriel, Hanford, Selma, Stinson Beach, and Woodland. The Contractor also specializes in providing screening and early detection of acute and chronic health conditions that are common in first responders that lead to lost time and workers compensation cases. Services meet the standards articulated in *The Fire Service Joint Labor Management Wellness-Fitness Initiative, Fourth Edition* and *NFPA 1582: Standard on Occupational Medical Programs for Fire Departments.*

BACKGROUND

First responders have a higher rate of chronic medical and psychological injury and illness that has been directly correlated to shift work, traumatic experiences and stress, and exposure to carcinogens (Daniels, 2013) (Sritharan, 2017). Until recently there has been a stigma associated with coming forward with admission of psychological or medical conditions related to the work, thereby the data has been grossly under reported. Along with more funding dedicated to scientific research over the past several decades on these topics, it is now widely accepted that there are direct correlations from these disease processes to the work. Establishing and maintaining a complete annual physical and wellness program is critical in reducing lost time, mental illness, substance abuse and preventing or early detection of long-term chronic health conditions including cancer and heart disease within the first responder population.

Impacts of Shift Work

First responders routinely work shifts that cause disruption of the normal sleep/wake cycle. Nocturnal melatonin suppression and circadian rhythm disruption caused by night shift work function as carcinogens that increase the incidents of malignant tumors (Daniels, 2013) (Tsai, 2016). In addition to cancer, shift work has been associated with higher rates of Type II diabetes, heart disease, stroke, metabolic disorders, sleep disorders, increased risk for reproductive issues, such as irregular menstrual cycles, miscarriage, and preterm birth, chronic stress and depression (Smith, Cardiovascular Strain of Firefighting and the Risk of, 2016). Circadian disruption can harm biologic systems that help prevent cancer. For example, in addition to promoting sleep, melatonin can also inhibit tumor growth and protect against the spread of cancer cells.

Increase Risk of Cancer & Prevention

Research spanning decades, continents, and more than 80,000 firefighters validates the connection between firefighting and occupational cancer. Cancer is the most dangerous threat to firefighter health and safety today.

- Cancer caused 66 percent of the career firefighter line-of-duty deaths from 2002 to 2019, according to data from the International Association of Fire Fighters (IAFF). Heart disease caused 18 percent of career LODDs for the same period.
- Cancer caused 70 percent of the line-of-duty deaths for career firefighters in 2016 (Smith, Cardiovascular Strain of Firefighting and the Risk of, 2016).
- Firefighters have a 9 percent higher risk of being diagnosed with cancer and a 14 percent higher risk of dying from cancer than the general U.S. population, according to research by the CDC/National Institute for Occupational Health and Safety (NIOSH).

Firefighters' risks are significantly higher for some types of cancer than the general population, these include:

- testicular cancer – 2.02 times the risk (100% = double = 2 times);
- mesothelioma – 2.0 times greater risk;
- multiple myeloma -1.53 times greater risk;
- non-Hodgkin's lymphoma – 1.51 times greater risk;
- skin cancer – 1.39 times greater risk;
- malignant melanoma – 1.31 times greater risk;
- brain cancer -1.31 times greater risk;
- prostate cancer – 1.28 times greater risk;
- colon cancer -1.21 times great risk; and
- leukemia – 1.14 times greater risk (Daniels, 2013).

Continual and early screening is key. Screening is done when employees have no signs or symptoms. These tests help detect cancer at an early stage, before symptoms appear. When abnormal tissue or cancer is found early, it is often easier to treat or cure. By the time signs and symptoms appear, the cancer may have grown and spread making it more difficult, costly, or impossible to treat or cure.

Mental Health

First responders are more likely to die by suicide than in the line of duty. In 2017, there were at least 103 firefighter suicides and 140 police officer suicides in the US. In contrast, 93 firefighters and 129 police officers died in the line of duty. Suicide is a result of mental illness, including depression and PTSD, which stems from constant exposure to death and destruction.

There are a number of factors contributing to mental health issues among first responders and what leads to their elevated rate of suicide. One study found that on average, police officers witness 188 ‘critical incidents’ during their careers. This exposure to trauma can lead to several forms of mental illness. For example, PTSD and depression rates among firefighters and police officers have been found to be as much as 5 times higher than the rates within the civilian population, which causes these first responders to commit suicide at a considerably higher rate (firefighters: 18/100,000; police officers: 17/100,000; general population 13/100,000). Even when suicide does not occur, untreated mental illness can lead to poor physical health and impaired decision-making.

In addition, the Firefighter Behavioral Health Alliance (FBHA) estimates that approximately 40% of firefighter suicides are reported. If these estimates are accurate, the actual number of 2017 suicides would be approximately 257, which is more than twice the number of firefighters who died in the line of duty.

Entry level and comprehensive annual physicals are known to reduce healthcare costs, reduce absenteeism and reduce workers compensation costs associated with injuries and illness (Pinnacle, 2018) (Lynn Hancock, 2017). Additionally, responders that are healthy are more resilient, make better decisions and are more likely to be at work. The Contractor will provide entry level and annual physicals inclusive of screening for common acute and chronic health conditions.

ENVIRONMENTAL SUSTAINABILITY AND CLIMATE IMPACTS

Contractor will also be providing all services within the City of Berkeley, whereas previous contracts required employees to travel outside the City to participate in physicals and follow up examinations.

RATIONALE FOR RECOMMENDATION

The City conducted a competitive bid process and Pinnacle Training Systems, LLC successfully met the bid requirements and ranked highest for annual physicals and cancer prevention among all bidders. The pricing is deemed to be fair and reasonable.

The contract with Pinnacle Training Systems, LLC will benefit the City by affording a long-term continuity of excellent medical surveillance services to identify and/or prevent acute and chronic conditions that may otherwise go unidentified by vendors that have less specialized experience. Pinnacle provides occupational health services to a wide variety of emergency services providers within California.

ALTERNATIVE ACTIONS CONSIDERED

Staff considered remaining with the current vendor, but this is not a viable solution if the City wishes to meet a commitment to providing the initial and on-going annual screening that will detect chronic disease development early. Additionally, the current vendor has consistently demonstrated poor customer service including frequently being unresponsive to staff communications, conducting incomplete employee physicals, providing inaccurate or incomplete medical results and providing employee's medical information to the wrong employees.

<u>CONTACT PERSON</u>
Abraham Roman, Interim Fire Chief, (510) 981-3473

Attachments:

1. Resolution
2. Daniels, a. a. (2013). Mortality and cancer incidence in a pooled cohort of US firefighters from San Francisco, Chicago and Philadelphia (1950− 2009). *Occupational & Environmental Medicine*.
3. Lynn Hancock, M. (2017). *Law Enforcement Fitness Policies in Relation to Job.* Walden Dissertations and Doctoral Studies.
4. Nord, e. a. (2011). Accuracy of peak VO2 assessments in career. *Journal of Occupational Medicine and Toxicology*.
5. Pinnacle. (2018). Evidence that Wellness Programs Reduce Worker's Compensation Costs for Police Departments.
6. Poplin, e. a. (2013). The Association of Aerobic Fitness With Injuries in the Fire Service. *American Journal of Epidemiology*.
7. Smith, e. a. (2011). Firefighter Fitness: Improving Performance. *Current Sports Medicine Reports*.
8. Smith, e. a. (2016). Cardiovascular Strain of Firefighting and the Risk of. *Exercise and Sport Sciences Reviews*.
9. Sritharan, e. a. (2017). Prostate cancer in firefighting and police. *Environmental Health*.
10. Tsai, e. a. (2016). Risk of Cancer Among Firefighters in California, 1988–2007. *Am J Ind Med.*

RESOLUTION NO. ##,###-N.S.

Contract: Pinnacle Training Systems, LLC for occupational health annual and pre-employment medical examinations;

WHEREAS, first responders have a higher rate of chronic medical and psychological injury and illness that has been directly correlated to shift work, traumatic experiences and stress, and exposure to carcinogens, and

WHEREAS, cancer caused 66 percent of the career firefighter line-of-duty deaths from 2002 to 2019, according to data from the International Association of Fire Fighters (IAFF), and

WHEREAS, firefighters have a 9 percent higher risk of being diagnosed with cancer and a 14 percent higher risk of dying from cancer than the general U.S. population, and

WHEREAS, PTSD and depression rates among firefighters and police officers have been found to be as much as 5 times higher than the rates within the civilian population, which causes these first responders to commit suicide at a considerably higher rate (firefighters: 18/100,000; police officers: 17/100,000; general population 13/100,000), and

WHEREAS, routine annual physicals have been proven to reduce healthcare and workers compensation costs associated with injuries and illness, and

WHEREAS, first responders that are healthy (medically and psychiatrically) are more resilient, make better decisions and are more likely to be at work.

NOW THEREFORE, BE IT RESOLVED by the Council of the City of Berkeley that the City Manager is authorized to execute a contract and any amendments with Pinnacle Training Systems, LLC (Contractor) to provide occupational health annual and pre-employment medical examinations including cancer screening for the first responders from March 23, 2022 through March 22, 2026 in an amount not to exceed $325,000 per fiscal year with an option to extend for three additional two-year terms, for a total ten-year potential contract amount not to exceed $3,250,000.

OEM

Mortality and cancer incidence in a pooled cohort of US firefighters from San Francisco, Chicago and Philadelphia (1950–2009)

Robert D Daniels, Travis L Kubale, James H Yiin, et al.

Occup Environ Med published online October 14, 2013
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Notes

ORIGINAL ARTICLE

Mortality and cancer incidence in a pooled cohort of US firefighters from San Francisco, Chicago and Philadelphia (1950–2009)

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ABSTRACT

Objectives To examine mortality patterns and cancer incidence in a pooled cohort of 29 993 US career firefighters employed since 1950 and followed through 2009.

Methods Mortality and cancer incidence were evaluated by life table methods with the US population referent. Standardised mortality (SMR) and incidence (SIR) ratios were determined for 92 causes of death and 41 cancer incidence groupings. Analyses focused on 15 outcomes of a priori interest. Sensitivity analyses were conducted to examine the potential for significant bias.

Results Person-years at risk totalled 858 938 and 403 152 for mortality and incidence analyses, respectively. All-cause mortality was at expectation (SMR=0.99, 95% CI 0.97 to 1.01, n=12 028). There was excess cancer mortality (SMR=1.14, 95% CI 1.10 to 1.18, n=3285) and incidence (SIR=1.09, 95% CI 1.06 to 1.12, n=4461) comprised mainly of digestive (SMR=1.26, 95% CI 1.18 to 1.34, n=928; SIR=1.17, 95% CI 1.10 to 1.25, n=930) and respiratory (SMR=1.10, 95% CI 1.04 to 1.17, n=1096; SIR=1.16, 95% CI 1.08 to 1.24, n=813) cancers. Consistent with previous reports, modest elevations were observed in several solid cancers; however, evidence of excess lymphatic or haematopoietic cancers was lacking. This study is the first to report excess malignant mesothelioma (SMR=2.00, 95% CI 1.03 to 3.49, n=12; SIR=2.29, 95% CI 1.60 to 3.19, n=35) among US firefighters. Results appeared robust under differing assumptions and analytic techniques.

Conclusions Our results provide evidence of a relation between firefighting and cancer. The new finding of excess malignant mesothelioma is noteworthy, given that asbestos exposure is a known hazard of firefighting.

What this paper adds

- From previous studies, there is limited epidemiological evidence of increased risk of cancer from firefighting.
- We examined cancer in 30 000 career firefighters by pooling information from urban fire departments in three large US cities. The large sample size and long follow-up period improved risk estimates compared with previous studies.
- We report that firefighting may be associated with increased risk of solid cancers. Furthermore, we report a new finding of excess malignant mesothelioma among firefighters, suggesting the presence of an occupational disease from asbestos hazards in the workplace.

Linked

▸ http://dx.doi.org/10.1136/oemed-2013-101803

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INTRODUCTION

There are approximately 1.1 million volunteer and career firefighters in the US.[1] During firefighting activities, these workers may be exposed to many known carcinogens (eg, polycyclic aromatic hydrocarbons (PAHs), formaldehyde, benzene, 1,3-butadiene, asbestos and arsenic) in volatilised combustion and pyrolysis products or debris.[2] These exposures have raised concerns of increased cancer among firefighters and have prompted a number of exposure assessment and epidemiologic investigations. Some studies have found excess cancers of the brain,[3–8] digestive tract,[4 5 7–10] genitourinary tract[5 7 11 12] and lymphohematopoietic organs.[6 8 13] In a recent meta-analysis of 32 studies, significant excess risk was reported for brain, stomach, colon, rectum, prostate, testes, multiple myeloma and non-Hodgkin lymphoma (NHL).[14] Similarly, the International Agency for Research on Cancer (IARC) reviewed 42 studies and reported significant summary risks for prostatic and testicular cancers and NHL.[2] Given limited evidence, however, IARC concluded that firefighter exposures were only possibly carcinogenic to humans (Group 2B).

Most studies have examined mortality, but not cancer incidence, among relatively few firefighters recruited from one fire department. The current study examines mortality and cancer incidence in a pooled cohort of firefighters employed in three major US cities. Malignancies of the brain, stomach, oesophagus, intestines, rectum, kidney, bladder, prostate, testes, leukaemia, multiple myeloma and NHL were of a priori interest in the current study, based on possible sites identified in previous reviews.[2 14] Lung cancer and chronic obstructive pulmonary disease (COPD) were also of interest because inhalation is a major pathway for firefighter exposures, and there is evidence of chronic and acute inflammatory respiratory effects in firefighters, which may be linked to cancer.[2] Breast cancer was included as a result of interests shared in researcher discussions with firefighters.

METHODS

Data collection methods

This research was approved by the Institutional Review Boards of the National Institute for Occupational Safety and Health (NIOSH) and the National Cancer Institute (NCI). Personnel records and previous study data were used to assemble the study roster, which comprised male and female career firefighters of all races employed for at least 1 day in fire departments serving San Francisco, Chicago, or Philadelphia, from 1 January 1950, through 31 December 2009. Fire departments were selected based on size, location, work experience, records availability and the willingness of labour and city management to participate. 'Career firefighter' status was determined from job titles categorised by researchers and vetted by each fire department. Selected job titles included general classifications of firefighters, firefighter paramedics, and fire department arson investigators. Persons of known race were mostly Caucasian (81%) and those missing race (2.5%) were hired in earlier periods of lower minority hiring (median year at hire=1955). Therefore, persons missing race were assumed Caucasian and retained in main analyses to maximise study size. Analyses were also conducted excluding persons of unknown race.

Vital status was ascertained from the National Death Index-Plus (NDI-Plus), the Social Security Administration Death Master File (SSA-DMF), personnel and pension board records, and records from the previous studies.[9 10] Firefighters not found to be deceased were confirmed alive by matches to employment records, Internal Revenue Service (IRS) records, and data accessible through LexisNexis (a private vendor of residential information).

Causes of death were obtained from previous studies,[9 10] NDI-Plus, and death certificates collected from state vital records and retirement boards. Deaths of Philadelphia firefighters through 1986 were previously determined by Baris *et al*,[9] who retrieved and coded death certificates to the ninth revision of the International Classification of Diseases (ICD-9). San Francisco firefighter deaths were determined through 1982 by Beaumont *et al*.[10] In that and the current study, causes of death were coded to the ICD revision in effect at the time of death. The underlying cause of death determined by a trained nosologist was used for all mortality analyses.

Incident cases were defined as all primary invasive cancers, and in situ bladder cancers among firefighters matched to state cancer registries on name, gender, race, date of birth and Social Security number. The last known residence and the state of death were used to narrow inclusion of registries for case ascertainment to 11 states (ie, Arizona, California, Florida, Illinois, Indiana, Michigan, Nevada, New Jersey, Oregon, Pennsylvania and Washington) where nearly 95% of all deaths in known states occurred (see online supplementary table S1). The site and histology of each tumour were used to classify cancers in one of 41 diagnostic groups using the International Classification of Diseases for Oncology, 3rd Edition (ICD-O-3).[15] The conversion from ICD-O-3 to ICD-10 used the Surveillance, Epidemiology and End Results Program (SEER) recodes (dated 27 January 2003) following slight modification to align with mortality groupings and to account for recent classification changes. Diagnosis dates were assigned as of 1 July of the year of diagnosis if only the diagnosis year was known, and on the 15th of the month of diagnosis if only the diagnosis month and year were known. The death date was used when death preceded the estimated date.

Statistical methods

The NIOSH Life Table Analysis System (LTAS.NET) was used to examine mortality and cancer incidence.[16] Main analyses used the US population as referent. In all analyses, person-years at risk (PYAR) were stratified by gender, race (Caucasian, other races), age (age 15–85+ years in 5-year categories), and calendar year (in 5-year categories). Confidence limits for risk measures were estimated based on a Poisson distribution for the observed outcome, with exact limits for outcomes with 10 or fewer occurrences.

For mortality analyses, PYAR began on the latest of 1 January 1950 or the date of cohort inclusion, and ended the earliest of the date of death (DOD), the date last observed (DLO), or 31 December 2009. US mortality rates (1950–2009) were used to estimate the expected numbers of deaths for all causes, all cancers and 92 categories of underlying cause of death.[17] Additional mortality rates were developed to separately report on cancers of the small intestine, large intestine and testes to coincide with incidence rates; however, these rates were limited to time periods after 1959. In both cases, the subsites of interest (ie, colon and testes) account for the largest proportion of the deaths in the respective aggregate site (ie, intestine or male genital organs excluding prostate); therefore, the aggregate site reasonably approximates the subsite. The standardised mortality ratio (SMR) was calculated as the ratio of the observed to the total number of expected deaths.

Two approaches were used to examine cancer incidence. The main analyses included first and later primary cancers (ie, multiple-cancer approach) occurring within the risk period. PYAR accrued from the date of statewide ascertainment by the respective fire department's state cancer registry (eg, 1 January 1988 for San Francisco firefighters (see online supplementary table S1)) or cohort inclusion, whichever was latest, and ended at the earliest of the DOD, DLO, or 31 December 2009. Secondary analyses were restricted to the first occurrence of invasive cancer (ie, first-cancer approach). In these analyses, PYAR for cases ended on the date of first diagnosis. In both approaches, the standardised incidence ratio (SIR) was calculated as the ratio of observed malignancies to the expected number of cases estimated using US incidence rates (1985–2009) calculated from SEER data.[18] Additional steps required for first-cancer analyses were: selecting the most common cancer when diagnoses included multiple primary tumours on the same day (n=21), excluding firefighters known to have a cancer diagnosis prior to the start of the risk date (n=55), and adjusting US rates for cancer prevalence using methods described by Merrill *et al*.[19]

Heterogeneity in fire department-specific SMRs and SIRs was examined using Poisson regression modelling. To control for gender, age, calendar year and race, an offset term was set to the expected number of deaths or cases in each stratum of the classification table. To address differences between fire departments, a mixed model was used that specified a random intercept term. Thus, the model intercept is the log of the pooled SMR, adjusted for heterogeneity among the fire departments. The significance of heterogeneity was assessed by likelihood ratio test (significance level of 0.05).

Several sensitivity analyses were conducted. First, we examined the effects of including prevalent hires (workers employed before 1950) and short–term workers (those employed <1 year) in mortality analyses. Prevalent hires must be employed long enough to be recruited into the study; thus, these workers may have a survival advantage compared with persons hired during the follow-up period (ie, incident hires).[20] Short-term workers include temporary hires and probationary firefighters whose health and lifestyle patterns may differ from those employed one or more years. Short-term workers may also have had substantial occupational histories other than as firefighters, possibly in jobs with hazardous exposures. Second, we examined age effects on risk estimates in two age-at-risk categories (17–64, 65+ years). Testing of an effect across all 5-year age groups was accomplished using mixed models adjusted for age-at-risk groups. Third, we conducted SMR analyses restricting observation to age 84 years or less. Including PYAR for ages 85+ years could bias results from: rates used in analyses that are open-ended, more uncertainty in underlying cause of death at later ages, and subjects who are incorrectly traced as alive having a disproportionate effect in the open-ended age group.[21] Fourth, we calculated SMRs using California, Illinois and Pennsylvania State populations as referent for firefighters from San Francisco, Chicago and Philadelphia, respectively. Last, SMRs and standardised rate ratios (SRRs) were calculated for categories of employment duration (<10, 10–<20, 20–<30, 30+ years). Trend slopes with Wald-based two-sided p values (significance level of 0.05) were calculated for the change in SRRs with increasing duration.

RESULTS

There were 29 993 firefighters available for study, contributing 858 938 PYAR (table 1). The cohort was largely male (97%), with mean age at first employment and total years employed of 29 and 21 years, respectively. Fewer than 5% of firefighters were short-term workers and approximately 30% were first employed prior to 1950. A higher percentage of women (9.4%) were short-term workers compared with men (4.3%) (see online supplementary table S2). Prevalent hires, on average, tended to be employed longer (+7.9 years, t test p<0.001) and had a greater attained age (+17.0 years, t test p<0.001) than incident hires. Persons eligible for incidence analyses using the multiple-cancer approach (n=24 453) contributed 403 152 PYAR. The first-cancer approach included 24 398 persons contributing 383 577 PYAR. There were 4461 malignant tumours distributed among 3903 firefighters with cancer. Among these, 488 reported cancers at multiple primary sites. Mortality and cancer incidence results are summarised in table 2 and in online supplementary tables S3–S5. To aid in comparisons with previous studies, table 2 also shows summary risk estimates (SREs) reported by LeMasters *et al*[14], whose meta-analysis included studies published through 2003.

Mortality

With the US population referent, all-cause mortality was at expectation (SMR=0.99, 95% CI 0.97 to 1.01, n=12 028). Ischaemic heart disease was the leading cause of death (SMR=1.01, 95% CI 0.98 to 1.04, n=3619). There was significantly decreased mortality in other outcomes that may be related to healthy worker selection and survivor effects (HWE), such as non-malignant respiratory diseases (SMR=0.80, 95% CI 0.74 to 0.86, n=796), cerebrovascular disease (SMR=0.91, 95% CI 0.84 to 0.98, n=636), diabetes mellitus (SMR=0.72, 95% CI 0.62 to 0.83, n=175), nervous system disorders (SMR=0.80, 95% CI 0.69 to 0.93, n=187), and alcoholism (SMR=0.61, 95% CI, 0.41 to 0.86, n=31). In particular, there was a strong decrease in COPD mortality (SMR=0.72, 95% CI

Table 1 Demographic characteristics of the cohort by fire department and combined (1950–2009)

Description	All fire departments	San Francisco	Chicago	Philadelphia
Study cohort:				
Eligible for mortality analysis	29 993	5313	15 185	9495
PYAR	858 938	154 317	419 414	285 207
Years of follow-up; avg. (SD)	29 (16)	29 (16)	28 (16)	30 (16)
Race (%):				
White	24 244 (80.8)	4254 (80.1)	11 736 (77.3)	8254 (86.9)
Other	5008 (16.7)	986 (18.6)	2808 (18.5)	1214 (12.8)
Unknown	741 (2.5)	73 (1.4)	641 (4.2)	27 (<1.0)
Gender (%):				
Male	29 002 (96.7)	5009 (94.3)	14 694 (96.8)	9299 (97.9)
Female	991 (3.3)	304 (5.7)	491 (3.2)	196 (2.1)
Vital status:				
Alive (%)	17 965 (59.9)	3239 (61.0)	9241 (60.9)	5485 (57.8)
Deceased (%)	12 028 (40.1)	2074 (39.0)	5944 (39.1)	4010 (42.2)
Unknown cause of death	144	9	91	44
Attained age*; avg. (SD)	60 (16)	62 (16)	59 (16)	61 (16)
LTFU	175	1	32	142
PYAR potentially LTFU (%)	8809 (1.0)	59 (<1.0)	1483 (<1.0)	7267 (2.5)
Employment:				
Avg. hire year	1968	1967	1970	1965
Age at hire; avg. (SD)	29 (5)	29 (5)	29 (5)	27 (5)
Employment years; avg. (SD)	21 (11)	22 (11)	21 (11)	21 (11)
Hired before 1950 (%)	8085 (27)	1682 (32)	3294 (22)	3109 (33)
Employed <1 year (%)	1328 (4.4)	194 (3.7)	891 (5.9)	243 (2.6)

*Age attained at earliest of the date of death, date LTFU or 31 December 2009.
Avg., average; LTFU, lost to follow-up; PYAR, person-years at risk.

Table 2 Standardised mortality and incidence ratios in firefighters for select outcomes compared to results from a recent meta-analysis

	Current study results (US population referent)						Meta-analysis of LeMasters *et al*[14]*	
	Mortality (1950–2009)†		Cancer incidence (1985–2009)					
			All cancers		First cancer			
Underlying cause (ICD-10 codes)	Obs	SMR (95% CI)	Obs	SIR (95% CI)	Obs	SIR (95% CI)	Studies	SRE (95% CI), Likelihood rating
All cancers (C00-C97)	3285	1.14 (1.10 to 1.18)	4461	1.09 (1.06 to 1.12)	3890	1.09 (1.06 to 1.12)	25	1.05 (1.00 to 1.09), 3
MN oesophagus (C15)	113	1.39 (1.14 to 1.67)	90	1.62 (1.31 to 2.00)	80	1.71 (1.36 to 2.13)	8	1.16 (0.86 to 1.57), 3
MN stomach (C16)	110	1.10 (0.91 to 1.33)	93	1.15 (0.93 to 1.40)	72	1.02 (0.80 to 1.28)	13	1.22 (1.04 to 1.44), 2
MN intestine (C17-C18)	326	1.30 (1.16 to 1.44)	398	1.21 (1.09 to 1.33)	351	1.29 (1.16 to 1.43)	NA	NA
MN large intestine (C18)	264	1.31 (1.16 to 1.48)	381	1.21 (1.09 to 1.34)	335	1.28 (1.15 to 1.43)	25	1.21 (1.03 to 1.54), 2
MN small intestine (C17)	8	1.66 (0.72 to 3.27)	17	1.15 (0.67 to 1.85)	16	1.43 (0.82 to 2.33)	NA	NA
MN rectum (C19-C21)	89	1.45 (1.16 to 1.78)	166	1.11 (0.95 to 1.30)	140	1.09 (0.91 to 1.28)	13	1.29 (1.10 to 1.51), 2
MN lung (C33-C34)	1046	1.10 (1.04 to 1.17)	716	1.12 (1.04 to 1.21)	602	1.13 (1.04 to 1.22)	19	1.03 (0.97 to 1.08), 3
MN breast (C50)	8	1.39 (0.60 to 2.73)	26	1.26 (0.82 to 1.85)	24	1.32 (0.84 to 1.96)	NA	NA
MN prostate (C61)	282	1.09 (0.96 to 1.22)	1261	1.03 (0.98 to 1.09)	1176	1.03 (0.97 to 1.09)	13	1.28 (1.15 to 1.43), 1
MN other male genital (C60, C62-C63)	<5	0.47 (0.13 to 1.20)	17	0.62 (0.36 to 0.99)	17	0.67 (0.39 to 1.07)	NA	NA
MN testes (C62)	<5	0.73 (0.15 to 2.14)	15	0.75 (0.42 to 1.24)	15	0.79 (0.44 to 1.30)	4	2.02 (1.30 to 3.13), 2
MN kidney (C64-C66)	94	1.29 (1.05 to 1.58)	166	1.27 (1.09 to 1.48)	129	1.24 (1.04 to 1.48)	12	1.07 (0.78 to 1.46), 3
MN bladder (C67-C68)‡	84	0.99 (0.79 to 1.22)	316	1.12 (1.00 to 1.25)	272	1.18 (1.05 to 1.33)	11	1.20 (0.97 to 1.48), 3
MN brain (C47, C70-C72)	73	1.01 (0.79 to 1.27)	51	1.02 (0.76 to 1.34)	48	1.06 (0.78 to 1.41)	19	1.32 (1.12 to 1.54), 2
NHL (C46.3, C82-C85, C88.0, C88.3, C91.4, C96)§	123	1.17 (0.97 to 1.40)	170	0.99 (0.85 to 1.15)	145	0.99 (0.83 to 1.16)	8	1.51 (1.31 to 1.73), 1
Leukaemia (C91.0-C91.3, C91.5-C91.9, C92-C95)	122	1.10 (0.91 to 1.31)	100	0.94 (0.77 to 1.15)	85	0.93 (0.74 to 1.15)	8	1.14 (0.98 to 1.31), 2
Multiple myeloma (C88.7, C88.9, C90)	42	0.89 (0.64 to 1.20)	36	0.72 (0.50 to 0.99)	33	0.75 (0.52 to 1.06)	10	1.53 (1.21 to 1.94), 1
Other cancers:¶								
Mesothelioma (C45)	12	2.00 (1.03 to 3.49)	35	2.29 (1.60 to 3.19)	26	2.00 (1.31 to 2.93)	NA	NA
MN buccal and pharynx (C00-C14)	94	1.40 (1.13 to 1.72)	174	1.39 (1.19 to 1.62)	148	1.41 (1.20 to 1.66)	9	1.23 (0.96 to 1.55), 2

*Results from Table 5 of LeMasters *et al*[14]; likelihood of cancer risk by meta-analysis criteria: 1=probable, 2=possible, 3=unlikely.
†SMRs restricted to 1960–2009 for MN large intestine, MN small intestine, and MN testes and 2000–2009 for mesothelioma.
‡Urinary bladder incidence included in situ (D09.0) and invasive cases as per SEER protocol.
§NHL incidence data exclude Kaposi sarcoma (C46.3).
¶Sites not listed among cancers of a priori interest but reporting statistically significant excess mortality and cancer incidence.
ICD-10, International Classification of Diseases, 10th Revision; MN, malignancy; NA, not applicable; NHL, non-Hodgkin lymphoma; Obs, observed; SEER, Surveillance, Epidemiology and End Results; SIR, standardised incidence ratio; SMR, standardised mortality ratio; SRE, summary risk estimate.

0.65 to 0.80, n=367). Few non-malignant outcomes were elevated, although statistically significant excess mortality was observed for cirrhosis and other chronic liver disease (SMR=1.26, 95% CI 1.12 to 1.41, n=299) and acute glomerulonephritis with renal failure (SMR=1.56, 95% CI 1.07 to 2.20, n=32). Deaths from falls (SMR=1.31, 95% CI 1.08 to 1.58, n=113) and other accidents (SMR=1.17, 95% CI 1.01 to 1.34, n=197) were also elevated.

By contrast with non-malignant outcomes, we observed excess overall cancer mortality (SMR=1.14, 95% CI 1.10 to 1.18, n=3285) table 2). The elevation was largely attributable to excess cancers of the lung (SMR=1.10, 95% CI 1.04 to 1.17, n=1046), oesophagus (SMR=1.39, 95% CI 1.14 to 1.67, n=113), intestine (SMR=1.30, 95% CI 1.16 to 1.44, n=326) rectum (SMR=1.45, 95% CI 1.16 to 1.78, n=89) and kidney (SMR=1.29, 95% CI 1.05 to 1.58, n=94). There was little evidence of excess mortality from the remaining cancers of a priori interest; however, statistically significant SMRs were apparent for buccal and pharynx cancers (SMR=1.40, 95% CI 1.13 to 1.72, n=94), malignancies of the liver, gall bladder and biliary tract (SMR=1.30, 95% CI 1.06 to 1.57, n=107), and malignant mesothelioma (SMR=2.00, 95% CI 1.03 to 3.49, n=12).

Women and non-Caucasians

All-cause mortality among women was near expectation (SMR=0.91, 95% CI 0.59 to 1.33, n=26). Accidental death was the leading cause (SMR=2.79, 95% CI 1.21 to 5.50, n=8) resulting in 31% of the total deaths among women. While there was little evidence of excess overall cancer mortality among women (SMR=0.74, 95% CI 0.27 to 1.61, n=6), most cancer deaths were from breast cancer (SMR=1.46, 95% CI 0.30 to 4.26, n<5). Bladder cancer mortality was statistically significant (SMR=33.51, 95% CI 4.06 to 121.05, n<5) based on few cases. Non-Caucasian males were characterised by decreased all-cause mortality (SMR=0.68, 95% CI 0.62 to 0.74, n=453) and all-cancers (SMR=0.80, 95% CI 0.65 to 0.97, n=104). They had few observed deaths in any a priori outcome, and lung cancer mortality was below expectation (SMR=0.67, 95% CI 0.44 to 0.97, n=27). Only prostate cancer mortality showed an excess approaching statistical significance (SMR=1.64, 95% CI 0.95 to 2.63, n=17) among non-Caucasian males (table 3).

Cancer incidence

There was little difference in SIRs when comparing analysis approaches; therefore, reporting focused on results from the multiple-cancer approach (table 2). All-cancer incidence was slightly above expectation (SIR=1.09, 95% CI 1.06 to 1.12, n=4461). Observed elevations in cancers of a priori interest were generally consistent with mortality data as evidenced by significant excess cancers of the oesophagus (SIR=1.62, 95% CI 1.31 to 2.00, n=90); large intestine (SIR=1.21, 95% CI 1.09 to 1.34, n=381); kidney (SIR=1.27, 95% CI 1.09 to 1.48, n=166) and lung (SIR=1.12, 95% CI 1.04 to 1.21, n=716). As in mortality analyses, there were excess buccal and pharynx cancers (SIR=1.39, 95% CI 1.19 to 1.62, n=174) and malignant mesothelioma (SIR=2.29, 95% CI 1.60 to 3.19, n=35). Of those diagnosed with mesothelioma, 31 (88.6%) were pleural. Excess laryngeal cancer incidence was also observed (SIR=1.50, 95% CI 1.19 to 1.85, n=84). The incidence of most remaining cancer sites was near expectation; however, multiple myeloma was significantly decreased (SIR=0.72, 95% CI 0.50 to 0.99, n=36).

Women and non-Caucasians

Overall cancer incidence among women was elevated, but not significantly (SIR=1.24, 95% CI 0.89 to 1.69, n=40). Consistent with mortality, female bladder cancer incidence was statistically significant but based on few cases (SIR=12.53, 95% CI 3.41 to 32.08, n<5). Nearly half of all cases were breast cancer (SIR=1.45, 95% CI 0.86 to 2.29, n=18). Nearly all breast cancers were diagnosed prior to the attained age of 55 years, with the highest SIR between the ages of 50 and 54 years (SIR=2.66, 95% CI 0.86 to 6.21, n=5). Left-sided disease appeared more frequent (61%, n=11). Overall cancer incidence among non-Caucasian male firefighters was near expectation (SIR=0.92, 95% CI 0.81 to 1.05, n=240). There was excess prostate cancer (SIR=1.26, 95% CI 1.02 to 1.54, n=94) but decreased lung cancer (SIR=0.67, 95% CI 0.43 to 1.00, n=24) (tables 3 and 4).

Sensitivity analyses

Except for COPD and cancers of the lung, prostate and brain, there was little evidence of heterogeneity in SMRs (see online supplementary table S6) or SIRs (see online supplementary table S7) across fire departments for outcomes of a priori interest. For mortality, the between-department variance was largely attributable to outlying decreased lung cancer (SMR=0.76, 95% CI 0.64 to 0.89, n=142) and COPD (SMR=0.53, 95% CI 0.40 to 0.69, n=57) in San Francisco firefighters, and excess cancers of the prostate (SMR=1.28, 95% CI 1.08 to 1.50, n=152) and lung (SMR=1.23, 95% CI 1.13 to 1.34, n=566) in Chicago firefighters. The between-department variance in mortality persisted when using state populations as referent (see online supplementary table S8). Similarly, heterogeneous lung cancer incidence stemmed from decreased cases among San Francisco firefighters (SIR=0.70, 95% CI 0.56 to 0.87, n=81); however, there was outlying excess prostate cancer incidence among San Francisco firefighters (SIR=1.22, 95% CI 1.08 to 1.37, n=276). Brain cancer SIRs varied widely across fire departments; excess cancer was observed in San Francisco firefighters (SIR=1.95, 95% CI 1.14 to 3.12, n=17), while decreased cancer was reported for Chicago (SIR=0.53, 95% CI 0.28 to 0.91, n=13).

Restricting analyses to firefighters with one or more years of employment had negligible effects (see online supplementary table S9). Slight increases in SMRs were observed for most a priori outcomes when restricting the cohort to incident hires, although these differences were not statistically significant. Age-at-risk differences in mortality also lacked statistical significance, but SMRs generally appeared greater at older ages. SMRs for cancers of the breast (SMR=1.42, 95% CI 0.46 to 3.32, n=5), oesophagus (SMR=1.41, 95% CI 1.05 to 1.86, n=51), and kidney (SMR=1.47, 95% CI 1.09 to 1.95, n=48) were highest among workers less than 65 years of age (see online supplementary table S10). Significant age-at-risk differences in SIRs were evident for prostate ($p<0.001$) and bladder ($p=0.002$) cancers (see online supplementary table S11). The heterogeneity was largely attributable to significant increases in prostate (SIR=1.21, 95% CI 1.10 to 1.33, n=426) and bladder (SIR=1.33, 95% CI 1.08 to 1.62, n=97) cancer risks among firefighter aged 64 years or less. Excess prostate cancer was limited to ages 45–59 years (SIR=1.45, 95% CI 1.28 to 1.64, n=249), while the age pattern of excess bladder cancer incidence was unclear. The effects of restricting PYAR to age-at-risk <85 were inconsequential (see online supplementary table S12). Excluding firefighters without race information also had little

Table 3 Standardised mortality and incidence ratios among men compared with the US population for causes of a priori interest

	Mortality (1950–2009)				Cancer incidence (1985–2009)*			
	Caucasian		Other		Caucasian		Other	
Underlying cause (ICD-10 codes)	Obs	SMR (95% CI)	Obs	SMR (95% CI)	Obs	SIR (95% CI)	Obs	SIR (95% CI)
All causes	11 549	1.01 (0.99 to 1.03)	453	0.68 (0.62 to 0.74)	NA	NA	NA	NA
All cancers (C00-C97)	3175	1.16 (1.12 to 1.20)	104	0.80 (0.65 to 0.97)	4181	1.10 (1.07 to 1.13)	240	0.92 (0.81 to 1.05)
MN oesophagus (C15)	110	1.46 (1.20 to 1.75)	<5	0.51 (0.11 to 1.49)	87	1.70 (1.36 to 2.09)	<5	0.73 (0.15 to 2.15)
MN stomach (C16)	105	1.12 (0.92 to 1.36)	5	0.81 (0.26 to 1.89)	87	1.19 (0.96 to 1.47)	6	0.76 (0.28 to 1.66)
MN intestine (C17-C18)	319	1.32 (1.18 to 1.48)	7	0.68 (0.27 to 1.40)	379	1.23 (1.11 to 1.36)	18	0.90 (0.53 to 1.42)
MN rectum (C19-C21)	86	1.46 (1.17 to 1.81)	<5	1.21 (0.25 to 3.53)	159	1.16 (0.99 to 1.36)	7	0.62 (0.25 to 1.28)
MN lung (C33-C34)	1019	1.12 (1.05 to 1.19)	27	0.67 (0.44 to 0.97)	689	1.15 (1.07 to 1.24)	24	0.67 (0.43 to 1.00)
MN breast (C50)	5	1.43 (0.46 to 3.34)	0	NC	6	0.79 (0.29 to 1.72)	<5	3.32 (0.40 to 12.00)
MN prostate (C61)	265	1.06 (0.94 to 1.20)	17	1.64 (0.95 to 2.63)	1167	1.02 (0.96 to 1.08)	94	1.26 (1.02 to 1.54)
MN other male genital (C60, C62-C63)	<5	0.49 (0.13 to 1.26)	0	NC	16	0.64 (0.37 to 1.04)	<5	0.38 (0.01 to 2.13)
MN kidney (C64-C66)	91	1.31 (1.05 to 1.60)	<5	1.05 (0.22 to 3.07)	151	1.26 (1.06 to 1.47)	14	1.46 (0.80 to 2.45)
MN bladder (C67-C68)†	80	0.96 (0.76 to 1.19)	<5	1.19 (0.14 to 4.30)	305	1.11 (0.99 to 1.24)	7	0.92 (0.37 to 1.91)
MN brain (C47, C70-C72)	72	1.03 (0.81 to 1.30)	<5	0.44 (0.01 to 2.47)	49	1.05 (0.78 to 1.39)	<5	0.67 (0.08 to 2.42)
NHL (C46.3, C82-C85, C88.0, C88.3, C91.4, C96)‡	119	1.18 (0.98 to 1.41)	<5	1.01 (0.28 to 2.60)	161	1.02 (0.87 to 1.19)	7	0.56 (0.23 to 1.16)
Leukaemia (C91.0-C91.3, C91.5-C91.9, C92-C95)	117	1.10 (0.91 to 1.32)	5	1.28 (0.41 to 2.98)	88	0.88 (0.71 to 1.09)	11	1.90 (0.95 to 3.40)
Multiple myeloma (C88.7, C88.9, C90)	41	0.92 (0.66 to 1.25)	<5	0.35 (0.01 to 1.97)	35	0.76 (0.53 to 1.06)	<5	0.24 (0.01 to 1.32)
COPD (J40-J44)	362	0.73 (0.65 to 0.81)	5	0.50 (0.16 to 1.16)	NA	NA	NA	NA

*Incidence results based on analysis of all invasive primary cancers (ie, multiple-cancer approach).
†Urinary bladder incidence included in situ (D09.0) and invasive cases as per SEER protocol.
‡NHL incidence data exclude Kaposi sarcoma (C46.3).
COPD, chronic obstructive pulmonary disease; ICD-10, International Classification of Diseases, 10th Revision; MN, malignancy; NA, not applicable; NC, not calculated; NHL, non-Hodgkin lymphoma; Obs, observed; SIR, standardised incidence ratio; SEER, Surveillance, Epidemiology, and End Results; SMR, standardised mortality ratio.

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Table 4 Standardised mortality ratios (US population referent) and rate ratios for select outcomes* by employment duration (lagged 10 years)

	Employment duration (years)								
	0–<10		10–<20		20–<30		30+		
Underlying cause (ICD-10 codes)	Obs	SMR (95% CI) SRR (95% CI)	Obs	SMR (95% CI) SRR (95% CI)	Obs	SMR (95% CI) SRR (95% CI)	Obs	SMR (95% CI) SRR (95% CI)	Trend slope†, p Value
MN oesophagus (C15)	13	1.17 (0.62 to 2.00) (Reference)	28	1.72 (1.14 to 2.48) 2.43 (1.07 to 5.50)	53	1.40 (1.05 to 1.83) 1.17 (0.56 to 2.41)	19	1.18 (0.71 to 1.84) 0.60 (0.27 to 1.35)	-2.14×10^{-6}, 0.141
MN stomach (C16)	12	0.80 (0.41 to 1.40) (Reference)	18	0.92 (0.54 to 1.45) 0.33 (0.08 to 1.43)	47	1.07 (0.79 to 1.43) 0.39 (0.10 to 1.55)	33	1.53 (1.06 to 2.15) 0.40 (0.10 to 1.58)	3.06×10^{-7}, 0.822
MN intestine (C17-C18)	27	0.86 (0.57 to 1.26) (Reference)	52	1.27 (0.95 to 1.67) 1.16 (0.38 to 3.54)	171	1.42 (1.22 to 1.65) 0.62 (0.27 to 1.44)	76	1.28 (1.01 to 1.60) 0.40 (0.17 to 0.94)	-7.54×10^{-6}, <0.001
MN rectum (C19-C21)	13	1.48 (0.79 to 2.54) (Reference)	19	1.58 (0.95 to 2.46) 0.99 (0.33 to 2.97)	37	1.35 (0.95 to 1.86) 0.61 (0.24 to 1.52)	20	1.52 (0.93 to 2.34) 0.43 (0.16 to 1.14)	-1.61×10^{-6}, 0.001
MN lung (C33-C34)	123	1.02 (0.85 to 1.22) (Reference)	184	1.03 (0.88 to 1.19) 1.32 (0.97 to 1.80)	523	1.14 (1.05 to 1.24) 1.24 (0.91 to 1.68)	216	1.12 (0.98 to 1.28) 0.80 (0.59 to 1.08)	-8.83×10^{-6}, 0.216
MN prostate (C61)	24	1.39 (0.89 to 2.07) (Reference)	23	1.08 (0.68 to 1.62) 0.66 (0.31 to 1.41)	148	1.10 (0.93 to 1.29) 0.84 (0.47 to 1.50)	87	1.01 (0.81 to 1.25) 0.69 (0.39 to 1.22)	-2.03×10^{-6}, 0.192
MN kidney (C64-C66)	12	1.10 (0.57 to 1.92) (Reference)	18	1.24 (0.73 to 1.95) 0.61 (0.26 to 1.48)	47	1.43 (1.05 to 1.90) 1.25 (0.58 to 2.69)	17	1.19 (0.69 to 1.91) 0.70 (0.29 to 1.67)	-1.05×10^{-7}, 0.924
MN bladder and other urinary (C67-C68)	8	1.05 (0.45 to 2.08) (Reference)	7	0.65 (0.26 to 1.34) 0.25 (0.08 to 0.79)	46	1.08 (0.79 to 1.45) 1.15 (0.49 to 2.70)	23	0.94 (0.60 to 1.41) 1.03 (0.38 to 2.83)	2.58×10^{-6}, 0.258
MN brain and other nervous (C47, C70-C72)	12	0.65 (0.34 to 1.13) (Reference)	15	0.88 (0.49 to 1.46) 0.80 (0.30 to 2.19)	32	1.17 (0.80 to 1.65) 1.48 (0.60 to 3.68)	14	1.47 (0.80 to 2.46) 1.52 (0.53 to 4.34)	1.01×10^{-6}, 0.118
NHL (C46.3, C82-C85, C88.0, C88.3, C91.4, C96)	18	0.98 (0.58 to 1.55) (Reference)	9	0.51 (0.23 to 0.96) 1.18 (0.41 to 3.45)	63	1.35 (1.04 to 1.73) 1.15 (0.60 to 2.22)	33	1.47 (1.01 to 2.06) 1.04 (0.51 to 2.15)	-7.39×10^{-8}, 0.849
Leukaemia (C91.0-C91.3, C91.5-C91.9, C92-C95)	18	0.91 (0.54 to 1.44) (Reference)	23	1.36 (0.86 to 2.05) 2.24 (0.92 to 5.50)	54	1.11 (0.83 to 1.45) 1.36 (0.65 to 2.87)	27	1.06 (0.70 to 1.54) 1.13 (0.48 to 2.67)	-5.10×10^{-9}, 0.997
Multiple myeloma (C88.7, C88.9, C90)	5	0.84 (0.27 to 1.96) (Reference)	<5	0.52 (0.14 to 1.34) 0.56 (0.11 to 2.82)	22	0.97 (0.61 to 1.47) 1.59 (0.47 to 5.41)	11	0.99 (0.49 to 1.77) 1.25 (0.33 to 4.75)	5.27×10^{-7}, 0.407
COPD (J40-J44)	33	0.78 (0.54 to 1.10) (Reference)	38	0.69 (0.49 to 0.94) 1.07 (0.60 to 1.91)	185	0.70 (0.60 to 0.81) 1.03 (0.67 to 1.60)	111	0.75 (0.62 to 0.91) 0.83 (0.53 to 1.31)	-2.80×10^{-6}, 0.005

*Excluding a priori causes with total observations <20.
†Cause-specific deaths per year of employment-person-year.
COPD, chronic obstructive pulmonary disease; ICD-10, International Classification of Diseases, 10th Revision; MN, malignancy; NHL, non-Hodgkin lymphoma; Obs, observed; SMR, standardised mortality ratio; SRR, standardised rate ratio.

effect on a priori outcomes (results not shown). Finally, there was no apparent trend in increasing risk with employment duration; however, negative trends in COPD and colorectal cancer SRRs were evident (table 4). Subsequent sensitivity analyses revealed that SRRs were largely dependent on selection of cut-points and lag periods (results not shown).

DISCUSSION

This study is among the largest examining cancer risk in career firefighters. The pooled approach and long follow-up period improved risk estimates relative to previous studies. With few exceptions, there was little evidence of significant cancer risk heterogeneity across fire departments or age groups. Furthermore, sensitivity analyses did not suggest the potential for significant bias from including short-term workers, prevalent hires, or person-time in the open-ended age-group (85+ years). Despite notable differences in the analytical approaches, we observed remarkable similarities between mortality and incidence analyses. Additionally, the results of incidence analyses were not significantly affected by the choice of including multiple primaries or only the first cancer diagnosis. The lack of significant differences in results between fire departments, end-points, and analytic techniques suggest that the pooled study findings are robust and generalisable to similar firefighter populations.

We observed decreases in many non-malignant diseases that suggest improved health in these firefighters compared with the general population. This finding is not surprising given health requirements for entering and remaining in the fire service. Nevertheless, there was a modest excess in overall cancer mortality and incidence brought about by excess solid cancers at several sites of a priori interest. With few exceptions, our results are consistent with those previously reported and similar to SREs presented in the meta-analysis by LeMasters *et al*.[14] Nevertheless, we found little evidence of excess cancers of the testes, brain and lymphohematopoietic systems, which is contrary to the synthesis by LeMasters *et al*[14] and subsequently published studies.[8 11]

We observed about a twofold increase in malignant mesothelioma mortality and incidence compared with the US population. Malignant mesothelioma is largely attributable to asbestos exposure, with sparse evidence of other causes.[22] Excess malignant mesothelioma in US firefighters was not previously described; however, excess incidence was recently observed in Nordic firefighters aged 70+ years,[23] and increased risk of asbestos-induced pulmonary and pleural fibrosis was reported in a study of New York City firefighters.[24] Although firefighter exposures to asbestos are known, the absence of previous reports of malignant mesothelioma is not surprising given the rarity and extremely long latency (20–40 years) of the disease. The average time between the date first employed and the date of diagnosis in the current study was 45 years; therefore, firefighting exposure-induced disease may be discernible only after lengthy follow-up. Also, previous studies have been hindered by the lack of specific codes for mesothelioma deaths before ICD-10.

We observed excess digestive cancers, mainly of oesophageal and colorectal sites. Information on occupational causes is sparse, although there is limited evidence suggesting asbestos and diesel exhaust exposures may be weakly associated with gastrointestinal cancers.[25 26] Still, the relation between these hazardous exposures and digestive cancers appears small compared to the effects of other factors such as diet, obesity, physical activity, tobacco use and alcohol consumption.[22 27] We also found increased risk of oral, pharyngeal and laryngeal cancers, compared with the US population. Similar to digestive cancers, important risk factors for these sites are tobacco and alcohol consumption, with lesser evidence that exposures to wood dusts, smoke, asbestos, PAHs and acid mists may also increase risk.[22 28 29]

Some insight into the degree of a potential bias from the lack of controlling for lifestyle factors can be gained from previous surveillance of firefighter behaviours. For example, the prevalence of smoking among current firefighters appears less than the general population, and is decreasing, [30–33] a trend that is consistent with observed decreases in non-malignant smoking–related diseases (eg, COPD, stroke) but contradictory to excess digestive, oral and respiratory cancers. As another example, previous studies suggest there is increased obesity among firefighters compared with the general population. [34–36] Obesity, or a dietary intake that is high in meat, fat, or overall caloric intake could contribute increased gastric or colorectal cancer risk, although concomitant elevations in health outcomes that are more strongly related to these factors (eg, ischaemic heart disease, diabetes mellitus, hypertension and stroke) were not found. Last, information on alcohol consumption within the fire service is sparse and inconsistent.[37–40] Some studies suggest that firefighter behaviours may differ from the general population, although it is not clear that any perceived behavioural difference is sufficient to explain disparities in alcohol-related health outcomes. In the current study, the information on non-malignant and potentially alcohol-related mortality was at conflict; there was excess mortality from cirrhosis and other chronic liver disease, but fewer than expected alcoholism deaths. Alternate explanations for increased cirrhosis mortality may be exposures to chemical toxins or infectious disease, [41–43] which may also account for excess acute renal dysfunction, a disease that is more common among those with chronic liver disease.

Fewer than 4% of firefighters in our study were women. There was evidence of excess female bladder and breast cancers; however, only bladder cancer mortality and incidence reached statistical significance. Modest excess bladder cancer has been observed in some occupations involving known or suspected bladder carcinogens (eg, PAHs, and diesel exhaust), yet contrary to our findings, risk patterns by occupation tend not to differ by gender.[22] There is little evidence linking female breast cancer to workplace exposures; however, prolonged shift work may be a risk factor (and to a lesser extent a risk factor for prostate, colon and endometrial cancers).[2] Moreover, similar findings had not been reported previously, although increased risk of Hodgkin lymphoma and cancers of the cervix and thyroid among women firefighters (n=2017) was recently described.[11] Given the small sample and the lack of confirmatory results, our findings on female outcomes merit cautious interpretation.

Excess bladder and prostate cancer incidence was found among firefighters less than 65 years of age. Interestingly, the prostate cancer excess was limited to ages between 45years and 59 years, which was consistent with recent observations in Nordic firefighters.[23] Similar mortality patterns were not observed. These cancers have relatively high survival; therefore, the underlying cause of death may be an inferior risk measure compared to cancer diagnoses. The early onset of these cancers suggests an association with firefighting. Prostate and bladder cancer diagnoses can occur following routine screening.[44 45] As an alternative explanation, differences in medical screening (eg, prostate-specific antigen tests) among firefighters compared to the general population could have contributed to the observed excess. Data on cancer screening practices are lacking; however, it is plausible that screening may be more frequent among firefighters with improved healthcare availability and heightened cancer awareness.

There was little evidence of increasing cancer risk with increasing employment; however, there were notable analytical shortcomings that merit discussion. First, rather than specifying cut-points and an exposure lag period specific to each outcome, we applied cut-points (10, 20 and 30 years) used in earlier studies[5 9 46] and a common exposure lag period (10 years) to all outcomes; these choices were found to be influential in subsequent sensitivity analyses. Second, our methods have limited capability to account for HWE or other sources of bias that may have masked a dose response. Last, employment duration may poorly represent exposure potential given that some jobs are prone to lower exposures compared with others. For these reasons, a detailed exposure assessment is underway to support multivariable regression modelling for improved dose-response analyses.

Death certificates and registry data used in the current study are imperfect measures of cancer risk. In the absence of a national cancer registry, coverage is limited geographically; therefore, cases occurring outside catchment areas would be missed. Cases occurring before the registries attained comprehensive coverage have also been missed. Mortality analyses have the advantage of broader temporal and spatial coverage, but may poorly characterise cancers with relatively high survival (eg, cancers of the breast, bladder, testes and larynx). Finally, there may have been errors in tracing which can also bias study results. Although errors in ascertainment cannot be ruled out, our use of multiple information sources and end points, and the low numbers of participants lost to follow-up or moving out of catchment areas, act to minimise these errors.

CONCLUSION

In this first phase of examining health effects in career firefighters, we report on mortality and cancer incidence among nearly 30 000 career firefighters followed from 1950 through 2009. Compared with the US population, we found small to moderate increases in risk for several cancer sites and for all cancers combined, stemming mostly from excess malignancies of the respiratory, digestive and urinary systems in otherwise healthy individuals. Our findings are consistent with previous studies and strengthen evidence of a relation between firefighters' occupational exposure and cancer. We found a previously unreported twofold excess of malignant mesothelioma among firefighters. Given that asbestos is the only known causal agent for malignant mesothelioma, and firefighter exposures are probable, the excess is likely to be a causal association.

This report provides the foundation for subsequent analyses of firefighter risks, some of which are ongoing. In upcoming research, detailed employment histories (eg, number and types of fire runs) and institutional knowledge (eg, use of respiratory protection and source capture ventilation of diesel exhaust) will be used to derive exposure metrics to more accurately examine dose response. Future regression modelling will also enable examination of temporal effects that are poorly suited to life-table analyses, such as time since first exposure. Expansion and continued follow-up of this cohort would enhance future analyses, particularly among women and non-Caucasian firefighters.

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Contributors RDD participated in design, data collection, analysis and manuscript development. TLK conceived the study and participated in design and data collection. JHY participated in design, data collection and analysis. MMD, TRH, DB, SHZ, JJB and KMW participated in design and data collection. LEP participated in design and critical appraisal. All authors participated in the interpretation and presentation of results and have read and approved the final manuscript.

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Competing interests None.

Ethics approval This research was approved by the Institutional Review Boards of the National Institute for Occupational Safety and Health (NIOSH) and the National Cancer Institute (NCI). Approvals for cancer registry access were granted by 11 states (ie, Arizona, California, Florida, Illinois, Indiana, Michigan, Nevada, New Jersey, Oregon, Pennsylvania and Washington). Approvals were also granted by vital records centres for death certificates maintained in 25 states (Alaska, Arizona, Arkansas, California, Florida, Georgia, Hawaii, Idaho, Illinois, Indiana, Iowa, Massachusetts, Michigan, Minnesota, Mississippi, New Jersey, New York, Ohio, Oklahoma, Oregon, Pennsylvania, Texas, Virginia, Washington and Wisconsin). The state public health entities provided vital status information in accordance with state policies, and disclaim responsibility for any analyses, interpretations, or conclusions herein.

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Data sharing statement Data were supplied by the Illinois Department of Public Health and the Bureau of Health Statistics and Research, Pennsylvania Department of Health. These public health entities specifically disclaim responsibility for any analyses, interpretations, or conclusions. The Florida cancer incidence data used in this report were collected by the Florida Cancer Data System (FCDS) under contract with the Florida Department of Health (FDOH). The views expressed herein are solely those of the authors and do not necessarily reflect those of the FCDS or FDOH. The collection of cancer incidence data used in this study was also supported by the California Department of Public Health as part of the statewide cancer reporting programme mandated by California Health and Safety Code Section 103885; the National Cancer Institute's Surveillance, Epidemiology and End Results Program under contract N01-PC-35136 awarded to the Northern California Cancer Center, contract N01-PC-35139 awarded to the University of Southern California, and contract N02-PC-15105 awarded to the Public Health Institute; and the Centres for Disease Control and Prevention's National Program of Cancer Registries, under agreement #U55/CCR921930-02 awarded to the Public Health Institute. The ideas and opinions expressed herein are those of the authors, and endorsement by the State of California, Department of Public Health, the National Cancer Institute, and the Centres for Disease Control and Prevention or their contractors and subcontractors is neither intended nor to be inferred.

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2017

Law Enforcement Fitness Policies in Relation to Job Injuries and Absenteeism

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This is to certify that the doctoral dissertation by

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has been found to be complete and satisfactory in all respects,
and that any and all revisions required by
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2017

Abstract

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by

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MA, Sam Houston State University, 1997

BA, University of Northern Iowa, 1994

Dissertation Submitted in Partial Fulfillment

of the Requirements for the Degree of

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August 2017

Abstract

After employment, job-related fitness requirements vary for law enforcement agencies within North Carolina. Police academies mandate specific job-related fitness requirements for recruits as a condition of graduation. Once employed, little is known about why some law enforcement agencies in North Carolina have physical fitness policies and others do not, particularly when injury rates and healthcare costs continue to rise. To better understand this inconsistency, the current study used a mixed methods approach to examine 6 midsized law enforcement agencies in North Carolina with varying fitness policies. The policy of each agency, along with OSHA work-related injuries and absenteeism reports, were examined quantitatively to determine if a relationship existed between policy and injuries and absenteeism. Analysis of variance (ANOVA) and post-hoc tests found a greater statistical significance between policy levels and injury rates than between policy level and absenteeism rates. An interview with agency personnel qualitatively identified common themed responses to determine whether the utility function of rational choice theory explained fitness policy implementation. It was difficult to determine whether the utilitarian component was the reason behind policy decisions, but data-driven results seemed to serve as an agent of fitness policy decision making. The results contributed to the limited academic literature on this topic although further research recommendations were made. The findings advocate for better officer health and fitness standards to reduce the risk of on-the-job injuries and absenteeism, and reduce health care costs to all involved.

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Dedication

This study is dedicated to the men and women in blue who put their lives on the line every time they put on the uniform. My prayer is that you stay healthy and steadfast to serve your community with integrity and honor. And to my beloved Ken, I will love you always…

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Trust in the Lord with all thine heart; and lean not unto thine own understanding. In all thy ways acknowledge him, and he shall direct thy paths (Prov. 3: 5-6, KJV). Much has been done, but there is also much to do. A sincere thank you is not enough for those who have encouraged and helped me along this path, my mom and my dad, sisters Cindy, Debbie, Pam, and Mandy. Manders, you are my inspiration. Dr. Nancy McCurry, you gave me the courage to continue my education and in your retirement, you will be deeply missed. My co-worker and boss, Neil Weatherly, thank you for your understanding and flexibility in allowing me to occasionally use work time for school obligations. And Pastor Shook, thank you for being a blessing in my life.

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Last, but certainly not least, thank you so much to the law enforcement agencies who agreed to participate in my study. The time and resources that were asked of you will be remembered and is much appreciated. I hope your worthy contributions have been demonstrated in this research.

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Chapter 1: Introduction to the Study

A police officer is faced with daily unknowns on the job, which can be both physically and psychologically demanding (Guffey, Larson, & Lasley, 2014). It seems fitting that a law enforcement agency would require officers to maintain a certain standard of fitness or wellness to secure their safety and well-being as well as to benefit the agency, as a healthier lifestyle encourages fewer missed days of work and lower health care costs. However, this does not seem to be common practice among law enforcement agencies in North Carolina. Though fitness requirements for police academy cadets are mandated by state training and standard boards, not all agencies mandate fitness as a condition of continued employment. This creates a misunderstanding as to why consistency does not exist beyond academy training and what factors contribute to specific fitness policy decision-making at the agency level. This research examines (a) why state-mandated physical fitness standards for police academy cadets are used at some law enforcement agencies but not others as a condition of employment and (b) whether more stringent fitness policies contribute to reduced job-related injuries and absenteeism rates. If there is a significant relationship between certain fitness policies and work-related injury rates and absenteeism, then future research might address this issue and support efforts to improve officer health and lower agency costs due to officer injuries and absenteeism.

Background of the Study

There is little debate that the job demands of first responders (including law enforcement) place stress on and affect a body's efficiency. Physical and psychological stress go hand in hand and the effects can include lower back pain and heart disease

(Armstrong, Clare, & Plecas, 2014; Heneweer, Picavet, Staes, Kiers, & Vanhees, 2012). These job demands stress the importance of officers maintaining optimal cardiovascular endurance in order to reduce the risk of injury on the job. Given that officers must physically deal with individuals and equipment while on the job, it is not shocking that they maintain a higher heart rate compared to the general public (Armstrong et al., 2014). Over a career, exposure to these demands along with shiftwork can affect an officer's fitness for duty, especially for officers who have 20 or more years of experience (Wirtz & Nachreiner, 2012). Thus, although physical activity is known to benefit general health and promote prevention of injuries, many law enforcement agencies do not require certain fitness standards as a condition of employment. This is the case even though the North Carolina training and standards board continues to research and update task analysis standards for its police academies.

In 2015, the North Carolina Department of Justice concluded a study to update its Police Officer Physical Abilities Test (POPAT) from years past. The completion of the POPAT within a certain time limit is required of all North Carolina police academy cadets. The test is made up of various physical tasks that are designed to mirror real situations that patrol officers might encounter on the job. Its purpose is to differentiate between those who can and cannot perform the physical functions of a police officer's job at an adequate level of proficiency (North Carolina Justice Academy [NCJA], n.d.). Ensuring that people are physically fit for work by matching capabilities with physical job requirements is an important step toward reducing injury and absence rates (Rayson, 2000). A cadet's successful completion of POPAT means passing the basic law enforcement training academy. Unsuccessful completion means failing the entire academy. Nevertheless, the question is this: If the state deems certain physical tasks necessary to perform the job in the police academy setting, why are many law enforcement agencies not requiring similar standards for officers working in the field?

Plat, Frings-Dresen, and Sluiter (2011) recommended using early intervention to promote a healthy lifestyle, which can reduce the risk of future injuries. In their study, emergency medical services (EMS), fire, and military personnel were examined; however, similar effects would be expected among police officers. Even though prevention would seem beneficial no matter the occupation, this needs to be explored further.

Guffey et al. (2014) did not find a direct correlation between officer fitness and injuries specifically but did find a correlation between officer weight and injuries after efforts were made by several departments to improve officer wellness. This cannot be discounted because weight can be a contributing factor to overall wellness and fitness. Perhaps weight needs to be considered in hypothesizing that more stringent fitness policies lower work-related injury and absenteeism rates.

One way to promote work injury prevention is to educate personnel and use resources already in place. For example, North Carolina legislation provides for a full public health mandate, which includes injury prevention. This responsibility lies within the North Carolina Health and Human Services Department. To promote health and fitness, funding could be available for injury prevention programs (Stier, Thombley, Kohn, & Jesada, 2012) within a number of occupations. This is an important issue that should be addressed within law enforcement management to determine, first, if agencies are aware of these resources, and second, if there is interest in using these state resources to assist with fitness policy implementation. If supported by decision makers, available funding might justify routine health screening as a prevention tool. Making agencies aware of these available resources could enhance a positive management system that strengthens an agency's commitment (Dick, 2011) to fitness. In this study, management support of fitness policies (or lack thereof) was examined to determine commitment to officer fitness. Theoretical application determined whether agency incentives for fitness improvement came from leadership, and if so, whether this influence was present in policy. Leadership management is an important component to consider when examining the policies of an agency (Schulhofer, Tyler, & Huq, 2011).

Problem Statement

Law enforcement personnel have an increased risk for cardiovascular disease and other health issues due to the common shiftwork involved and the unknown demands of the job (Armstrong et al., 2014; Wright, Barbosa-Leiker, & Hoekstra, 2011). This type of work environment can lead to an increased risk of injuries if officers are not appropriately prepared to the best of their abilities. Injuries can be reduced through such prevention approaches as improved physical activity (Heneweer et al., 2012). The importance of a healthy lifestyle has been emphasized in a plethora of research (Means, Lowry, & Hoffman, 2011b). It is also known that officers are at a higher risk for injury than the average person simply because of their profession. These factors justify the action of an agency to require officers to maintain an optimal health level, especially given that medical expenses and lost productivity in the workplace total more than $400 billion in the United States each year (Stier et al., 2012). Law enforcement is one of the industries included in those figures.

Law enforcement agencies in North Carolina define and determine their own standard operating procedures (SOPs), including fitness requirements. An agency can elect to set standards as a condition of employment as long as each standard is justified by the job requirements (Department of Labor, n.d.). Unfortunately, little is known about why some law enforcement agencies in North Carolina do and some do not have fitness standards, given the support that fitness has in research. It is not known whether having a physical fitness policy in place directly relates to job injuries and absenteeism rates. Using a sample of law enforcement agencies, the current research examined which factors contributed to implemented agency policy and determined whether the use of a fitness policy directly related to injury and absenteeism rates within an agency. Additionally, I sought to determine the following: If there was a relationship, did lost productivity, in part or whole, contribute to unfit officers getting injured?

Purpose of the Study

This mixed methods study was conducted for the purpose of testing the utility function component of rational choice theory to determine if it explained fitness policy implementation and determined whether policy affected reported work-related injuries and absenteeism among North Carolina law enforcement agencies. The quantitative portion of the study examined the independent variable *policy* (defined as the presence or absence of an agency's fitness policy) over a 5-year period. The dependent variables *injuries* and *absences* consisted of the total number of work-related injuries and absences reported each year at an agency. The control variable, *progressive policy,* was defined according to an agency's increased fitness requirements over a 5-year period.

Research Questions and Hypotheses

Three questions guided this research:

RQ1. What relationship, if any, exists between a North Carolina law enforcement agency's fitness policy and work-related injuries and absenteeism?

H_0: No significant relationship exists between the stringency of fitness policy and job-related injuries and absenteeism.

H_1: The more stringent a fitness policy is, the lower the job-related injuries and absenteeism.

RQ2. When research emphasizes the benefits of maintaining a certain fitness level, particularly for first responders, does the utility function within rational choice theory explain why some North Carolina law enforcement agencies mandate physical fitness requirements for officers and others do not?

H_0: Based on the utility function, rational choice theory does not explain why an agency has the current fitness policy in place.

H_1: Rational choice theory presumes that policy decision-making is representative of a utility function and does explain why agencies have any or more stringent fitness policies in place.

RQ3. Are data-driven results of injury or absenteeism an agent or constraint as they pertain to the present fitness policy?

H_0: Injuries and/or absenteeism rates are neither an agent nor a constraint of the current fitness policy.

H_1: Injuries and/or absenteeism rates are either an agent or a constraint of the current fitness policy.

Theoretical Framework

As applied to public policy, rational choice theory contends that individuals interact through a social process and these interactions ultimately achieve organizational decision-making. Therefore, individual actions can affect the outcomes of policymaking (Green, 2002; Jones, Boushey, & Workman, 2006). As rational choice theory is specifically applied to this study, it would be expected that fitness policy implementation is influenced by the decision-making process. To test this, managers and administrators from the sample of law enforcement agencies were questioned about their fitness policies over the last 5 years and were asked about the rationale for the policy, such as whether any incentives or consequences were tied to policies. The issue of what affects agency fitness policy was explored, including circumstances such as politics, budget, data-driven results, and personal decisions. Rational choice theory is explored further in Chapter 2. The results found will be shared with all involved organizations and may influence or impact agency policy concerning officer fitness standards, either presently or in the future (Lunenburg, 2011; Royle & Hall, 2012).

Definitions of Terms

For this study, the following terms are used or referenced:

Basic Law Enforcement Training (BLET): A North Carolina state-mandated 616-hour (minimum) training course composed of 36 separate blocks of instruction and practical exercises, concluding with a comprehensive written exam and skills testing. It prepares individuals with entry-level skills needed to become certified law enforcement officers in the state (North Carolina Department of Justice, 2015). It is also referred to as the "police academy."

Law enforcement: Individuals and agencies responsible for enforcing state and local laws in the course of maintaining public order and safety (Bureau of Justice Statistics, 2016).

Physical fitness: "The ability to meet life's daily demands, without undue fatigue, while maintaining sufficient energy or leisure time pursuits and to overcome emergency situations that may arise personally and professionally" (Commission on Accreditation for Law Enforcement Agencies [CALEA], 2010).

Police administration: Police officers whose role is to manage and supervise police agencies.

Police officer: Uniformed, sworn officers assigned to the patrol function of policing.

Police Officer Physical Abilities Test (POPAT): Scientifically-tested series of tasks designed to assess important physical abilities necessary for effective job performance as a police officer, developed to mirror real-life situations that officers might encounter on the job (North Carolina Department of Justice, 2015).

Nature of Study

A purposive sample consisting of six North Carolina midsized law enforcement agencies in the Piedmont Triad region (see Appendices A and B) was chosen to participate in the study. Two agencies from each of the following categories were sought: (a) those with no mandated/voluntary fitness policy over the last 5 years, (b) those with a progressive or changed fitness policy over the last 5 years, and (c) those with a continued mandated fitness policy over the last 5 years. The search for agencies that fit these criteria began by using U.S. Census Bureau data to identify midsized populations in the North Carolina Piedmont Triad region. Using a quasi-experimental design, the sample of six was placed into nonrandomly assigned groups (independent, nominal variables). The number of work days missed in each of the years 2011-2015 due to work-related injuries served as the dependent, ratio-level variable.

Upon written agency permission and a guarantee of anonymity, agency administrators were asked to participate in a brief interview to answer a short, open-ended questionnaire inquiring about fitness policy implementation as it pertained to decision-making within the agency. The intent was to help determine what influences and affects these policy decisions within the agency. Descriptive statistics were used for each variable, and ANOVA and post-hoc tests were used to identify any significant relationships between the independent and dependent variables. *Progressive policy* was used as a control variable in an attempt to lessen the cause and effect order. An advisory committee was used to both construct questionnaire content and review the research process and purpose.

Permission was also secured to examine each agency's fitness policy and Occupational Safety and Health Administration (OSHA) 300A summary reports of work-related injuries and absences from the years 2011-2015. It was assumed that both fitness policies and injury reports were internally valid and therefore measured what they were supposed to. To ensure external validity prior to analysis, a collaborative effort between the researcher and agency administrator was used to review these documents to verify that what was reported represented an accurate portrayal of information. This included a review of fitness policies, OSHA documents, and completed questionnaires.

Assumptions, Limitations, Delimitations

It was assumed for this study that the participating agencies would answer interview questions honestly and provide current, accurate policy and OSHA data. In order to support this premise, questionnaires were provided in advance and question responses as well as OSHA forms were reviewed with each agency for accuracy. Any research presents potential validity and reliability issues; this study was not an exception. The stringency level of an agency's fitness policy served as a control variable; the stringency level was used to determine whether the absence or the presence of a mandate was a reliable measure of work absenteeism. It is important in research that any instrument used measures what is intended; therefore, instruments in this study were analyzed for validity to determine if the content being measured was accurate (Frankfort-Nachmias & Nachmias, 2008).

To maintain internal validity, all distributed questionnaires consisted of the same questions pertaining to fitness policy standards and absenteeism rates over the same 5-year period. For consistency purposes, an average standardized absentee rate was calculated per agency to allow cross comparisons. To establish questionnaire tool validity and reliability, a criminal justice advisory board (made up of local agency representatives) was presented with preliminary questions and solicited for feedback prior to questionnaire distribution.

Research integrity was promoted and any misconduct was avoided, as such actions reflect an organization or institution (Creswell, 2013). Data collection and participant anonymity, privacy, and confidentiality all needed to be protected, as this helped to ensure my trustworthiness as a researcher. Data analyses and discussion were presented in neutral language and at the appropriate level for audience understanding (Creswell, 2013). The Academy of Criminal Justice Sciences (ACJS) code of ethics guided the conduct of this research. Although the steps I took did not eliminate researcher bias, they helped to reduce it. Applying reflexivity within qualitative research implies that a researcher is upfront regarding his or her background, and that any interpretation and gains that might come from the study will be fully acknowledged (Creswell, 2013). To help eliminate additional bias, a written transcription of all responses was provided to each interviewee for review of accuracy. This step was pertinent because researchers have an obligation to monitor and report as fully and truthfully as possible all procedures that were used in a study (Patton, 2002).

Also important to researchers is awareness of potential ecological and individual fallacies in a study (Frankfort-Nachmias & Nachmias, 2008). It should be emphasized that an agency's lack of enforcement of a fitness standard does not imply that officers cannot or do not take individual responsibility for their own duty fitness. It also cannot be inferred that the presence of high absentee or injury rates reflects poor officer or agency performance.

A final limitation of this study was that a sample of six agencies was used. Using such a small sample limited the detection of large differences and did not allow for the generalization of results found, either within or outside the state. However, findings help to address the research questions presented and contribute to what little is known about the relationship between fitness policies and work-related injuries and absenteeism within law enforcement in North Carolina. The results add to the knowledge of how policies are derived.

Significance of Study

A thorough search of the literature on officer fitness and injuries found very limited studies specifically comparing physical fitness policies to job injuries nationwide or in North Carolina. Every industry is required by OSHA to document and report work-related injuries. Therefore, the results of this study add to the literature by addressing whether mandated fitness requirements are related to agency-documented OSHA injury rates within the law enforcement profession. This study also contributes to the gap in field research because, although fitness is encouraged, little is being done to improve officer health as work-related-injury costs continue to rise. More specifically, research at the state level is lacking on whether fitness policies even influence the number of injuries reported among North Carolina law enforcement agencies, and what the rationale is for current policies. By addressing these issues, the study contributes to law enforcement field knowledge and any significance between fitness policies and work-related injuries and absenteeism. The significance between policy and injury rates found within the study demonstrates the need for widespread participation in wellness initiatives. This could not only improve individual officer health, but also better equip officers to perform their duties with a reduced likelihood of getting hurt. Simply put, being more fit could increase the chance of officers going home injury free at the end of each shift.

Ensuring that officers are safely and physically able to fulfill their required duties should be not only a personal officer responsibility but also a concern for each agency. Current policies may be sufficient, and there may be no relationship between work injuries or absences, but this is understudied in North Carolina. However, because one may affect the other, and wellness, along with increased job performance and cost savings prevails, everyone involved wins. Rejecting the null hypothesis of the current statistical analyses can provide a base for positive fitness policy changes within law enforcement, thereby sustaining the importance of fitness for officers beyond academy training. Results provide an opportunity for agencies to promote fitness and wellness as a means to improve officer health and reduce injuries and absenteeism. This could benefit officers, lower agency health costs, and lower overall health insurance provider costs.

Social Change

A police officer's job is not routine; it is never the same from day to day. It is difficult to predict what officers will need to do to protect themselves and the public. Therefore, officers should train and be prepared to respond to the unpredictable. This can be done through the use of combined physical and psychological exercises as provided in police academy training. Training includes intense encounters, development of survival instincts, and exercises to build strength and power endurance. These tactics should be included in regularly scheduled in-service events (Zagaria, 2007) because many officers do not continue fitness training beyond the academy, and physical training often trails off if an agency does not either promote or mandate fitness-level standards. Examining agencies that both do and do not institute fitness policies in North Carolina, I sought to bring attention to policy discrepancies at a state level. This study represented an opportunity to raise awareness of possible fitness–injury correlations and informs agencies of available resources they might not be aware of, such as health and injury prevention programs and potential funding for these programs.

Ultimately, a significant relationship between policy and injury and absenteeism rates provides a springboard to advocate for better health and fitness among officers in the state. Sharing results could also increase awareness of officer health and safety benefits as they pertain to the law enforcement job, meaning providing the necessary tools to promote officer wellness (Office of Community Oriented Policing Services, 2015) and decrease injury risks. In turn, better wellness increases both officer health/wellness and public service efficiency.

Summary

This research was conducted to examine fitness policies and OSHA injury reports among six North Carolina law enforcement agencies over a 5-year period. Using a quantitative analysis, I sought to determine whether a significant relationship existed between these variables. Analyses rejected the null hypothesis, and a certain category of policies related to fewer injuries and absences; thus, findings supported the promotion of physical fitness policies for police officers beyond the police academy.

Additional analysis through qualitative examination of questionnaire responses from police administrators determined whether rational choice theory supports policy decision-making, focusing on the utility function. Responses helped in determining which factors contributed to policy decision-making and whether decisions were based on personal preferences, political influence, or other circumstances, or whether decisions were based on a representation of larger objectives. Chapter 2 explores the variety of studies I found that were related to this topic.

Chapter 2: Literature Review

Introduction

A generally sedentary population is at a greater risk of coronary disease than those who are more active. The same stands true for those who have more physically demanding jobs; their risk for heart attack and absenteeism is lower (Donoghue, 1977). Police work can be physically demanding as well as stressful and dangerous (Zimmerman, 2012). As patrol officers answer calls for service, they never know what will happen next, or what abilities or skills might be required of them at any given time. Therefore, suffering injury or worse is always a possibility. Law enforcement has one of the highest rates of injuries and illnesses among occupations (Bureau of Labor Statistics [BLS], 2014) and has greater mortality and morbidity rates than the general public (FitForce, Inc., 2010; Quigley, 2008; Smith & Tooker, 2011; Wright et al., 2011). Research has shown that improved endurance performance makes the body less susceptible to fatigue and a person less likely to commit errors (Donoghue, 1977). Various factors work into this equation, but one specifically, officer fitness, is the focus of this discussion. Though the police academy helps cadets prepare for entry into the law enforcement workplace, the rest of the preparation and experience depends on the officer and the hiring agency. The agency sets the tone for what is deemed acceptable and important. Sometimes certain health and fitness levels are required, or at least encouraged throughout an officer’s career, but among North Carolina law enforcement agencies, this general policy seems to be more the exception than the rule, which in part was what this research set out to discover.

Health and fitness among those in law enforcement is declining. *Health* is considered "a state of complete physical, mental, and emotional well-being" (Smith & Tooker, 2011, p. 3). The consequences of not being healthy include vulnerability to on-duty illness and injury, and increased exposure to liability (FitForce, Inc., 2010; Pronk, 2015). However, does being in better health or better shape necessarily contribute to fewer work-related injuries for police officers? Interventions offered to improve physical job performance have shown diverse results (Plat et al., 2011). Therefore, the literature was explored further to address whether better officer fitness is related to fewer job injuries or less absenteeism.

Having physically fit police officers has benefits. Fit officers tend to use less time off because of injury or illness and tend to be less stressed (Bissett, Bissett, & Snell, 2012; Quigley, 2008). *Physical fitness*, as defined by the Commission on Accreditation for Law Enforcement Agencies (CALEA, 2010), is "the ability to meet life's daily demands, without undue fatigue, while maintaining sufficient energy or leisure time pursuits and to overcome emergency situations that may arise personally and professionally" (Smith & Tooker, 2011, p. 2). Yet who decides which fitness standards to implement and why is unclear. Whether the decision is personal, administrative, or political is known only by the agency. Other factors such as personnel, resources, and funding might contribute to policy decision-making. As funding for public safety decreases (Bueermann, 2012), it is important that agencies be able to do more with less. Doing more includes informing decision makers about using the best strategies with the most desirable outcomes.

Police academies instill physical fitness training and testing as a condition of graduation. Adequately preparing cadets at the police academy adds value to their future performance (Caro, 2011), as both strength training and cardiovascular exercise have rewards and can improve individuals' quality of life in many ways (Williams, 2002). However, most departmental policies do not require that officers maintain that fitness and then leaders wonder why officers have high stress levels and suffer from various health conditions at a higher rate than the general public (Williams, 2002). Physical activity is an integral part of healthy living (Pronk, 2009), as it helps to prevent heart disease and assists with weight control, thus protecting the body from injury (Quigley, 2008). Physical tasks required of police officers are similar worldwide. Some studies have found that certain physical agility tests are not strongly related to actual job requirements (Bissett et al., 2012; Bonneau & Brown, 1995). It seems evident that policing requires strength and endurance, in that officers are engaged in physical challenges regularly (Guffey et al., 2014). Because policing is a profession whose members experience a high level of job-related stress (Hartley, Burchfiel, Fekedulegn, Andrew, & Violanti, 2011), it seems that police officers who maintain their fitness are better able to cope with job stress and are better prepared for critical incidents than their peers who do not (Ebling, 2002). Thus, given all the benefits a fit lifestyle can bring, one might wonder why many officers are still unfit for the job (Williams, 2002).

Searching the Literature

A comprehensive review of the literature was conducted using several databases and search engines. Sources were obtained from Walden University's library using ProQuest Criminal Justice, EBSCO, and other databases. Google Scholar was also used to search and obtain peer-reviewed and topic-pertinent information. Key words were used in three main categorical searches for peer-reviewed articles. First, *police, law enforcement,* and *cops* were used interchangeably as 'OR' Boolean factors. Then *fitness, wellness,* and *health* were used as 'OR' Boolean factors. Finally, *policies, injuries,* and *absenteeism* were included. *Rational choice theory* was also searched in the various databases. These key words resulted in multiple returns, which were then examined for relevancy according to the topic at hand. The main focus was on recent literature within the last 5 years; however, other later sources were also used if it was determined that the content had relevance to this study. Electronic sources such as the BLS, OSHA, U.S. Department of Health and Human Services, and U.S. Equal Employment Opportunity Commission were used to find the most up-to-date information on health and work-related injuries.

From the literature obtained and reviewed, the following themes for discussion emerged: (a) the physical demands of law enforcement, (b) work-related injuries, (c) physical fitness policies in law enforcement, (d) the legalities of fitness standards, (e) physical fitness testing, (f) the POPAT, (g) the impact of *fit*ness for duty, (h) fitness resources for the workplace, (i) leadership in law enforcement, and (j) rational choice theory.

Physical Demands of Law Enforcement

Emergency service professionals are exposed to hazards that are inherent in the job (Plat et al., 2011). The physical demands placed on law enforcement officers specifically have been documented to include such activities as apprehending suspects, foot pursuit, and even firing a weapon (Anderson, Plecas, & Segger, 2001; Brown, Tandy, Wulf, & Young, 2013; Zimmerman, 2012). These demands include being able to apprehend and restrain individuals. In over 75% of police apprehensions, suspect resistance is moderate to strong, and the average amount of time to subdue a subject varies between 30 seconds and 2 minutes (Quigley, 2008). Such tasks require effort, which can be physically challenging (Anderson et al., 2001).

When police officers encounter high-risk situations, certain physiological patterns can be predicted and measured. Armstrong et al. (2014) documented that an officer's average heart rate throughout a shift was 22 beats a minute above an average resting heart rate. As officers encountered simulated use of force, their heart rates increased an average of 40 beats per minute. This demonstrates extra stress placed on the heart, which affects an officer both psychologically and physically (McCraty & Atkinson, 2012).

Even though police officer work patterns are characterized mainly by relatively long periods of low-level activity, occasionally, short periods of high-intensity activity are needed. To safely and effectively perform police functions, it is necessary to maintain a certain amount of physical fitness throughout one's career. Though much of the job can be executed independent of physical fitness, some tasks will require certain levels of physical fitness. However, how fit officers need to be and what factors can be used to predict successful performance are debatable (Collingwood, Hoffman, & Smith, 2004; Dillern, Jenssen, Lagestad, Nygard, & Ingebrigtsen, 2014). Ensuring that those in public safety are physically ready for their jobs can aid officers in performing their duties more safely. This effort can be enhanced by stressing positive lifestyle habits, as these habits help decrease health risks, improve quality of life, and assist agencies in reducing their liability by controlling risks and associated costs (FitForce, Inc., 2010).

A police department should ensure safe working practices, especially given that their officers face potentially violent situations (Bissett et al., 2012; Bonneau & Brown, 1995; Brown et al., 2013; "Fitness Tests Will Help Police," 2012). For example, arrests are commonplace among police officers, and research suggests that higher fitness levels affect arrest encounters positively. Because the physical task most frequently demanded of officers is arrest, upholding some level of fitness is important (Dillern et al., 2014). Anderson et al. (2001) collected data observations that justify certain occupational requirements for police work. These observations included officers having to physically control suspects. Testing of physical abilities include tasks wherein officers have to get to a problem, control the problem, and remove the problem through appropriate simulated measures. Such observations, along with self-report surveys, can be accurately measured and tested (Anderson et al., 2001).

The last several decades have demonstrated much change in police work, such as the encouragement of alternative methods of dispute resolution and new computer and technology skills. Therefore, some have questioned whether physical abilities are still important for police officers (Bonneau & Brown, 1995). The fact remains, however, that there is nothing routine about police work, and it often requires short, intense encounters. Therefore, officers should train to condition their bodies to adapt and perform under various unpredictable conditions (Zagaria, 2007).

Police are subjected to both physical and psychological stress as they relate to the workplace (Phadke, Khan, Iqbal, & Ramakrishnan, 2014). Thus, another important component of officer fitness is psychological fitness for duty. Fitness-for-duty evaluations (FFDEs) can be and are used when situations exist wherein officers must be psychologically ready for duty. The key object of this type of evaluation is to reduce an agency's liability (Fischler et al., 2011). Physical skills can be quite crucial when they are needed; they also have an important function from a psychological perspective for officers. Officers report that good physical skills can provide them with confidence as well as security when interacting with the public (Lagestad, 2012), therefore tying physical and psychological well-being to one another. However, it could be argued that the police job itself does not cause poor officer fitness and health; rather, a lack of agency fitness standards and programs is likely to blame (FitForce, Inc., 2010). This idea is explored later.

Work-Related Injuries

The Occupational Safety and Health (OSH) Act of 1970 requires certain employers to maintain work-related injury and illness records (Form 300) and note the extent and severity of each case. An injury or illness is considered work-related if an event or exposure in the work environment caused or contributed to the condition or significantly aggravated a preexisting condition (OSHA, n.d.). Trends show that recently, law enforcement has experienced a reduction in health and fitness in the United States, making officers even more prone to work-related injuries and illness (Quigley, 2008).

In fact, duty leave due to injury appears to be at a high rate among public safety workers, a large portion of whom are police officers (Violanti et al., 2013). Because police work can be physically demanding, stressful, and dangerous, officers have among the highest rates of injury and illness of all occupations (BLS, 2014). National accident, injury, and illness data show that 20% of an average police agency's workforce is responsible for 80% of accident costs, suggesting that this small percentage of least-fit officers is responsible for a large majority of injuries (Quigley, 2008). The leading causes of work injuries for police officers are falls, trips/slips, and mental stress (Ferguson, Prenzler, Sarre, & de Caires, 2011). Lower fitness levels tend to be associated with an increase in injury risk (Orr, Stierli, Hinton, & Steele, 2013), but the impacts of increased levels of fitness are a little less clear (Pronk, 2015). In a study of Milwaukee police officers across a 13-year span, Brandl and Stroshine (2012) found that accidents accounted for the majority of lost time from work when medical attention was sought.

Physical Fitness Policies in Law Enforcement

There are limited sources that define or identify law enforcement agencies in North Carolina that have a fitness policy, and if so, to what level or extent. One recent study in the state found that among 145 police agencies, a significant association between fitness maintenance policies and officer injury existed (Fortenbery, 2016). However, to further explore specific policy requirements and reasons for implementation, each agency would have to be contacted to learn more about standing policies. Research has been conducted in other states that provide a better picture of fitness policy prevalence. For example, among 37 police departments in Michigan, only three (8%) had a policy regulating fitness standards or programs (Williams, 2002). Policies on fitness standards vary; sometimes they are vague, but other times they are quite specific, with noncompliance potentially leading to termination (Burlington Police Department [BPD], 2010; Farley, 2011). The intent of this study was to explore this issue further within the state of North Carolina.

Fitness is something for employers to contemplate because it is directly related to work performance, productivity, and health care costs, which are all factors to consider in operating an effective agency. It is important to the employee because it affects income, health, and other quality-of-life issues. If employers would indeed benefit from fit officers, they should promote fitness backed by supportive policy, adhering to both state and federal regulations (Pronk, 2015).

The Legalities of Fitness Standards

In a general sense, employers are responsible for protecting their employees against physical harm that may reasonably be expected to arise in employment. If the necessary duty of care is not exercised, employers can be at risk for litigation (Rayson, 2000). Yet if certain measures or tests are to be used, those standards need to be job-related. Fitness tests should define the physical abilities needed in police work both objectively and realistically (Anderson et al., 2001) while complying with laws prohibiting discrimination (U.S. EEOC, n.d.). Data need to back up any standards or tests that are used in order to demonstrate that such standards or tests are correlated to job performance. Such data are available and should be used to document certain components of fitness such as body composition, cardiovascular endurance, anaerobic power, flexibility, strength, and agility in relation to the job (Collingwood et al., 2004; FitForce, Inc., 2010; Smith & Tooker, 2011). Ensuring that tasks are relevant to the industry assists in designing specific occupational standards that help to keep officers prepared to meet their job demands and avoid injury (McGill et al., 2013).

Several factors can hamper an employer's use of physical fitness tests because of disputes over the standards used; however, testing is necessary in this work environment

(Adams et al., 2014). One thing that an employer needs to take into consideration is Title VII of the Civil Rights Acts of 1964 and 1991. Title VII states, "it shall be an unlawful employment practice for an employer … to discriminate against any individual with respect to his compensation, terms, conditions, or privileges of employment, because of such individual's race, color, religion, sex, or national origin." This includes discrimination in relation to any aspect of employment, including certain terms and conditions of employment (U.S. EEOC, n.d.). An agency cannot have different fitness standards for men and women if they are doing the same job because this can have a legal effect of invalidating the standards (Means et al., 2011b). If an agency is to terminate police officers based on specific agency fitness standards, the legality of this matter depends on how the court interprets Title VII (Guffey et al., 2014).

Courts are increasingly scrutinizing departmental physical agility requirements, particularly if entry-level officers and incumbent officers are held to different standards; however, health-based standards are more likely to be upheld, as they focus on general fitness assessments (Bissett et al., 2012). The Americans with Disabilities Act (ADA) of 1990 also needs to be considered when making physical or medical inquiries of incumbent employees. If such inquiries are made, they need to be based on objective reasoning (Fischler et al., 2011). In *Tennessee v. Garner* (1985), police use of deadly force to apprehend fleeing felons was restricted. This ruling had an implication that officers should be adequately fit to both pursue and subdue suspects without having to depend on deadly force. A similar ruling in *Parker v. District of Columbia* (1988) found that an unfit officer was unable to affect an arrest and so resorted to the use of deadly force. Based on these rulings, administrators should consider adequate monitoring of officer fitness levels.

Proper medical and health screenings can help reduce litigation risk (Lee & Mallory, 2004). Employers need to adhere to all regulations that protect the health and safety of its workers (Pronk, 2015). If departments hire officers who possess sub-standard strength and ability skills, they could be held liable as it is the employer's responsibility to demonstrate that the physical standards required are based on essential elements of the job, and that the performance demanded is reasonable (Bissett et al., 2012; Bonneau & Brown, 1995).

Physical Fitness Testing

A consensus says that law enforcement officers should maintain at least some level of physical fitness, but what that level is varies according to who one asks, and how should this be assessed? (Means, Lowry, & Hoffman, 2011a). Recruit training is designed to prepare officers for duty, and so includes tasks that relate to daily police work (Orr et al., 2013). Across the state of North Carolina, law enforcement training academies include a standard fitness component as part of training. Research recommends that academy curricula be based on needs-assessment as well as job-task analysis using the most practical approach to testing content (Bonneau & Brown, 1995; Caro, 2011; Plat et al., 2011). Personal and team accomplishments are usually stressed because it is important for both personal well-being and survival in a profession that comes with high levels of stress and danger (Ebling, 2002). Police officers are taught in ways that correlate to the type of work they do (Zagaria, 2007) but sometimes contrary to what are found once in a place of employment.

Fitness testing in theory is a way to motivate police personnel to maintain a fitness level to promote job readiness (Adams et al., 2014). However, standards first need to be established, and justified as to their significance. Several fitness activities have been identified as commonly being used in police work. These include running, jumping, lifting, carrying, and dragging to name a few. It is critical that testing assesses all physical abilities that are required of the job, or what Bonneau and Brown (1995) refer to as *occupational fitness*. While officers may utilize aerobic endurance on duty, research suggests that physiological demands may also be anaerobic in nature (Orr et al., 2013). Fitness can be measured using various physiological standards, from oxygen consumption to physical strength (Bonneau & Brown, 1995).

It is recommended that fitness assessments are conducted to determine and record officers' fitness levels. Scores can then be compared to norms and standards (Cooper Institute, 2014) and should be evaluated on up-to-date standards (Schulze, 2012). Cooper Institute standards are used by many agencies, as well as academy fitness training. The Cooper Institute is renowned for its history, research, and publication in ability/agility testing. Often a 50^{th} percentile is used as a fitness benchmark (Bissett et al., 2012), as minimum fitness standards are directly related to adequate job performance (Pronk, 2015) because higher injury risk was associated with factors such as older age, slower run times, and lower self-rated physical activity (including aerobic exercise) (Knapik et al., 2011).

There is no 'one size fits all' when it comes to required fitness standards for officers. Individual departments need to consider the job demands and the working environment. There is some debate about whether the programs should be voluntary.

Bissett et al. (2012) do not believe that voluntary programs are going to be enough. Williams (2002) agrees and emphasizes that without a policy, even resources provided often go unused without any kind of incentive behind it. That is why a policy would be most beneficial because it regulates fitness of individual officers. However, FitForce, Inc. (2010) would argue that a voluntary fitness/wellness program would be the most effective and cost effective approach. Another approach might be to use a worker's health surveillance (WHS) to detect health effects resulting from occupational exposure. A WHS can assist employees in safely and healthfully meeting job requirements. The goal is to periodically monitor employees and detect adverse health effects as early as possible so preventative measures can be taken (Plat et al., 2011). For these purposes, *wellness* is defined as "those purposeful actions taken to attain and maintain optimal health and fitness" (Smith & Tooker, 2011, p. 3).

To standardize a job-related test, one's ability to perform the physical demands of core police tasks needs to be examined (Strating, Bakker, Dijkstra, Lemmink, & Groothoff, 2010). Both construct and criterion validations are accepted as job-related standards. Criterion such as job descriptions and injury reports can be examined to identify these standards. And because job tasks are not often performed in isolation, utilizing sequence events makes them more real-world situations (Collingwood et al., 2002). Job simulations are often used in testing to measure multiple physical abilities. These types of tests are beneficial because they possess a higher content validity than simple, single ability tests. But, job simulations can only predict performance within its administered context (Courtright, McCormick, Postlethwaite, Reeves, & Mount, 2013). Collingwood et al. (2004) used multivariate regression to demonstrate validity as it relates to fitness activities. Regression analysis indicated that a group of specific test items can be good predictors of job tasks, and multiple primary physical factors that they analyzed met these criterions. Data must support and demonstrate a correlation between fitness testing and any job criterion performance, thereby establishing continuity in standards. It is incumbent standards that are key to successful job-related testing (Means et al., 2011a).

One concern about testing is that some criteria used by law enforcement agencies are argued to be discriminatory, particularly against sex. Large male-female differences exist within certain physical abilities. Therefore, test validity needs to demonstrate and defend its use, or different performance measures for women and men need to be developed based on normed scores (Anderson et al., 2001; Bissett et al., 2012; Courtright et al., 2013). Yet caution is needed when using gendered tests because separate standards could reinforce biases when it comes to gender since standards tend to establish biological sex and not biologically determined physical ability (Schulze, 2012). But, Means et al. (2011b) argue that whatever levels of fitness are required to perform the essential minimum physical functions of the job, they are achievable by most, regardless of gender or age, with as little as three hours of training per week. Another concern is tests that are used for employment selection generally focus on entry-level skills and ability. But a disjunction seems to exist if certain physical abilities are deemed essential to the job, and incumbent officers are not expected to also maintain these abilities (Bissett et al., 2012). The challenging part is that no matter what the demographics are of the police officer, the fundamental tasks to be performed on the job are the same (Bonneau &

Brown, 1995), even though women and older persons tend to test lower or slower (Strating et al., 2010).

Fitness standards for law enforcement officers should be tested to ensure that both new and incumbent officers possess the physical abilities to perform necessary tasks of the job. Standards should be developed, and training programs should be provided so that all officers have the access to and knowledge of skills needed to maintain personal fitness throughout their career (Means et al., 2011a). Such tests are important because those who do not meet job-related demands tend to perform lower, have more injuries, and more absenteeism (Collingwood et al., 2004; Courtright et al., 2013), all which can equate to reduced resources available. Lower levels of physical activity have been associated with absenteeism in the workplace, therefore employers should implement programs that will promote healthy activity levels (Pronk, 2009; Steinhardt, Greenhow, & Stewart, 1991).

Even administrators have recognized the need not only for officer fitness, but for lasting fitness maintenance programs (Lee & Mallory, 2004). Perhaps mandatory standards are not necessarily the answer, but the solution could be mandatory *testing* (Panos, 2010).

Police Officer Physical Abilities Test (POPAT)

There are no national guidelines for physical fitness tests of police cadets, though most academies require some type of fitness standard (Schulze, 2012). In North Carolina, that standard is POPAT. The POPAT has been scientifically validated as being job specific, as it measures certain abilities that are required for general police duties (Anderson et al., 2001; North Carolina Department of Justice, 2015). In North Carolina, for over 20 years, BLET students have been required to demonstrate job-related physical ability competencies as a condition of graduation. This test consists of a series of tasks that are designed to assess the physical abilities necessary to effectively perform the job of a police officer. The tasks were developed to mirror real situations that an officer might encounter on the job (North Carolina Department of Justice, 2015).

In 1998 the North Carolina Justice Academy (NCJA, 2000) POPAT subcommittee was specifically tasked with examining and evaluating various options as they related to the proposed POPAT. They were then to develop as well as deliver recommendations for using POPAT as a physical fitness measure (pass/fail) of the BLET program. In April of 2000, the committee agreed to adopt the POPAT report for several reasons. First, they felt such a test was reasonable, fair, and trainable. It was also deemed to be safe, practical, and consistent. The skills included in the POPAT were related to task analysis conducted in 1998 and the committee justified each of the following according to this task analysis. To be completed in seven minutes and twenty seconds (7:20) or less in duty belt and gear, cadets were to do the following:

1. Verbally recall street location
2. Exit police vehicle from seat belted position and run 200 yards
3. Pull a 150-pound person from vehicle and drag them 50 feet
4. Run up and down a five-step staircase three times
5. Push open and go through a 50-pound weighted door
6. Do 20 push-ups and twenty sit-ups
7. Run up and down a five-step staircase three times
8. Crawl through a 25-foot culvert

9. Do 20 push-ups and twenty sit-ups
10. Run 200 yards and return to vehicle
11. Drag a 150-pound person 50 feet
12. Verbally recall street names (NCJA, 2000).

The committee rationalized that the POPAT was reasonable and consisted of tasks that officers might perform while on duty. Officers need to be able to respond to multiple activities that include speed, agility, balance and stamina, and the POPAT was seen as a representation and combination of a variety of skills that may be required of an officer (NCJA, 2000). For example, the Burlington Police Department (2010) utilizes biannual POPAT testing of newly sworn officers as of January 2014. Collingwood et al. (2004) identified many of the same underlying and predictive fitness activities as they pertain to the POPAT. The primary factors identified include absolute upper-body strength (pushups), agility, anaerobic power (1.5 mile run), and anaerobic power (300-meter run). Their data indicates that certain physical activities can help determine a police officer's capability to perform essential tasks.

In 2008 another job analysis gave credence to altering the former POPAT test, which became effective for all BLET students starting in the fall of 2015. The scientific validation of the "new and improved" POPAT yielded a 95% confidence level. The test was designed to differentiate between individuals who can and cannot perform certain physical functions of a police officer's job at an identified adequate level of proficiency (North Carolina Department of Justice, 2015). The new test consists of two scenarios. Scenario 1 (chase and apprehension, to be completed in six minutes (6:00) or less wearing a ballistic vest), is as follows:

1. From a seated position, run 40 feet and back twice
2. Run 60 feet and return, with a 4-foot broad jump, 4 foot “fence” climb, and 2 feet high crawl obstacle in between
3. Roll a 100-pound dummy three times
4. Do 20 push-ups
5. Conduct another three-repetition dummy roll drill
6. Run 60 feet and return, with a 4-foot broad jump, 4 foot “fence” climb, and 2 feet high crawl obstacle in between
7. On step box, take 30 steps up and down
8. Conduct a three-repetition roll drill
9. Do 20 push-ups
10. Conduct a three-repetition roll drill (North Carolina Department of Justice, 2015).

Scenario 2 (rescue, to be completed in three minutes (3:00) or less wearing a ballistic vest), is as follows:

1. Run 50 feet and back twice
2. On step box, take 30 steps up and down
3. Run 50 feet and back twice
4. Drag a 175-pound dummy 25 feet and back (North Carolina Department of Justice, 2015).

Training programs should constantly be assessed to ensure they are both current and relevant. Violence is prevalent in the current environment and so training should be as realistic as possible. Officers should be provided with solid, research-based scenarios that prepare them for an evolving and changing climate within which they work (Miller, 2015).

The Impact of *Fit*ness for Duty

Though police work tends to largely be sedentary (Ramey et al., 2014; Steinhardt et al., 1991) and not always physically demanding, when officers need to engage in physical agility, their fitness level may very well be a determining factor of the outcome (Brown et al., 2013). Shiftwork is often an inevitable circumstance of police work that can contribute to this issue. Wirtz and Nachreiner (2012) concluded that the exposure to shiftwork had a significant impact on fitness for duty, particularly after 20-22 years working in this environment. An effective fitness program can help counteract some of the adverse health impacts of sedentary and shift work (Pronk, 2015). The inability to maintain resilience can impair judgment and the ability to make decisions. Results can potentially lead to inappropriate application of force which can carry lasting consequences such as compromising public safety, injuries and even lawsuits (McCraty & Atkinson, 2012; Zimmerman, 2012) as discussed earlier.

An unfit officer increases the probability of injury both to him or herself and to others (Boyce, Hiatt, & Jones, 1992). Unfit officers can be a liability in several ways. First, officers may use excessive force to compensate for an inability to use physical restraints, or second, unfit officers may cause other officers to be injured because they are unable to render adequate assistance. This not only presents potential legal exposure for those officers, but vicarious liability can also be extended to that officer's agency (Guffey et al., 2014).

Improved physical ability profits both the officer and employer. Officers profit from increased job performance, reduced stress and better mental preparation. Agencies benefit in terms of fiscal responsibility and efficiency (Quigley, 2008). Employers are the ones who bear the financial consequences of reduced work productivity and increased medical spending, and therefore are likely to benefit from a healthier workforce. Investing in and providing both means and incentives would seem to gives an employer a return on their investment (van Dongen et al., 2011). Boyce, Jones, and Hiatt (1991) set out to investigate this relationship between physical fitness and work absences in police officers. But they found that the extent to which fitness predicts absenteeism is actually low. This is contrary to other and more up-to-date research, but does provide a valid focus to distinguish between absenteeism versus injuries.

Studies involving law enforcement officers indicate that more fit and active officers report 40-70% less absenteeism. This equates to a cost savings to the agency, therefore demonstrating that agency money spent on workplace fitness and wellness saves dollars as fit officers miss fewer work days (Smith, 2010; Smith & Tooker, 2011). These employees are also more highly productive (FitForce, Inc., 2010). Local and state governments across the United States are spending more money on policing than they did several decades ago. In a time where budget cuts are more likely than budget increases, a way to reduce some policing costs is to maximize productivity (Gascon & Foglesong, 2010). Unfit employees cost agencies lost days from work and increased insurance costs (Panos, 2010). Since a lack of fitness standards can be costly it leaves to wonder why departments do not set standards and provide training (Williams, 2002).

But, physical activity and fitness have a preventive effect on these factors (Sassen, Kok, Schaalma, Kiers, & Vanhees, 2010; Wright et al., 2011) which can have implications for the workplace. Therefore, the need to stay healthy requires both diet and exercise in order to maximize fitness level (Guffey et al., 2014; Hartley et al., 2011; McCraty & Atkinson, 2012). For example, interventions such as increasing physical activity and fitness can help improve cardiovascular risks (Sassen et al., 2010) as higher levels of cardiovascular fitness can be related to reduced absenteeism (Steinhardt et al., 1991).

Even though officer fitness is important, fitness alone is not sufficient. The focus should be on more than one risk factor to reap beneficial outcomes (Gerber et al., 2013). A healthy weight and physically active lifestyle are important for general health. But fitness also matters as it pertains to disease and illness prevention, as well as social and economic concerns in the workplace. However, since the workplace is but one component of life, a broader fitness perspective does need to extend beyond the workplace (Pronk, 2015). In fact, Ramey et al. (2014) and Boyce et al. (1992) found that police were more active off-duty, or unsupervised, than at work, or supervised. Work is connected to the home and the community. Health behaviors extend across all environments and are difficult to separate (Hymel et al., 2011).

Injuries pose a public health problem and effective strategies could help decrease this burden. But, public health practice has been a bit slow to address injury prevention (Stier et al., 2012), perhaps because of reluctance. Law enforcement agencies may be reluctant to partner with public health agencies because they are unclear on mandates.

However, North Carolina has taken initiative by partnering with various agencies to identify resources and responsibilities (Stier et al., 2012).

The advantages of a healthier, fitter, and energetic workforce include lowering absenteeism rates related to sickness. This is worth the necessary measures ("Fitness Tests," 2012). Past studies have demonstrated that a correlation exists between the length of time on the police job and a decline in health and fitness (Panos, 2010) so agencies could benefit from a fit workforce in both performance and health. This leads to greater contributions and enables communities to invest elsewhere (Pronk, 2015). Exercise can help with the stress associated with the law enforcement job and contribute to more positive coping. Agencies recognize that fitness is important for their officers, and encourage maintaining a healthy and adequate fitness level, but many find it difficult to implement some kind of fitness program (Ebling, 2002; Lagestad, 2012). When police officers engage in physical activity on a regular basis, it better prepares them to deal with work-related situations requiring physical force, and helps strengthen their psychological well-being (Lagestad, 2012).

If departments choose to test and evaluate officer fitness, programs need to be put into place that can assist officers to both attain and maintain a necessary fitness level for the job (Bonneau & Brown, 1995). Of several national voluntary fitness and wellness programs, data showed improvements in overall fitness, therefore increasing productivity and reducing both absenteeism and worker's compensation claims (Quigley, 2008). Health, fitness, and wellness should be included in a program as they are related and complement one another (Smith & Tooker, 2011). A supervised and job-specific exercise program for police officers improved fitness after 6 months in men and women.

However, a continued supervised exercise program is likely needed to maintain long-term health benefits (Rossomanno, Herrick, Kirk, & Kirk, 2012). Fitness and wellness programs also show to increase loyalty, generally improve morale, and reduce turnover (Quigley, 2008; Smith & Tooker, 2011).

Ferguson et al. (2011) suggested that prevention should be a focus of future work, given the critical role that police officers play in preventing crime, maintaining order, and providing emergency services. Prevention begins in the police academy. If police candidates are not screened and fail to successfully perform certain duties, this can result in injury/disability, turnover, and poor productivity which can have both a human and economic cost (Anderson et al., 2001). In total, medical expenses and lost productivity from injuries are estimated to exceed $400 billion (Stier et al., 2012). Law enforcement agencies take up a piece of this pie.

The Cooper Institute (2014) believes that fitness in law enforcement is necessary because it relates to (1) the ability of officers to perform essential job functions, (2) minimizing excessive force situations, (3) minimizing health risks associate with the police job, and (4) meeting the legal requirements to avoid litigation. To emphasize these points, an agency that does not address officer fitness requirements is susceptible to litigation for negligent (1) hiring of those not fit to do the job, (2) training to help officers maintain their physical capabilities of job demands, and (3) supervision of such individuals (Williams, 2002). Ensuring fitness for work can lead to increased quality of production, both decreased absenteeism and turnover, and lower medical costs which reduces incidence of injury (Rayson, 2000).

Fitness Resources for the Workplace

Once employed officers continue to train in many areas such as legal updates, driving, firearms, and defensive tactics to name a few. Yet most often fitness is not one of those areas of focus (Williams, 2002) although we know its benefits. Pronk (2009) demonstrated that most fitness interventions resulted in positive effects among employees. Research supports that comprehensive, multicomponent physical interventions lead to significant improvements in health, as well as reduce absenteeism (Steinhardt et al., 1991). This generates positive return for the employer (Pronk, 2009). There are potential resources available to agencies within the state, but little is known as to whether agencies are aware of, or are using such resources.

North Carolina is one of seven states that mandate full-scope injury prevention programs. General Statute 130A-224 provides that "the Department of Health and Human Services establish and administer a statewide injury prevention program and designate the Division of Public Health as the lead agency for injury prevention activities." Injuries are often predictable and preventable, but laws by themselves cannot prevent injuries, action must be taken (Stier et al., 2012). Both health protection and promotional programs need to be intertwined to promote a healthier and safer workforce. A healthier workforce will be safer and a safer workforce will be healthier (Hymel et al., 2011). Program intervention should extend outside the workplace, utilizing community resources as well through incentives (Pronk, 2015).

Under the auspices of the U.S. Department of Health and Human Services (HHS, 2015), the *Prevention and Public Health Fund* provides workforce wellness program opportunities. It emphasizes prevention initiatives and provides grants to small employers to assist with the implementation of such programs. The pressure is placed on both workers and employers as health costs skyrocket. Health measures aimed at improving the workforce could significantly have a long-term impact and save billions in costs (Hymel et al., 2011). According to Harte, Mahieu, Mallett, Norville, & VanderWerf (2011), health impacts workforce productivity, and if an organization integrates a wellness benefit program, it can achieve a substantial saving between 15-35%.

Leadership in Law Enforcement

Improving the overall health of law enforcement officers can provide economic motivation for an agency. However, an officer who meets physical fitness standards upon initial employment does not necessarily ensure overall health maintenance throughout a career (Bissett et al., 2012). An important part of one's well-being lies within the work environment. Health can be affected by work conditions, and although different types of stress exist, physical stress affects health the most (Phadke et al., 2014). A well-oriented and trained leadership is essential to a successful fitness program (FitForce, Inc., 2010). Workplace health promotion programs should engage employees and show long-term impacts on health and costs, as well as minimize absenteeism. But absenteeism needs to be specifically defined as it is difficult to measure (Steinhardt et al., 1991). Programs should operate in an environment that embodies best practices (Pronk, 2015) but to be successful, physical programs need top management support, exist in a supportive environment, and engage all levels of management (Pronk, 2009).

How officers are managed strongly influence their commitment and employees are more likely to contribute in positive ways, meaning cost benefits through lower absenteeism and lower turnover rates (Dick, 2011). Police leader management is linked to agency organization and is influenced by norms. These para-military organizations tend to have high levels of organizational commitment because the culture has strong obligational norms. A supervisor that wishes to implement a fitness program has a good chance of earning support from higher up. This type of support may have many benefits, including on-duty benefits (Williams, 2002). Physical fitness is part of a culture and can be supported from the top (i.e.: chief) down (Panos, 2010). Even when it comes to stress, quality work-peer relationships along with organization support are correlated with stress among police officers, and stress can affect the physical health and well-being of officers (Papazoglou & Andersen, 2014). Absence from work can be influenced by work structure. Policy that institutes any kind of health circumstances needs to consider the employer's structural influences and advocate presenteeism and its desirable outcomes. Organizations seeking to minimize absenteeism should perhaps focus on not only is an individual fit for work, but does the work fit the individual (Irvine, 2011).

Because public sector agencies (like law enforcement) have little or no incentive to change, leaders might question the relevance of supporting change. However, hiring processes and training academies change to adapt to the changing needs of the new generation; therefore, administrative practices and leadership also needs to change. Agencies need to balance both constancy and predictability that change must be adapted (Batts, Smoot, & Scrivner, 2012; Dick, 2011).

Within public decision-making, most ethical codes rely on internal, organizational controls (Franklin & Raadschelders, 2004). Franklin and Raadschelders (2004) found that both structural and procedural controls provide guidance to the decision-making process. The vertical chain-of-command can lend itself to isolated functions and so law enforcement agencies need to be proactive in their leadership to provide continuous and cross-functional development (Putney & Holmes, 2008). Supervisors, particularly executive management needs to both participate and support any fitness program (Quigley, 2008; Smith & Tooker, 2011). They should promote an appropriate culture of wellness that encourages employees to maintain a healthy lifestyle (Zimmerman, 2012). This commences the planning process.

Strategic planning in public sector agencies takes a "big picture" approach. It uses futuristic thinking and analyzes courses of action to ensure that an agency's effectiveness and abilities add to public value (Poister, 2010). Policy initiation is crucial to decision-making where first identifying background and problems are critical because there is always a gap between a problem and acting based on a decision (Political Science Notes, 2013). Commitment from top-level leadership is essential to successful strategic planning and execution as strategic planning needs to be consistent with top executive management style and the reality of an organization's decision-making process (Ugboro, Obeng, & Spann, 2011; Williams, 2002).

As good and practical as a fitness program may seem, the budget process may present dilemmas for its progress. Decisions made might favor some but not other values, but choices must be made (Franklin & Raadschelders, 2004). Civil servants play an important role in choices made during policy-making. Since they do not hold political office, they are not held to as intense political pressure because of reelection interests, so they bring a solid perspective to the playing field (Franklin & Raadschelders, 2004). Public agencies need to make an effort to be inclusive of their external stakeholders and involve them in the decision-making process, for example using surveys, focus groups or even forums (Poister, 2010). When it comes to fitness, levels in the workplace can directly or indirectly impact the community and society as it enhances local as well as national security and safety (Pronk, 2015).

Effective leadership will be critical in order for a police fitness program to be successful (Lee & Mallory, 2004). Strategy needs to be formulated by both top executives and line managers if planning is to be supported. This can be done by monitoring performance measures, aligning budgets with strategic plans, and communicating strategies to all stakeholders (Poister, 2010). Both internal and external partnerships are essential in collaborative efforts to ensure employee quality (Putney & Holmes, 2015).

Rational Choice Theory

Rational choice theory as initially described by Becker (1976) was applied to law enforcement leadership decision-making, attempting to explain the absence (or presence) of physical fitness standards at law enforcement agencies in North Carolina. Rational choice theory holds that individuals act as utility maximizers that include individual preferences and self-interest. More specifically in the social sciences, both individual behavior and social interaction affect the policymaking processes in government (Jones et al., 2006). It can be applied dynamically in which planning for the future and considering the present are included (Green, 2002). Analysis will usually begin with a question and can be worked through in several steps:

1. identifying relevant agents and constraints,
2. determining and applying consistent rules for each agent,

3. exploring predictions and experience, and
4. drawing conclusions (Green, 2002).

Rational is applied in social sciences as meaning that choices made reflect the most preferable and feasible alternatives that are available. The theory can be applied by focusing on three main components. (1) Maximizing *utility* is the assumption of rational choice theory, or in other words, choosing the preferred alternative that benefits the most. (2) Another element of the theory is *constraints*, or things/circumstances that exist in which making a choice is necessary, therefore also taking into the consideration the (3) *environment* in which choices are made. Theory follows the pursuit of specific objectives at an organization (Green, 2002). Even though policy is made by organizations, it is the interacting of human decision makers and individual choice that put such policy into action (Jones et al., 2006).

Rational choice theory contains several characteristics including that decision makers first, hold both ranked and ordered preferences for outcomes, and second, possess the necessary information to connect choices to outcomes to optimize preferred outcomes (Jones et al., 2006). Decisions are not made in a vacuum but they are made to serve definite purposes. Rationality needs to be important in the decision-making process, or public utility will be adversely affected (Political Science Notes, 2013).

Evidence suggests that a supportive organizational work environment has both a positive and direct influence on organizational commitment. In other words, commitment is influenced by the way employees are managed rather than by job demands (Dick, 2011). Rational choice theory, though most often an approach used to explain economics, can be applied to understand human behavior within the social sciences. It begins with making choices by one or more individual decision-making units and assumes such choices are made based on larger "typical" or "representative" populations. Analysis then examines how individual choices interact with one another to produce outcomes (Green, 2002).

Summary

A clear majority of police academies in the United States use some physical agility test that tests mostly for strength and endurance. Some agencies use agility tests, either as a pre-employment condition and/or a condition of continued employment. The reason is that these tests are most widely accepted as underlying factors that attribute to physical demands placed on police officers. Even though agility tests are commonly used to screen police applicants, the requirements of officers to maintain a standard of health and fitness are fewer (Bissett et al., 2012; Glassman, 2003), particularly among North Carolina agencies (Fortenbery, 2016). Studies consistently show that physical fitness does have a direct impact on reducing injuries as well as improving personal well-being and work performance (Quigley, 2008). Police agency policies do not reflect the findings for various, unknown reasons. Aside from personal health and agency cost benefits, a certain fitness level also portrays a more professional image, and contribute to reducing excessive use of force incidents (Williams, 2002). Both topics are worth pursuing in future research as it relates to officer fitness. But for now, chapter 3 presents the current research's methodological approach.

Chapter 3: Research Method

Introduction

The North Carolina Criminal Justice Commission mandates employment and training standards for law enforcement officers in the state. The Commission also regulates the required standards for the BLET program, including physical fitness. However, fitness is not one of the employment guidelines. A foundation for fitness is laid, but only across law enforcement training academies in the state; policy does not mandate fitness once officers are employed. Commission responsibilities do not extend into the agencies themselves when it comes to requiring certain fitness standards to remain employed. Therefore, there is a gap in academic research as to why some agencies continue fitness standards and others do not, particularly given knowledge of the benefits of healthy, fit individuals. Further, although the Department of Labor requires all industries to report work-related injuries to OSHA, it is not known whether there is some kind of connection or correlation between injured officers and set agency fitness standards. If there is, this information could both inform agencies across the state and contribute to the literature pertaining to North Carolina law enforcement agencies. The intent of the current mixed-methods study was to fill this gap in the literature, described in more detail as follows.

Research Design

This research study consisted of a mixed-methods approach using both quantitative and qualitative methodologies. A quantitative approach provided the statistics necessary to determine whether a relationship or correlation existed between fitness policies and work-related absenteeism and injuries among a small sample of law enforcement agencies in North Carolina. It did not provide an explanation as to why some agencies have instituted physical fitness policies and some have not. When research points not only to individual benefits, but agency benefits as well, the question is left unanswered as to why some policies are not in place. Therefore, the second phase of this study used a more detailed case study through a qualitative design to better understand this gap. For example, the use of a questionnaire explores who knows something as well as what is known (Bergman, 2008) within an agency.

Case Study

A multisite case study approach guided this research, as data collection involved multiple sources of information including policy and injury report documents and interview questionnaires (Creswell, 2013). Upon gaining appropriate approval to participate, six law enforcement agencies were examined to try to gain an understanding of why policy differences exist among agencies that have no (or voluntary) fitness policies, agencies that require some participation in fitness activities, and agencies that have very stringent and rigid policy. These agencies were selected purposely according to size and type of policy. In this study, a particular area of interest was determining whether a relationship existed between fitness policy and work injury and absenteeism, so it was necessary to first collect descriptive, quantitative data. The qualitative aspect further entailed examination of policy decision-making and implementation using interviews.

Research questions were considered before determining the order in which elements of the methodology were applied because order can influence results. For the current study, I used a concurrent QUAN -> QUAL design. The quantitative component was one stage of the concurrent design and was conducted at the same time as the qualitative component, which included the use of interview responses (Nastasi, 2010) to understand administrative roles in policy decision-making. The justification for the quantitative aspect was that I would use a sample to first determine whether a relationship existed between the independent and dependent variables, controlling for level of policy. I then examined how policy decision-making might influence any significant findings (*see Figure 1*).

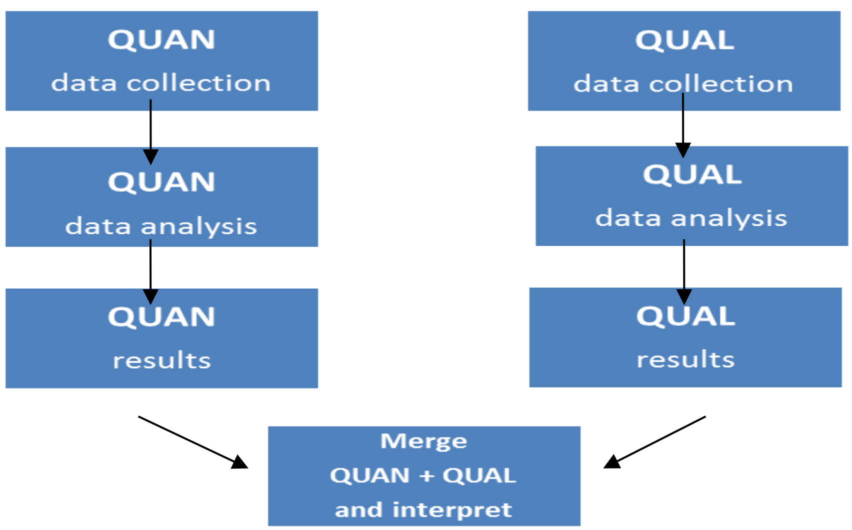

Figure 1. Concurrent/triangulation design. Adopted from *The Mixed Methods Reader* (p. 380), by V. L. Plano Clark & J. W. Creswell, 2008, Thousand Oaks, CA: SAGE. Copyright 2008 by Sage Publications, Inc.

Role of the Researcher

Having been a North Carolina BLET fitness instructor for 14 years, I have become aware that a gap exists between police academy fitness standards and law enforcement agency fitness standards in the state. In an effort to address this lack of understanding, I conducted an extensive search of academic and trade literature, looking at studies both within the United States and worldwide that pertained to police officer fitness, wellness, and job injuries. As I became familiar with this literature, I found that the same questions remained unanswered, and these questions consequently became the focus of this study. First, I sought to determine whether fitness requirements that carried over to law enforcement employment were related in any way to the prevalence of workplace injuries and/or absenteeism. Second, I sought to identify who made agency fitness policy decisions and what the rationale and influences were behind these policies.

To address whether fitness policy correlated with injuries and absenteeism, it was important to narrow down the field of study while remaining focused on law enforcement agencies in North Carolina. Because of time and cost constraints, it was necessary to identify a manageable sample of agencies within the state. Because past qualitative studies in this area had used a sample of six, it was determined that a sample of six agencies would serve the purpose of this study and answer the research questions being sought. First, agency fitness policies and OSHA 300A summary forms were examined and analyzed for significant variance. Second, an interview was conducted with a training officer at each site to gain a better understanding of the policy-making process. This meant first constructing a questionnaire in which the content addressed these questions. Feedback from a local advisory committee was sought to ensure that questions were on target regarding the information being pursued.

The next step was to identify and contact six law enforcement agencies in the Piedmont Triad area that were willing to participate. I explained the study before I gained the necessary permission to review the requested documents. Phone contacts were made until two agencies from each policy level category (voluntary, changed or progressive, and mandatory over a 5-year period) were identified. Mid-size agencies (serving a population of 50,000 – 500,000) were used for fair comparison purposes.

Creswell (2013) suggested that qualitative researchers collect their own data. Therefore, after gaining appropriate permission from the participating agencies, I made an appointment with each to both review documents and interview training officers. Anonymity was guaranteed, and results will be shared with the agencies after final analysis. It was my responsibility as the researcher to collect and analyze all data once appropriate Institutional Review Board approval had been secured. No individuals or agencies encountered any expenses related to participating in this study. Any expenses incurred because of this research were my responsibility as the researcher, including any supplies, travel, and documentation needed.

Research Population and Sample

According to the North Carolina Justice Academy (NCJA, n.d.), there are approximately 495 police agencies in the state, including state, municipal, county, hospital/healthcare, college, and airport agencies. The state is made up of 100 counties and is geographically divided into three regions: the Mountains, the Piedmont, and the Coastal Plains (see Appendix A). The Piedmont is the middle region of the state. Within this region, the Piedmont Triad consists of 12 counties (Piedmont Triad Regional Council, 2012). This region was the focus of the current study from which a sample was drawn for location and convenience purposes. In selecting a sample of law enforcement agencies located within the Piedmont Triad region (see Appendix B), the focus was on "midsize" populated areas (50,000–500,000 people) as defined by the International Association of Chiefs of Police (IACP, 2014). The IACP (2014) has cited nearly 700 midsize cities in the United States, hosting a combined population of more than 75 million. This is almost twice the population of major cities (those with populations greater than 500,000) and represents nearly one-quarter of the total U.S. population. These jurisdictions comprise a significant proportion of the American urban and suburban landscape. This is a significant presence in the American municipal landscape, and it has not been until recently that midsize cities and their associated police agencies have been a distinct area of focus for research, funding, or advocacy as recognized by the IACP in 2009. Since then, research priorities have focused on the needs and interests of midsized populations. For these reasons, I chose to draw a sample for the current research from this population base. Appendix C identifies the counties, cities, and state agencies that met the above criteria within the Piedmont Triad population base.

A sample of six midsize municipal North Carolina law enforcement agencies in the Piedmont Triad region was used for convenience. Two agencies from each of the following categories were studied: (1) no mandated/voluntary fitness policy over the last 5 years, (2) a changed or progressive fitness policy over the last 5 years, and (3) a continued mandated fitness policy over the last 5 years (2011-2015). Using these midsized agencies provided adequate data and statistics, from which any significant relationships in variance should be evident between policy level and injury and absenteeism reports. Using three categories allowed for comparison across policy type, and a 5-year period allowed for examination across multiple years to ascertain whether trends remained consistent.

Instrumentation

The documents collected at each agency consisted of instituted fitness standards for the years 2011-2015, as well as OSHA 300A forms documenting missed work days due to injuries or absenteeism for the same 5-year period. Hard copies of all documents have been kept in a locked file drawer within my personal home office, with the key located in a place only known to and accessible by me in order to protect confidentiality. Any electronic documents or correspondence related to this study have been saved on a designated research flash drive and kept in my locked possession. Backup electronic documents have been stored in a password-protected folder on my personal home computer. All records will be kept for a minimum of 5 years.

The second part of the study continued with interviews. Interviews are commonly used in qualitative research (Creswell, 2013). Interview questions addressed the following: (1) the rationale for department officer fitness standards, (2) whether policy was intended to address work-related injuries and illnesses, and (3) how policy decisions were made and influenced. Question wording in an interview is important because how questions are asked can affect the responses they elicit (Patton, 2002). The question categories listed above seemed appropriate to explore differences in policies, whether policy might contribute to work-related injury rates, and what influenced policy. The interview process allowed for the flexibility of emergent design with the questions covered. It allowed for both the interviewer and interviewee to include any additional information that emerged and was pertinent to the study through the use of open-ended questions.

Ethical Procedures and Considerations

The Code of Ethics of the Academy of Criminal Justice Sciences (ACJS, n.d.) was the guiding code for this study. This organization addresses the scientific discipline of those who study, research, teach, or practice in the criminal justice field. Criminal justice professionals are expected to adhere to the Code of Ethics when applying ethical behavior in their everyday professional activities. General principles within the code include recognizing the potential for harm, not knowingly placing the well-being of oneself or others in jeopardy within professional work, and ensuring anonymity in research (ACJS, n.d.). These principles guide law enforcement administrators, organizations, and educators, specifically within their policy and field practices.

Protection of Human Participants

Protecting human participants is important in research. In this study, data collection through interviews required human participation and contact. Because interviews were conducted at law enforcement agencies, physical safety was assumed. Because the content was not of a personal nature, there were no anticipated psychological effects. Participants were briefed on informed consent and privacy and were advised that at any time, they could elect to cease study participation without any repercussions.

Informed Consent

Informed consent is a process that includes telling participants who is conducting a study as well as why they were selected to take part. Rudestam and Newton (2007) provided practical guidelines on how to proceed with informed consent. When asking subjects to participate, it is appropriate to indicate the time commitment and any benefits that can be expected to arise from the study. In this case, the time commitment was approximately 2 hours per agency, and participants will be provided with both the data analysis and questionnaire results. Potential risks needed to be addressed, which in this study were minimal to none in relation to participants' agreement to provide policy documentation as well as injury statistics reports. All agencies that agreed to participate were asked to sign and return a letter of cooperation.

Right to Privacy

Participants are entitled to confidentiality (ACJS, n.d.), so it was important to protect the identity of all agencies and any names associated with them. Protection of both agency and individual identities was achieved by assigning each agency a number (e.g., Agency 1, Agency 2, or Training Officer from Agency 1, etc.). Allowing participants to ask questions and ensuring that participation was voluntary were also necessary (Rudestam & Newton, 2007) and were emphasized in the research process, both verbally and in writing.

Honesty

Honest communication and reporting of results is essential to ethical research. I engaged in no intentional misrepresentation or misleading action of any kind during the study. High ethical standards were applied, and the results were reported completely and honestly.

Institutional Review Board (IRB)

To ensure that ethical standards were applied, the IRB process served as a critical step in this research. Walden's IRB ensures that any research conducted under the auspices of the university complies with both ethical standards and federal regulations. Students, along with their committee members, must submit and receive IRB approval before collecting any data (Walden, 2010). To comply with Walden IRB requirements, I submitted a completed application prior to seeking participants for this study. Once approved, agency participants were contacted to voluntarily participate in this study.

Data Analysis

Statistical Package for Social Sciences (SPSS) was used to record and analyze the quantitative data to test the study's hypotheses. Frequencies, variance, standard deviation, and crosstabs were applied to provide a general distribution of descriptive statistics. Analysis of variance (ANOVA) was used in the data analysis to determine the significance of any variance between the study's variables. If the variables were found to be significantly related, the null hypothesis was rejected. I determined and defined the level of measurement for each variable used, which helped to determine the statistical analyses that were used (Thornton, 2011). In a quantitative analysis in which the aim is to generalize to a larger population, sample size is important. Given that a sample of six was used out of a population of 495, generalization was of course not possible.

Dissemination of Study Findings

The research results in total will be shared with participating agencies as well as the North Carolina Justice Academy and other interested law enforcement agencies in the state. Confidentiality and unanimity were and will be maintained. Personal contact will be made with each agency training officer upon completion of data analysis and results. Law enforcement trade magazines will be solicited for potential publication, making study results available to this targeted audience.

Validity and Reliability

To establish transferability in the qualitative aspect of this study, Creswell (2013) suggested that sampling is essential, particularly to establish external validity. In this study, purposeful sampling was utilized to select police agencies that made up varying levels of fitness policies. One of the most credible manners to ensure internal validity is through triangulation, or collecting data from various sources such as interviews, questionnaires, and assessing different documentation of data. Triangulation uses different research designs to examine data from different perspectives, which is why interviews were also conducted and included in the study evaluation. Every effort was made both verbally and in writing to ensure that all participants and agencies were respected and appreciated for their time and interest.

Summary

This study used a sample of six North Carolina law enforcement agencies to determine whether fitness policy influenced work-related injuries and absenteeism and what factors contributed to policy decision-making. By first using a quantitative analysis, results yielded whether a significant relationship between policy and injuries and absences among the sample agencies existed. If the null hypothesis was rejected because certain policies were related to fewer work-related injuries and absences, this study will provide support for advocating continued fitness beyond the police academy.

Additional analysis through examination of questionnaire responses determined whether rational choice theory supported policy decision-making, focusing on the utility function. This helped determine what factors contributed (at least partially) to policy and whether decisions being made were personal in nature, or representative of larger objectives. Organizations constantly undergo change, which can impact leadership. The one recognized as the leader is the one who has the potential and capacity to influence the group (Karp & Helgo, 2008). According to Bennis (2007), leadership is a matter of values. The next chapter discusses the results and how both quantitative and qualitative analyses have contributed to this field of study.

Chapter 4: Results

Introduction

The purpose of this mixed methods study was to test the utility function component of rational choice theory to determine whether it explains fitness policy implementation and whether such policy affects reported work-related injuries and absenteeism among a sample of midsized law enforcement agencies in the Piedmont Triad region of North Carolina. The quantitative portion of the study examined the stringency of agency fitness policy over a 5-year period (2011-2015; independent variable). Injury and absenteeism rates were calculated from OSHA 300A summary forms for each agency within this time frame (dependent variables). A control variable was also used based on whether an agency's fitness policy changed over this 5-year period, to measure any change in injury and absenteeism rates. The qualitative portion of the study examined the interview responses of training officers at each agency pertaining to fitness policy implementation, decision-making, and rationale. Responses were examined for common themes and whether they represented rational choice theory decision-making.

The research questions that guided this study were the following:

1. What relationship, if any, exists between a North Carolina law enforcement agency's fitness policy and work-related injuries and absenteeism?
2. When research emphasizes the benefits of maintaining a certain fitness level, particularly for first responders, does the utility function within rational choice theory explain why some North Carolina law enforcement agencies mandate physical fitness requirements for officers and others do not?

3. Are data-driven results of injury or absenteeism an agent or constraint as they pertain to the present fitness policy?

An extensive review of the literature was conducted pertaining to the content of interest, focusing on (but not limited to) current research done in this area over the last 5 years. Previous research focused on officer fitness, physical fitness testing, legal standards, policy implications, work injury and absences, and leadership. Very limited studies were found on law enforcement agencies in North Carolina pertaining to fitness policy, and none were found pertaining to OSHA-reported injuries and absences. Thus, this population became the focus for the current study, particularly when it was known that a gap existed involving state police academies requiring a fitness component while many law enforcement agencies had no such requirements as a condition of employment.

In this chapter, I report on my analysis of the findings from a sample of six law enforcement agencies based on fitness policy standards and change over a 5-year period, as well as yearly reported work-related injuries and absences. Additionally, I discuss how rational choice theory may play a role in fitness policy decision-making at an agency level when the utilitarian concept is applied, thereby explaining the data analysis of each research question that guided the study. In the last chapter, I present conclusions and implications of this research.

The Researcher

Creswell (2013) suggested that researchers provide information about themselves, the IRB process, steps to gaining entry to the sample, and ethics. As the researcher in this study, I had 6 years of experience as a sworn law enforcement officer in North Carolina, as well as 17 years as a criminal justice instructor at a community college. In 2001 and

2002, I became a certified general instructor and specialized physical fitness instructor, respectively, for the BLET program in the state. I was taught and administered the state-mandated fitness testing of cadets based on valid and scientifically tested research pertaining to physical activities that police officers are likely to encounter as part of the job. These credentials allowed me to teach any general curriculum block of instruction within BLET as well as oversee and assess physical fitness activities within the police academy. I routinely tested and evaluated police cadets on the required obstacle courses and fitness assessments, all necessary as a condition of graduation. I wondered why cadets were held to such a high standard of fitness in the police academy, whereas, more times than not, these or any physical requirements were not mandatory conditions of employment at a law enforcement agency. Policy was determined at the agency level, yet who was involved in these decisions, and what was the rationale behind them? This interest and concern for the well-being of officers in terms of wellness and safety followed me into my doctoral studies and thus led to the development of the current study. Therefore, it may appear that I had some bias concerning this topic; however, I made every effort in proposing, conducting, and analyzing this research to present the information in an ethical and objective manner.

Before collecting data, the appropriate and necessary steps were taken based on Walden University's IRB requirements. An application was submitted to the IRB outlining each step of the proposed research and my plans to protect both the confidentiality and identity of participants. Conditional approval was granted with the understanding that each participant (agency) would sign a letter of cooperation prior to any data collection. I then began contacting each of the agencies within my proposed population via telephone, soliciting the agencies' voluntary participation in my study. After an agency agreed to participate, a signed letter of cooperation was obtained and forwarded to the Walden IRB. Once an e-mail confirmation was received from the IRB, data collection at that agency commenced. A consent form as well as a data use agreement form were also collected from each participating agency and filed in that agency's electronic and hard files. After the total sample of six was reached, I had the necessary data to begin analyzing both my quantitative and qualitative data.

Setting and Recruitment Process

The population of midsized law enforcement agencies in the Piedmont Triad region of North Carolina totaled 11. An attempt was made to contact the training officers of all 11 agencies by telephone to ask them to participate in this study after I had briefly explained its intent. Several voicemail messages were left and of those agencies that did not respond, a follow up call was made. After reaching the appropriate contact at an agency and explaining my study, the conversation was followed up with an e-mail detailing the study's purpose, voluntary participation and the necessary information being sought for analysis, along with the need for a signed letter of cooperation if they agreed to participate. If no response was received from an agency within a 2-month period via e-mail, a follow-up e-mail was sent again inviting the agency to participate. After a period of 6 months, six agencies had responded and agreed to participate. For convenience and because of availability, these six law enforcement agencies were used as the nonprobability sample for case study analysis.

Instruments

Several instruments were used to collect data from the sample in the study. For the quantitative aspect of the analysis, a copy of each agency's fitness policy (see the sample agency fitness policy in Appendix D) was obtained (if such a policy existed) for each of the years 2011-2015. Additionally, a copy of each agency's OSHA 300A summary form (see Appendix E) was collected for the same 5-year period. A short questionnaire was used to analyze the responses pertaining to the qualitative aspect of the study, to gain a better understanding of the process and factors involved in policy decision-making at an agency.

Statistical Package for the Social Sciences (SPSS, 2015) was used for quantitative analysis to address Research Question 1. The rationale for the choice of statistical test and assumptions associated with the statistic were based on the research question and therefore are discussed in more detail below. Line-item data mining in Windows Excel was used for qualitative analysis to address Research Questions 2 and 3. Responses and themes were explored to test rational choice theory.

Quantitative

Each agency's physical fitness policy for the years 2011-2015 was coded per policy level and assigned a value; 1 (*no policy/voluntary participation*), 2 (*general policy/voluntary participation*), 3 (*annual in-service/testing*), and 4 (*biannual testing*); (Means, Lowry, & Hoffman, 2011c). For analysis purposes, each agency was then placed in a category per the stringency level of its fitness policy (from least to greatest) and assigned a value number. Whether policy changed over the years between 2011 and

2015 was also indicated; 1 (*no change*) and 2 (*increased standards*) for each agency, each year.

Absence and injury rates were computed for each agency's OSHA 300A form for the years 2011-2015. The absence rate was computed by dividing the total number of days away from work by the total number of employees multiplied by 100 and rounded to the nearest hundredth. Absence rates ranged from 0–156.14. The injury rate was computed by dividing the total number of injuries by the total number of employees multiplied by 100 and rounded to the nearest hundredth. Injury rates ranged from .82–14.56. These rate standardizations allowed for comparison across agencies due to the variance in number of employees. See Appendix F for a summary of the quantitative data.

Qualitative

Each training officer (or designee as determined by the agency head) at the six agencies was provided with a questionnaire inquiring about the number of sworn officers within an agency, and whether the agency was accredited by the Commission on Accreditation for Law Enforcement Agencies (CALEA), with the assumption being that those agencies that were CALEA accredited were likely to have some type of fitness policy in place. The questionnaire also included whether an agency had a fitness policy over the 5-year period of 2011-2015, and if so, whether participation in fitness and wellness activities was voluntary or mandated. The remaining five questions were meant to test rational choice theory and address the policy decision-making process. These questions included the following:

- What is the rationale behind having/not having a fitness policy in place, or for changing policy?
- Who are involved decision makers in fitness policy?
- What factors determine or affect fitness policy?
- Was policy intended to address work-related injuries and illnesses?
- Are you aware that North Carolina provides a full public health mandate that includes injury prevention, and if no, would you want more information, or if yes, was this considered in fitness policy implementation? (See Appendix G.)

Qualitative research can be deemed valid using triangulation and member checking (Creswell, 2013), and so at the same time policy and OSHA data were being collected, these questions were reviewed and verified by speaking with the training officer or designee. For data to be considered qualitatively reliable, consistency is important (Creswell, 2013); therefore, the same questions were asked of each agency.

Demographics

For analysis purposes, participants were actual agencies, for which employee demographics were not known, except by raw numbers. This was done to protect the confidentiality of agency employees. Though the questionnaire was completed by one individual employee at the agency, these individual demographics were not recorded, but the employee's agency responsibilities were noted.

Agency 1

Agency 1 was a county law enforcement agency located in the Piedmont Triad region of North Carolina serving an estimated population of 142,799 (U.S. Census Bureau, n.d.). The number of employees at the agency ranged from 228–262 over the years 2011–2015. This agency did not have a fitness policy for sworn officers (and so it was voluntary on the employee's part to participate in any physical fitness activities) during the 5-year period.

Agency 2

Agency 2 was a county law enforcement agency located in the Piedmont Triad region of North Carolina serving an estimated population of 158,276 (U.S. Census Bureau, n.d.). The agency ranged in number of employees from 892–1206 over the years 2011–2015. This agency did not have a fitness policy for sworn officers (and so it was voluntary on the employee's part to participate in any physical fitness activities) during the 5-year period.

Agency 3

Agency 3 was a municipal law enforcement agency located in the Piedmont Triad region of North Carolina serving an estimated population of 110,268 (U.S. Census Bureau, n.d.). The agency ranged in number of employees from 248–268 over the years 2011–2015. This agency did not have a fitness policy for sworn officers during the 5-year period; however, incentives at either the city or county level were available to employees, though participation to receive these incentives was voluntary.

Agency 4

Agency 4 was a municipal law enforcement agency located in the Piedmont Triad region of North Carolina serving an estimated population of 285,342 (U.S. Census Bureau, n.d.). The agency ranged in number of employees from 881–929 over the years 2011–2015. This agency had a general policy that addressed the necessity of employees maintaining their health to adequately perform job functions. This policy remained the same over the 5-year period, and several incentives at either the city or county level were available to employees, but participation in these incentive programs was voluntary.

Agency 5

Agency 5 was a county law enforcement agency located in the Piedmont Triad region of North Carolina serving an estimated population of 369,019 (U.S. Census Bureau, n.d.). The agency ranged in number of employees from 230–243 over the years 2011–2015. Over the 5-year period, the agency did require sworn officers to participate in 2 hours of health and wellness in-service training each year, and annual POPAT testing was mandated.

Agency 6

Agency 6 was a municipal law enforcement agency located in the Piedmont Triad region of North Carolina serving an estimated population of 52,472 (U.S. Census Bureau, n.d.). The agency ranged in number of employees from 164–182 over the years 2011–2015. Over the 5-year period, the agency gradually incorporated a mandated biannual POPAT testing of all sworn officers.

All sites had onsite fitness facilities that employees could use at no charge. Several agencies also offered either free or discounted memberships at local fitness facilities. The first three agencies with no fitness policy were not CALEA accredited; the last three agencies with written fitness policies were CALEA accredited, as assumed.

Data Collection

The location of the population of interest in this study—the Piedmont Triad region of North Carolina—was purposely selected for convenience purposes as well as the purpose of collecting data from a similar geographical region. Again for consistency purposes, midsize agencies were also the focus of this study; the total number of agencies fitting these criteria from which to draw a sample was 11. The purpose was initially to capture a total of six agencies for case study analysis, representing three categories of varying fitness policies: two not having any fitness policy in place, or a voluntary policy; two having increased in policy stringency over a 5-year period; and two having strict, mandated fitness standards required for officers. After I had contacted each agency and explained the study, six of the 11 responded with their willingness to participate; however, the categories of policy that they represented were not what I had initially proposed. After mining through the data, I observed that four levels of policy were distinguishable and would make for a more detailed analysis. The quantitative data were made up of policy level, any change of policy within the 5-year period, and OSHA 300A injury and absenteeism summary reports. This information was analyzed to address Research Question 1. The qualitative data were made up of questionnaire responses and were analyzed for common themes to assess, first, whether the utilitarian function within rational choice theory existed (Research Question 2), and second, whether data served as an agent or constraint to current fitness policy (Research Question 3).

Data Analysis

Three research questions guided this study:

RQ 1. What relationship, if any, exists between a North Carolina law enforcement agency's fitness policy and work-related injuries and absenteeism?

RQ 2. When research emphasizes the benefits of maintaining a certain fitness level, particularly for first responders, does the utility function within rational choice theory explain why some North Carolina law enforcement agencies mandate physical fitness requirements for officers and others do not?

RQ 3. Are data-driven results of injury or absenteeism an agent or constraint as they pertain to the present fitness policy?

Using these questions, the research data were analyzed both quantitatively and qualitatively. Descriptive statistics, crosstabs, one way ANOVA, and an *F*-test were calculated. Then line analysis data mining with Excel was utilized to test rational choice themes. Per agency policy, agencies were listed in order according to policy stringency, with the first agency listed having no policy or incentives at the top, on down to the last agency listed that had a mandated, biannual testing policy. The policy level (independent variable) for each agency (each of the 5-year period) was coded to form an ordinal variable from 1 – 4; *1* being no fitness policy to *4* requiring biannual fitness testing. Policy change was used as a control variable, to determine if a change in policy over these years affected injury or absenteeism rates. This was coded ordinally where *1* meant no change from one year to the next, and *2* meant an increase in fitness standards required from one year to the next. Both absent rate and injury rate (ratio, dependent variables) were calculated into standardized rates for comparison purposes. Descriptive statistics are provided for each variable as they describe what the data shows (Trochim, 2006). Table 1 shows the six-agency sample arranged per strictness of policy level. Policy change indicates from one year to the next whether policy did not change, or increased in required fitness standards.

Table 1

Agency Demographics of Sample

Variable	Labels	Level of measurement	Mean	*SD*	Range
Agency	1 = Agency 1 2 = Agency 2 3 = Agency 3 4 = Agency 4 5 = Agency 5 6 = Agency 6	ordinal			
Policy level (IV)	1 = no policy/ voluntary participation 2 = general policy/ voluntary participation 3 = annual in-service/ testing 4 = biannual testing	ordinal			
Policy change 2011-2015 (CV)	1 = no change 2 = increased standards	ordinal			
Absence rate (DV)		ratio	31.21	32.91	0-156.14
Injury rate (DV)		ratio	6.90	3.17	.82-14.56

Research Question 1

The first research question attempted to determine whether having a strict fitness policy affected work-related injuries or absences. The null hypothesis suggests that no significant relationship exists between the stringency of fitness policy and job-related injuries and absenteeism rates; therefore, the alternative hypothesis suggests that the more stringent a fitness policy is, the lower the job-related injuries and absenteeism rate.

A bivariate correlation could not be conducted because the data violated several assumptions of this analysis. First, variables must be continuous; in the sample both the independent and control variables are ordinal level measurements. A second assumption is that a linear relationship exists between variables, and with this study's data they do not (which also eliminates the use of partial correlation and linear regression). Another assumption of correlational analyses is that no significant outliers exist which was also not true with the data. A fourth assumption assumes homoscedasticity, and upon conducting a scatterplot of the data, heteroscedasticity was detected, so therefore not suggested that correlation be used in analysis (Laerd Statistics, 2013).

When a group comparison of at least one independent variable is being used, analysis of variance (ANOVA) can be used as a statistical test (Creswell, 2013). For this test, the independent variable should be categorical, and the dependent variable should be continuous, which in this study is the case; therefore, ANOVA was selected as the statistical test to answer Research Question 1. Green and Salkind (2011) state that a one-way ANOVA can be used to analyze data from a quasi-experimental study and the F-test evaluates whether the group means on the dependent variable differ significantly from each other. Then, an overall analysis of variance test can assess whether dependent variable means are significantly different among groups.

In social research, Trochim (2006) advises a statistical power greater than 0.8 in value as a rule of thumb. This means having at least 80 chances out of 100 of finding a relationship when there is one. Statistical power is the ability to detect effects given the variance and sample size (Vogt & Johnson, 2011). Several factors interact to affect power. One is to use a larger sample size, another is to increase the risk of making a

Type I error, or increasing the chance that a relationship is found when it is not there. This can be done by raising the alpha level (Trochim, 2006). In this study the agency sample size of six is small; however, the total number of employees that the sample represents is over 2700. So, it could be argued that using an alpha level of .05 demonstrates a significant statistical power of .95.

ANOVA

First, a one-way ANOVA was conducted to evaluate the relationship between policy level of an agency and absenteeism rate. The independent variable, the policy level factor, included four levels of fitness policy: no policy/voluntary participation, general policy/voluntary participation, annual in-service/testing, and biannual testing. The dependent variable was the rate of work days missed each year over the 5-year period of 2011-2015. The ANOVA was significant $F(3,27) = 5.02$, $p < .01$. The strength of relationship between policy and absent rate, as assessed by η^2 was strong, with policy level accounting for 36% of the variance of the dependent variable.

Next, a one-way ANOVA was conducted to evaluate the relationship between policy level of an agency and injury rate, which was the rate of injuries each year over the same 5-year period. The ANOVA was significant $F(3,27) = 6.96$, $p < .001$. The strength of relationship between policy and injury rate, as assessed by η^2 was strong, with policy level accounting for 44% of the variance of the dependent variable.

Because the overall ANOVA was significant and there were more than two levels in the independent variable, follow-up tests are usually conducted to evaluate pairwise differences (Green & Salkind, 2011). Therefore, it was decided to conduct follow-up tests of Tukey, REGWQ and Dunnett's *C* as suggested by Green and Salkind (2011) to evaluate pairwise differences among means. Dunnett's *C* test does not assume equal variances among the four groups and so these results were used to assess both absenteeism rate and injury rate between policy level. There was no significant difference in the means between any policy level and absent rate. However, there was a significant difference in the means between the following:

- Level 1 policy (no policy/voluntary participation) and Level 3 policy (annual in-service/testing)
- Level 1 policy (no policy/voluntary participation) and Level 4 policy (biannual testing)
- Level 2 policy (general policy/voluntary participation) and Level 3 policy (annual in-service/testing)
- Level 3 policy (annual in-service/testing) and Level 4 policy (biannual testing).

The agencies that required annual in-service and testing showed a greater decrease in injury rates compared to agencies with other policy types. The 95% confidence intervals for the pairwise differences, along with the means and standard deviations for the four policy groups, are reported in Table 2.

Table 2

95% Confidence Intervals of Pairwise Differences in Mean Changes of Injury Rates

Policy level	*M*	*SD*	Level 1	Level 2	Level 3
1 – No policy/ voluntary participation	7.25	3.24			
2 – General policy/voluntary participation	7.67	1.97	[-3.84, 3.01]		
3 – Annual in-service/testing	3.13	1.51	[.42, 7.82*]	[.97, 8.11*]	
4 – Biannual testing	10.79	1.05	[-7.02, -.05*]	[-6.49, .25]	[-11.39, -3.93*]

A second set of ANOVA were conducted examining the control variable (change in policy). A one-way ANOVA was conducted to evaluate the relationship between policy change and absent rate. The control variable, whether policy changed from one year to the next, included two levels: no change and increased standards. The dependent variable was the rate of work days missed each year over the 5-year period of 2011-2015. The ANOVA was significant $F(1,29) = 14.92$, $p < .001$. The strength of relationship between policy change and absent rate, as assessed by η^2 was strong, with policy change accounting for 34% of the variance of the dependent variable.

A one-way ANOVA was conducted to evaluate the relationship between policy change and injury rate, which was the rate of injuries each year over the same 5-year period. The ANOVA was significant $F(1,29) = 7.02$, $p < .01$. The strength of relationship between policy change and injury rate, as assessed by η^2 was strong, with policy change accounting for 20% of the variance of the dependent variable.

The interpretation of the current data has been evaluated on ANOVA analyses. In conclusion, to answer whether a relationship exists between a North Carolina law enforcement agency's fitness policy and work-related injuries and absenteeism, the analyses assumes there is a relationship, therefore rejecting the null hypothesis and accepting the alternative hypothesis.

Research Question 2

Research Question 2 attempted to test whether the utilitarian function of rational choice theory explained why specific fitness policies were in place. In other words, was policy decision the preferred alternative that would benefit agency employees most? Several questions in the agency questionnaire were designed to address this.

The first question inquired about the rationale behind having/not having a fitness policy in place, or the reason for changing policy. Agencies had varying responses. Of those agencies that had a fitness policy, improving employee wellness and productivity, along with increasing officer safety were common responses. Agency 6 identified several motivational factors to include:

- reducing long-term medical costs for employees
- improving employee wellness and productivity
- increasing officer safety
- increasing the life span of employees

Agency 4 identified a standard operating procedure in which their objective was to "develop and maintain a level of fitness in police personnel and to ensure their ability to accomplish assigned duties and provide satisfactory job performance without undue risk of injury or fatigue." The change in policy for Agency 5 was due to a Sheriff initiative to improve the overall health of employees. Of the agencies that did not have a fitness policy, one indicated that it was "due to case law, cost, manpower, buy in from administration, and law suits." Having no policy may be impacted of Title VII of the Civil Rights Act which requires all employers with more than 15 employees to refrain from policies that discriminate against specified categories of individuals (U.S. EEOC, n.d.). Title VII can be ambiguous and many standards have not been interpreted by the Supreme Court. Even federal circuit courts differ on these decisions. Since the courts cannot clearly define these standards, it can burden administrations with continued monitoring of court decisions and legislation. Under Title VII, physical fitness standards face scrutiny when they might discriminate against a protected group (for example females, individuals over 55 years of age). Employees must demonstrate that the practice is job-related and necessary. Therefore, in justifying physical fitness requirements, can it be justified as a necessity of law enforcement work? To demonstrate this, administrators must show a significant relationship between the physical fitness requirement and job responsibilities (Brooks, 2001). Agency 2 indicated that "the agency was in the process of reviewing and updating several policies and have not addressed this issue yet", and Agency 3 reported that "physical fitness policy had never been addressed."

The next question asked who was involved in the policy decision-making process. Not surprisingly, all responded that the agency head (Chief of Police or Sheriff) were the final decision makers. However, of those involved with the input process, responses ranged from few individuals within the agency to larger committees that included members outside of the agency. Four agencies indicated that decision makers on such policy came from within the agency such as executive staff, administration (directors, commanders) and other employees. Two agencies also included decision makers outside of the agency itself such as occupational health staff, human resources director, city manager, and city attorney. There was no consistency in agency type as far as who was included in decision-making. Or in other words, municipal agencies were just as likely as county agencies to involve personnel outside of the agency in policy decision-making.

The last question asked to address Research Question 2 sought to determine what factors affected fitness policy decision-making. Common responses included manpower, cost, and resources. Some were also concerned with the legality of such a policy and how standards would be enforced or maintained. But, these common theme responses existed within agencies that both had stricter policies and those that had none. Interestingly, of the two agencies that had the more stringent policies, though cost, training, and manpower were also mentioned, the agencies prioritized these resources to comply with policy. Taking a more holistic approach was also a factor for these agencies. As it pertains to their fitness policy, one stated that they had "to find a balance between stewardship to the taxpayer and providing our employees some opportunities to maintain and improve their health." All agencies had on-site fitness facilities and equipment and/or community resources such as recreation centers, gyms, or fitness centers. See Table 3 for a summary of agency responses to these questions.

Table 3

Agency Responses to Policy Rationale

Question	Agency/Responses
What is the rationale behind having/not having a fitness policy in place, or for changing policy?	1 – the agency is in the process of reviewing and updating policies in order to apply best practices.
	2 – case law, cost, manpower, buy in from administration, law suits
	3 – physical fitness policy has never really been addressed
	4 – the objective of the department is to develop and maintain a level of fitness in police personnel and to ensure their ability to accomplish assigned duties and provide satisfactory job performance without undue risk of injury or fatigue
	5 – it was one of the Sheriff's initiations in 2002
	6 – to reduce long-term medical costs for employees, to improve employee wellness and productivity, to increase officer safety, and to increase the life span of officers/ employees
Who are involved decision makers in fitness policy?	1 – Sheriff and Administrative Major who verifies policy changes to ensure it complies with law
	2 – Sheriff, Chief Deputy, Director Personnel/Training
	3 – Chief of Police and Executive Staff
	4 – Chief of Police Bureau Commander, Training Division Commander and/or other departmental employees
	5 – Sheriff and committee
	6 – Chief of Police, Occupational Health staff, HR Director, City Manager, City Attorney
What factors determine or affect fitness policy?	1 – resources, manpower, cost
	2 – resources, manpower, cost
	3 – time, money, effort, legality, injury, penalty for failure to maintain standards, resources, equipment
	4 – finding a balance between stewardship to the taxpayer and providing employees some opportunities to maintain and improve their health
	5 – we have the manpower, a more holistic approach was needed
	6 – cost, provide training, build a gym/fitness center, staffing was not a major concern

Rational choice theory assumes that individuals interact in a social process as part of decision-making, and in an organization, collective individual actions affect policymaking and input comes from both individual behavior and social interaction (Jones et al., 2006). It examines how individual choices interact with one another to produce outcomes, and how decisions are made by both considering the present and planning for the future (Green, 2002).

The above questions on the agency questionnaire were designed to test this theory to determine why specific policies were in place among a small sample of law enforcement agencies in North Carolina. The meaning of *rational* is applied to mean the most preferable and feasible alternatives available. One component of this theory holds that within a setting, decision makers will choose an alternative that benefits the most. This assumes that first decision makers have ranked preferences for outcomes and possess the necessary information to optimize the preferred outcomes (Jones et al., 2006). A closed-ended question on the questionnaire was asked of the agencies whether they were aware that North Carolina provides a full public health mandate that includes injury prevention. Only one responded yes. This agency had a more general wellness policy, but no specific fitness standards for officers. Two agencies responded no and three agencies did not answer definitively. Perhaps having knowledge or utilizing state resources available could assist agencies in this policy making process, but the question may have been vague or confusing, or maybe more detailed information should have been provided to the agency's before asking this question.

Decisions are made to serve definite purposes and populations. Therefore, rationality is important in the decision-making process otherwise public utility can be adversely affected (Political Science Notes, 2013). With the responses given, it was not entirely clear on how agencies determined fitness policy. Perhaps questions should have delved into more detail as to *how* each factor was considered, rather than just listing *what* factors were considered in policy. However, in all cases more than one individual was involved in the discussion and input of policy (or policy change), therefore confirming that an interaction process took place with a decision being made as to the best choice for the agency with the resources and information present. It is more difficult to determine whether the utilitarian component outshined other options because of the limited information provided within question responses. So, to apply rational choice theory in general makes sense per the responses from agencies, but not enough is known as to why the utilitarian function of the theory explained fitness policy implementation.

Research Question 3

Research Question 3 attempted to find out whether data-driven results of injury or absenteeism are an agent or constraint as it pertains to fitness policy. One question on the agency questionnaire was asked as to whether policy intended to address work-related injuries and illnesses. Two agencies that had no fitness policy and one agency that did not have a policy but did have employee fitness incentives in place responded negatively to this question. The other three agencies that responded positively had some type of fitness policy in place, with policy ranging from more general to very specific standards.

Applying rational choice theory to these responses make sense as one element of the theory is constraints, or things/circumstances that exist, making a choice necessary. Constraints also take into consideration the environment in which a choice was made (Green, 2002). Within each agency several factors as well as participants are involved in the decision-making process. Although ultimately it is the agency head who makes the final decision, there is no doubt that influences from others and the environment play a part. It is this interaction among human decision makers and individual choice that put policies into action (Jones et al, 2006).

Serving as constraints to agencies with no fitness policy seemed to be the common factors of cost, legal implications and manpower. These factors seemed to play a part in the policy decision-making process. Something that is not known is how much influence other individual(s) involved in the process had. It was not explored in the initial questioning but could have been valuable in addressing this particular research question.

For those agencies that had some type of fitness policy, common agents seemed to specify the necessity of officer health and safety, ensuring that officers could accomplish their duties. Wellness incentives in written policy emphasized the agency's commitment to the well-being of officers so they could perform essential job tasks. Taking a holistic approach and finding balance between providing public services and providing for employees were common rationale. These agencies sought funds (either through city/county funds or grants) and provided training and facilities to ensure officer needs were met.

With the data that was collected and qualitatively analyzed, it is concluded that the null hypothesis be rejected, assuming that injuries and/or absenteeism rates are an agent of the current fitness policy. This was determined by examining the written policy of the agencies that had a current fitness policy in place. This analysis used several steps according to rational choice theory; identifying relevant agents and constraints, applying consistency, exploring predictions, and drawing conclusions (Green, 2002).

Threats to Internal Validity—Instrumentation

After conducting the analyses for this research, several observations must be mentioned as it pertains to the validity of the instruments used. The first instrument used, also serving as the independent variable was written agency fitness policy. The information was interpreted at its face value and believed to be represented and interpreted correctly in the study. However, for comparison purposes, I defined four categories in ranked order, from no policy present to the most stringent, mandatory policy. Perhaps another researcher would define or categorize policies differently for analysis purposes.

To control for any differences in policy change over the 5-year period, a binominal variable was created to simply represent that a fitness policy did change from year to year, or did not change from year to year. This again was a discretionary decision, and perhaps others would approach control in a different manner.

The use of OSHA mandated reported injuries and absences on the summary 300A form became questionable as to whether these records could be considered valid. For example, one agency reported employees having 164 days away from work (absenteeism), yet the next year, two days were reported and the year after that zero days were reported. So, whether the OSHA form was the most appropriate measure of injuries and absenteeism is questionable. Perhaps a better, more accurate and valid instrument might better have addressed the research questions, but this information was not initially known and so not observed until after data analyses. In addition, OSHA forms did not specify or differentiate officer injuries and absences from other agency employees such as nonsworn or civilian. One county agency even included all county employees in the summary form and did not distinguish between officer and other personnel.

The last instrument used was the agency questionnaire designed to test rational choice theory in the policy decision-making process at agencies. I designed the questionnaire, with input from a criminal justice advisory committee, made up of local criminal justice practitioners. Upon qualitative analysis of the data, it became evident that the questionnaires did not delve deep enough into the details of policy input, such as whether agency heads were pressured into having or not having a fitness policy, or if politics in any way played a role in this process. Therefore, one might argue that the questionnaire might pose internal validity threats.

When discussing validity in general, conclusion validity might be worth mentioning. This is essentially whether a relationship between variables is a reasonable one or not, given the data being studied. In this study, it is possible to conclude that, while an overall significant relationship seems to exist between policy and injury and absenteeism rates, the policy itself may not have caused the outcome. Perhaps some other factor(s), and not policy alone was responsible for the results of the study (Trochim, 2006).

Trustworthiness

On 09/01/16 Walden University IRB approved the proposed research study with the condition that each agency provide a signed letter or cooperation prior to data collection (Walden University IRB approval #09-01-16-0316158). Over a period of 5 months (October 2016 – March 2017), the six agencies that agreed to participate were approved by IRB as data collection sites. I covered all documentation and travel expenses related to the study as not to incur any cost to the agencies. After collecting all documents and speaking to the training officer at each agency, both a verbal and appreciation was voiced and a thank you card was sent to those involved in providing the data from each agency. The information was then reviewed and validated to verify and gain a better understanding of it. This helped to protect the integrity of the research.

A case study was selected for this research to gather some data about fitness policy and injury and absenteeism rates, as well as how policy is decided among a sample of law enforcement agencies in the Piedmont Triad area of North Carolina. Case study is designed to focus on the activities of organizations and to describe rather than generalize. Therefore, transferability of the results outside of the study might be difficult to justify. The collection of data for this study is assumed to be trustworthy as each instrument used (policy, OSHA forms and questionnaires) were reviewed with the training officer of the agency to ensure both the validity of data and to verify any oral and written communication recorded on the questionnaire through confirmability, or a reflective use of participant perspectives. This was used to build justification for themes (Creswell, 2013).

Through the presentation of this study's purpose, data analyses, ethical considerations, and limitations discussion, it is hoped this research is viewed as both dependable and credible. Dependable in that an assessment of the integrated process of data collection, data analysis and theory generation were proposed and conducted; and credible in that every effort and intention was made to accurately interpret the data collected. All information was carefully documented and reported to provide the necessary details so similar future research might replicate the study if desired.

Summary

This chapter presented information on the recruitment process and instruments used to conduct the study pertaining to law enforcement fitness policies in relation to job injuries and absenteeism. Demographics on the six North Carolina law enforcement agencies in the sample were provided, as were the steps taken in the data collection process. Both qualitative and quantitative analyses were conducted to address the three research questions.

Agency fitness policies and OSHA 300A summary forms of six North Carolina midsized law enforcement agencies over a 5-year period were utilized in this multisite case study to determine whether a relationship existed between policy stringency and injury and absenteeism rates. Based on the quantitative analyses of ANOVA, Research Question 1 was addressed. A greater statistical significance was found between policy levels and injury rates than between policy level and absenteeism rates. When controlling for any change in policy from year to year, the opposite was found to be true.

Research Question 2 was analyzed qualitatively through responses on a questionnaire addressing policy decision-making factors and personnel. An agency's training officer or designee provided the responses. Overall data from participant responses resulted in the emergence of common themes that were then applied to the utilitarian function within rational choice theory. Research Question 3 also utilized specific questionnaire responses and determined that injuries and/or absenteeism rates were an agent of current fitness policy.

Chapter 5 interprets the findings and discusses the implications for social change. It also makes recommendations for further research and provides a conclusion to this study.

Chapter 5: Discussion, Conclusions, and Recommendations

Introduction

The purpose of this mixed methods multisite case study was to determine whether fitness policy affected reported work-related injuries and absenteeism among a sample of six law enforcement agencies in the Piedmont Triad region of North Carolina, and to test the utility function component of rational choice theory to ascertain whether it explains fitness policy implementation. OSHA-reported injury and absenteeism data were used from years 2011-2015 to examine any effects that may have resulted in policy change. Training officers were then asked about the policy decision-making process at each agency.

Interpretation of the Findings

A large amount of research has been conducted on the topics of law enforcement fitness for duty, as well as work-related injuries and absenteeism, both internationally and in the United States. However, a very limited amount of research has been conducted on agencies in North Carolina, and more particularly on midsize agencies across the state. No similar academic research was found that had been conducted to examine OSHA-reported injuries and absenteeism in relation to fitness policy levels. The findings correlated with much of the existing literature addressing the role that fitness plays in injury prevention.

Three research questions guided this study and were designed to measure the effects of both fitness policy decision-making and work-related injury and absenteeism rates:

1. What relationship, if any, exists between a North Carolina law enforcement agency's fitness policy and work-related injuries and absenteeism?
2. When research emphasizes the benefits of maintaining a certain fitness level, particularly for first responders, does the utility function within rational choice theory explain why some North Carolina law enforcement agencies mandate physical fitness requirements for officers and others do not?
3. Are data-driven results on injury or absenteeism an agent or constraint as they pertain to the present fitness policy?

Research Question 1

To determine whether a relationship existed between a certain fitness policy level and injury and absenteeism rates, participating agencies were asked to provide a copy of their fitness policy for years 2011-2015 as well as a copy of their OSHA 300A summary form for the same 5-year period. For each of the 5 years, a fitness policy was placed in to one of four categories, creating the independent variable *policy level.* The levels included (in increasing order) those agencies with (1) no fitness policy, (2) a general/voluntary fitness policy, (3) annual in-service and mandatory fitness testing, and (4) biannual mandatory testing. If fitness policy changed from one year to the next, it was noted and used as a dummy control variable (*policy change*) to determine whether change in policy made a significant difference in injury or absenteeism rates. It was only noted whether there was no change in policy, or whether an increase in policy level took place. For injury and days missed from work, a standardized rate (per 100 employees) was calculated to allow for comparisons across different agency sizes.

With SPSS, ANOVA was then applied using the *F*-test to evaluate whether group means within the dependent variable differed from each other among injury rates and absenteeism rates. It was found that ANOVA was significant between both policy level and injury rates, as well as policy level and absenteeism rates. The overall ANOVA was significant, and so follow-up tests were also conducted to evaluate pairwise differences among means. No significant difference was found between policy level and absenteeism rate, but a significant difference was found between policy level and injuries, with the agencies that required annual in-service and testing showing a greater decrease in injury rates when compared to agencies with other policies.

Theoretical Concepts

Rational choice theory (RCT) indicates that individual behavior and social interaction affect the policymaking process. This process begins with making choices; under rational choice theory, it is assumed that choices are made based on larger representative populations (Green, 2002). In RCT, rational is meant to reflect the most feasible and preferable alternative through utility maximization or the alternative that has the greatest benefit. The environment in which the choice is made contributes to the constraints or circumstances that exist, as decisions are not made in a vacuum. Then analysis examines how choices interact to produce outcomes (Green, 2002). Jones et al. (2006) contended that even though organizations make policy, the interaction of human decision makers along with individual choice is what puts policy into action because individuals want to maximize their preferences and self-interest. Decision makers hold ordered and ranked preferences for outcomes and possess the necessary information to connect choices to preferred outcomes. Therefore, the rationality component is important in decision-making; otherwise overall utility will be affected (Political Science Notes, 2013).

The next two research questions were designed to test RCT through qualitative analysis. A multisite case study was used because input from multiple agencies would provide more abundant insight about the decision-making process than input from one or few agencies. It also provided an opportunity to mine for common themes among responses. A questionnaire was designed to ask agency training officers about policy decision-making to determine if policy choice was indeed guided by RCT concepts. The questionnaire consisted of six main questions and four sub questions inquiring further into certain responses. Three of the questions were designed to address Research Question 2.

Research Question 2

To test whether the utility function within RCT explains policy decision-making, three questions were asked of agency training officers. The questions included inquiry about the rationale behind current policy, involved decision makers, and factors affecting policy. After a written record of the responses was received from each agency, member checking was conducted to verify response content. The narrative data were then analyzed, coded, and interpreted. Improving employee productivity and wellness, and increasing officer safety were common themes among agencies that had a fitness policy in place. Case law implications, cost, and lack of manpower and administrative support were common responses among those agencies without a fitness policy in place. Responses to the question inquiring as to who was involved in the decision-making process included both internal as well as external agency employees, with all agreeing that the agency head had the final say. Common factors affecting fitness policy were cost and resources, similar factors found in the rationale behind current policy.

It could be argued that the responses represent RCT, in that both individual behavior and social interaction played a role in the policymaking process. Of those agencies including input from multiple individuals (both inside and outside the agency), choices were made based on the most feasible option that would have the most benefit (Green, 2002). Those providing input might include agency employees, the public, or both.

Research Question 3

To determine whether results of injury and absenteeism reports served as an agent or constraint to fitness policy, a closed-ended question was asked concerning whether the agency's fitness policy was intended to address this issue. Then responses were compared to the factors given that contributed to current policy. At the agencies with fitness policies in place, policy was intended to address, at least partially, work-related injuries and absences. The agencies without fitness policies saw mainly the cost and resources to oversee such a policy as a constraint. Therefore, from the consistent information presented by agencies either having or not having policies, it was determined that an agent/constraint component of the RCT contributed to the overall decision-making process.

Existing Policies and Potential Approaches

North Carolina law enforcement agencies vary in fitness standards and policies. Policies range from voluntary self-initiation to required fitness participation and testing. Voluntary policies make it optional for officers to participate in fitness activities, either on their own time or through various agency-sponsored incentives. One example is an agency that provides officers an extended break time to exercise while on duty. Rather than a 30-minute lunch break, officers are allowed 60 minutes, if manpower and call volume allows. The department provides a fully equipped exercise room that is available 24 hours a day. This is a convenient incentive not only for police officers, but also for all agency employees.

Other agencies in the state require fitness training days, which might occur once, twice, or four times a year (for example) as part of an officer's in-service training. Requirements vary but may only necessitate that officers are present and participate in some way. Agencies that include mandated fitness policy ensure that facilities, consultation services, and appropriate resources are available to officers by offering various fitness and educational activities, or individual consultations if desired.

Limitations

Upon completion of this study, I found several limitations that must be disclosed. These limitations included the instruments used, the geographical location selected, ecological fallacies, and sample size. Each is discussed in more detail below.

The instruments used consisted of both primary and secondary resources. The primary resource consisted of the questionnaire that was developed to specifically address policy decision-making at agencies. I validated the questionnaire by using feedback from a local advisory committee made up of local police practitioners, and reliability was assumed, as the same questionnaire was used for each agency. Yet upon qualitative analysis, it was discovered that more in-depth inquiries could have been used to delve deeper into how individual decisions were made or perhaps persuaded.

Secondary data included written policy (if any) for an agency and OSHA 300A summary reports. It was learned that OSHA reporting varied. Not all agency forms distinguished injuries and absences by officers from those by nonsworn employees in the agency. Accountability and methods of data collection were also questioned due to large variance in some of the data recorded from one year to the next.

Because data were collected from midsized law enforcement agencies in the Piedmont Trial Region of North Carolina, the results were limited. Only six of 11 agencies fitting the population criteria were selected for a more in-depth case study analysis. Therefore, statistical results cannot be generalized because of the small sample size. More specifically, the results are unique to this region and might differ from those of smaller, larger, rural, or more urban areas within the state or elsewhere.

Important to researchers is also being aware of potential ecological and individual fallacies (Frankfort-Nachmias & Nachmias, 2008). It should be noted that an agency not having or enforcing a fitness policy or standard does not imply that officers cannot or do not take individual responsibility for their own fitness. It also cannot be inferred that high absentee or injury rates reflect poor officer or agency performance, as absence or injury may not be caused by poor fitness levels. Absence is not just about a day away from work; it is tied to circumstances of an employee's medical and personal life (Harte et al., 2011). Therefore, many factors must be considered when implementing a wellness or fitness program, given that multiple facets of life circumstances contribute to missing work for various reasons.

Findings in this study address the research questions in an effort to contribute to what little is known about the relationship between fitness policies and work-related injuries and absenteeism, specifically within law enforcement agencies in North Carolina. Information was gained on how and why fitness policies are derived in some agencies, and suggestions derived from the study's findings are made to promote positive social change.

Implications for Positive Social Change

This study has potential to contribute to positive social change at individual, community, and societal levels. The study's most important implications relate to police officers' role as public service responders. Though officers infrequently encounter situations that require them to meet physical demands, the inability to perform can have consequences for the individual officer, the agency, and the community (Means et al., 2011a). Study results suggest that some fitness standard is significantly related to lower injuries and fewer absences. The data should be encouraging to individuals and agencies alike that are seeking to promote the overall wellness and health of employees. More today than ever, organizations have to *do more with less* to maximize work output and increase productivity. This suggests that increasing productivity reduces organizational expense (Harte et al., 2011). According to the U.S. Department of Labor (n.d.), health improvement programs cost 0.5% of payroll, compared to 6.5% in combined costs related to replacement of workers, sick leave, short and long-term disability, and workers' compensation. Employers are challenged by supporting employees' needs (e.g., time off and health insurance) with cost-effective benefits that create a productive workforce. Particularly when an administration aligns organizational goals and employee needs, employees' productivity can be greatly influenced by their general health and well-being

(Harte et al., 2011). In this sense, the individual, agency, and taxpayers/recipients of public services all benefit.

Recommendations for Action

Investing in wellness programs that focus on preventing illness and maintaining health influences medical costs and absenteeism. Such programs can go a long way in helping to creative a high-performance environment, lower health care costs, and reduce absences (Harte et al., 2011). Funding for fitness programs could be included within agency budgets or agencies could seek state funding per North Carolina General Statute 130A-224 as it pertains to public health. This statute provides a full mandate for public health issues, including injury prevention (Stier et al., 2012). It is a collaboration worth exploring further. A partnership with the North Carolina Public Health Department would be advantageous to incorporating injury prevention programs. To justify continued funding, it would be necessary to routinely evaluate training methods (Ferguson et al., 2011). Evaluation results can be useful by also pointing out deficiencies or areas where improvements can be made. It is the obligation of criminal justice practitioners and researchers alike to render professional judgment to improve the well-being of those in the field (ACJS, n.d.). Poor health and fitness carry higher risks of injuries and absences, which in turn cost agencies and taxpayers more money. Therefore, to justify standards and funding, evaluation is a necessary component. Data collection that provides evidence-based results would help to justify the continuance (or elimination of) such programs in the future.

The main objectives of fitness policy include reducing the risks of both work-related injury and absenteeism (and therefore increasing the health benefits of officers) and reducing agency and officer costs by way of fewer medical expenses and less absenteeism. The stipulation is that data should be collected and funding should be contingent upon evidence-based results. This could also be a beneficial form of accountability.

The purpose of providing alternatives is to offer optional approaches in case the initial, intended proposal does not completely work (Bardach, 2012) or needs to be adjusted in some way. The current interest lies in reducing workplace injuries and absences. Employers are aware that health and work are interrelated and that employers have a role in facilitating job retention and wellness (Irvine, 2011). Therefore, they are key players in policy change.

Recommendations for Further Study

The results of this study are limited to what was found among six law enforcement agencies within one region of North Carolina. The intent was to concentrate mainly on the patrol function within policing; however, with OSHA 300A summary statistics, it is difficult to do that. Therefore, it is suggested that actual OSHA 300 forms be analyzed to select out how injuries and absenteeism among patrol officers might differ compared to other sworn or nonsworn positions within an agency. This analysis would require more time and resources because those reported on the OSHA 300 form as injured or absent are listed by name; therefore, confidentiality would first have to be considered, and with the assistance of human resources a role distinction would have to be made among names as to pull out patrol officers. Alternatively, perhaps those patrol officers could be contacted and interviewed to determine whether the injury or absenteeism was indeed work-related.

It might also be interesting to compare differences in fitness levels and requirements for specialty teams (for example, SWAT, K-9) versus patrol as specialty teams generally require more strict fitness levels. Though the responsibilities differ, there may be a significant difference in injury and absenteeism rate when compared to patrol officers. Also, because more stringent requirements are often a condition of belonging to such specialty teams, how or why this policy was rationalized and decided might be explored to further test RCT or to test additional decision-making theories.

Conclusion

This study was conducted to address the gap in the literature regarding why police academy cadets have required fitness standards but not all law enforcement agencies require a maintained fitness level as a condition of employment in North Carolina. In the hiring process, a critical qualifying factor is the use of fitness testing; however, if testing is used agencies need to understand fitness assessments if they are to implement required standards (Cooper Institute, 2014). During this research, very limited studies were found specific to North Carolina agencies and fitness policy, and none were found that specifically examined OSHA-reported injuries and absenteeism compared to various agency fitness policies.

Providing quality public services to the community is demanding and often agency resources are stretched thin. Agencies are trying to find that delicate balance with limited resources, whether dollars, manpower, or time. Agencies discussed varying reasons for having or not having physical fitness policies in place, but regardless; all stressed the importance of officer safety which can be increased by paying attention to officer wellness (Office of Community Oriented Policing Services, 2015).

Research continues to support the importance of a police officer's physical and psychological health, but fitness is only one piece of a larger puzzle. Improving workplace productivity calls for a comprehensive strategy that includes integrating evidence-based measurement because it is important to show that the health and productivity of the workforce directly relates to the health and well-being of the organization (Harte et al., 2011; Office of Community Oriented Policing Services, 2015).

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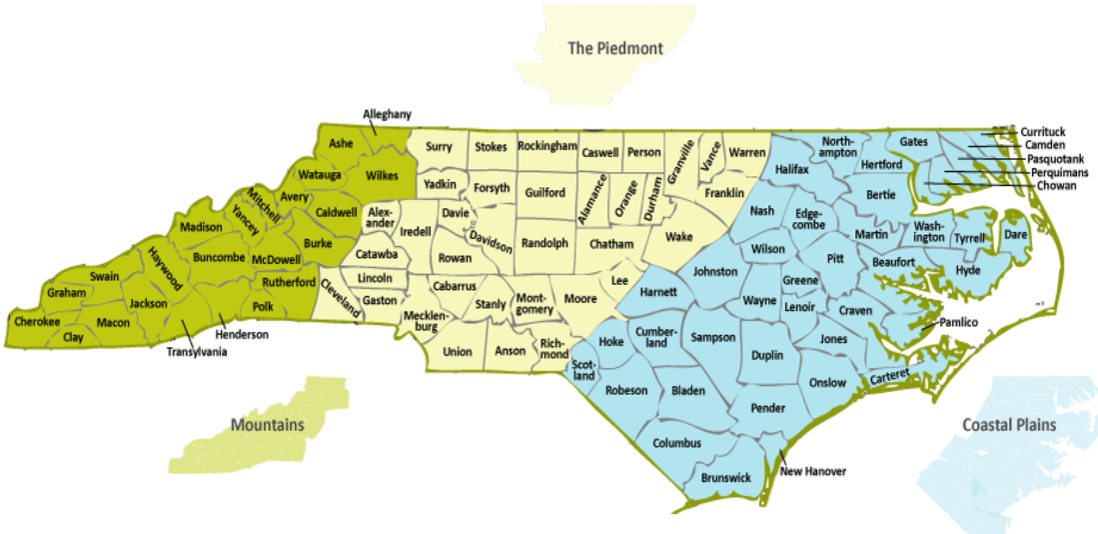
Appendix A: North Carolina Regions



Reference: Piedmont Triad Council. (2012). Retrieved from http://www.ptrc.org/

Appendix B: Piedmont Triad Region Law Enforcement Agencies

Agency	Population 50,0000 – 500,000
Alamance County	yes
-City of Burlington	yes
Caswell County	no
Davidson County	yes
Davie County	no
Forsyth County	yes
-City of Winston-Salem	yes
Guilford County	yes
-City of Greensboro	yes
-City of High Point	yes
Montgomery County	no
Randolph County	yes
Rockingham County	yes
Stokes County	no
Surry County	yes
Yadkin County	no

Appendix C: Population of Midsize Law Enforcement Agencies in the Piedmont Triad Region of North Carolina

Agency	2010 census population
[redacted] County Sheriff's Office	151,131
[redacted] Police Department	49,963
[redacted] County Sheriff's Office	162,878
[redacted] County Sheriff's Office	350,670
[redacted] Police Department	229,617
[redacted] County Sheriff's Office	488,406
[redacted] Police Department	269,666
[redacted] Police Department	104,371
[redacted] County Sheriff's Office	141,752
[redacted] County Sheriff's Office	93,643
[redacted] County Sheriff's Office	73,673

Note. From "2010 Census Interactive Population Search," by U.S. Census Bureau, n.d. (https://census.gov/). *N* = 11. Midsize = areas with 50,000-500,000 population.

Appendix D: Sample Agency Fitness Policy

STANDARD OPERATING PROCEDURE	UNIT: Training Division
SUBJECT: HEALTH AND FITNESS OF SWORN OFFICERS	NUMBER 7.4
EFFECTIVE DATE: 8/1/04	PAGE 1 OF 1
REVISION HISTORY: (Adopted 1/1/96) R1-7/1/99 R2 8/1/04 R3 8/10/07 R4 3.6.09 R5 10.14.13	

7.4.1 OBJECTIVE
The objective of the xxxxxxx Police Department is to develop and maintain a level of fitness in police personnel and to ensure their ability to accomplish assigned duties and provide satisfactory job performance without undue risk of injury or fatigue.

7.4.2 RESPONSIBILITIES
The Training Division is primarily responsible for the coordination and execution of all tasks pertaining to departmental directive 8.1.3.

7.4.3 COMPONENTS
The fitness services, provided at no charge by the department, includes:
1. An optional nutritional assessment. Officers complete a journal about their present health/eating habits.
2. A physical fitness assessment. The assessment consists of the following:

- Age, Height measurement, Weight measurement
- Body composition (Body Fat Percentage) – is measured by using skin fold calipers.
- Blood pressure and heart rate - are measured by a sphygmomanometer.
- Aerobic fitness - is measured by both a 1.5 mile walk/run and a 300-meter walk/run.
- Strength fitness - is measured by:
    - Maximum one-time bench press
    - Maximum number of push-ups within one-minute
    - Maximum number of sit-ups within one-minute

Once all tests are computed, each participant is categorized into one of five levels of fitness (age adjusted):
1) Very Poor 2) Poor 3) Fair 4) Good 5) Excellent 6) Superior
Each participant receives a synopsis of his/her results.

7.4.4 ANALYSIS OF RESULTS
Each officer will be given a copy of their physical assessment synopsis if requested. They may at any time schedule an appointment with the appropriate training coordinator for a free consultation concerning their results.

7.4.5 DUTIES
The Training Division will ensure that staff members performing tasks assessments are capable of properly conducting physical fitness assessments, providing fitness counseling and providing a written printout of results on each participant. Testing will be conducted at the Public Safety Training Facility utilizing Departmental equipment.

Retesting – Any participant can be retested upon request of the participant. Portions of any segment or the entire program can be retested.

7.4.6 FILE MAINTAINANCE
Any information obtained which pertains to the health and wellness program will be maintained in the Training Division and monitored by the appropriate training coordinator.

Appendix E: OSHA 300A Form

OSHA's Form 300A (Rev. 01/2004)

Summary of Work-Related Injuries and Illnesses

Year 20__ __

U.S. Department of Labor
Occupational Safety and Health Administration

Form approved OMB no. 1218-0176

All establishments covered by Part 1904 must complete this Summary page, even if no work-related injuries or illnesses occurred during the year. Remember to review the Log to verify that the entries are complete and accurate before completing this summary.

Using the Log, count the individual entries you made for each category. Then write the totals below, making sure you've added the entries from every page of the Log. If you had no cases, write "0."

Employees, former employees, and their representatives have the right to review the OSHA Form 300 in its entirety. They also have limited access to the OSHA Form 301 or its equivalent. See 29 CFR Part 1904.35, in OSHA's recordkeeping rule, for further details on the access provisions for these forms.

Number of Cases

Total number of deaths	Total number of cases with days away from work	Total number of cases with job transfer or restriction	Total number of other recordable cases
____	____	____	____
(G)	(H)	(I)	(J)

Number of Days

Total number of days away from work	Total number of days of job transfer or restriction
____	____
(K)	(L)

Injury and Illness Types

Total number of . . .
(M)

(1) Injuries ____
(2) Skin disorders ____
(3) Respiratory conditions ____
(4) Poisonings ____
(5) Hearing loss ____
(6) All other illnesses ____

Establishment information

Your establishment name ________________

Street ________________

City __________ State ____ ZIP _____

Industry description (*e.g., Manufacture of motor truck trailers*)

____

Standard Industrial Classification (SIC), if known (*e.g., 3715*)

__ __ __ __

OR

North American Industrial Classification (NAICS), if known (e.g., 336212)

__ __ __ __ __ __

Employment information *(If you don't have these figures, see the Worksheet on the back of this page to estimate.)*

Annual average number of employees ______

Total hours worked by all employees last year ______

Sign here

Knowingly falsifying this document may result in a fine.

I certify that I have examined this document and that to the best of my knowledge the entries are true, accurate, and complete.

____
Company executive Title

( ) - / /
Phone Date

Post this Summary page from February 1 to April 30 of the year following the year covered by the form.

Public reporting burden for this collection of information is estimated to average 58 minutes per response, including time to review the instructions, search and gather the data needed, and complete and review the collection of information. Persons are not required to respond to the collection of information unless it displays a currently valid OMB control number. If you have any comments about these estimates or any other aspects of this data collection, contact: US Department of Labor, OSHA Office of Statistical Analysis, Room N-3644, 200 Constitution Avenue, NW, Washington, DC 20210. Do not send the completed forms to this office.

Appendix F: Participating Agency OSHA-Reported Injuries in Order of

Fitness Policy Stringency

Agency	Year	# of employees	Days away from work	*Absent rate (per 100)	Total injuries	*Injury rate (per 100)
(1)	2011	228	2	.88	12	5.26
	2012	248	117	47.18	15	6.05
	2013	254	154	60.63	10	3.94
	2014	254	0	0.00	14	5.51
	2015	262	12	4.58	12	4.58
(2)	2011	missing	55	missing	23	missing
	2012	1206	248	20.56	61	5.16
	2013	892	411	46.08	65	7.29
	2014	1023	305	29.81	79	7.72
	2015	954	389	40.78	66	6.92
(3)	2011	248	138	55.65	31	12.50
	2012	261	191	73.18	38	14.56
	2013	268	19	7.09	30	11.19
	2014	266	75	28.20	12	4.51
	2015	279	43	15.41	18	6.45
(4)	2011	901	426	47.28	66	7.33
	2012	900	128	14.22	66	7.33
	2013	929	471	50.70	65	7.00
	2014	881	363	41.20	56	6.36
	2015	881	266	30.19	38	4.31
(5)	2011	230	3	1.30	8	3.48
	2012	238	164	68.71	12	5.04
	2013	240	2	.83	8	3.33
	2014	243	0	0.00	2	.82
	2015	235	18	7.66	7	2.98
(6)	2011	164	15	9.15	17	10.37
	2012	182	5	2.75	18	9.89
	2013	171	25	14.62	15	8.77
	2014	172	52	30.23	17	9.88
	2015	171	267	156.14	20	11.70

* Absenteeism/injury rate is total number of days away from work (or total number of injuries) divided by total number of employees times 100 (rounded to nearest hundredth)

Appendix G: Agency Questionnaire

Agency:

# of sworn officers:

Title:

Does your agency have a physical fitness policy? *(please include copies of years 2011-2015)*

If YES

is it mandatory or voluntary?

how long has the policy been in place?

What is the rationale behind having/not having a fitness policy in place, or for changing policy?

Who are involved decision makers in fitness policy? Who ultimately decides?

What factors determine or affect fitness policy? (ie: resources, manpower, cost, etc.)

Was policy intended to address work-related injuries and illnesses?

Are you aware that North Carolina provides a full public health mandate that includes injury prevention?

If no, would you want more information?

If yes, is that part of the rationale for having/not having a fitness policy?

Drew-Nord et al. Journal of Occupational Medicine and Toxicology 2011, 6:25
http://www.occup-med.com/content/6/1/25

JOURNAL OF OCCUPATIONAL MEDICINE AND TOXICOLOGY

RESEARCH Open Access

Accuracy of peak VO2 assessments in career firefighters

Dana C Drew-Nord[1*], Jonathan Myers[2], Stephen R Nord[3], Roberta K Oka[4], OiSaeng Hong[1] and Erika S Froelicher[5]

Abstract

Background: Sudden cardiac death is the leading cause of on-duty death in United States firefighters. Accurately assessing cardiopulmonary capacity is critical to preventing, or reducing, cardiovascular events in this population.

Methods: A total of 83 male firefighters performed Wellness-Fitness Initiative (WFI) maximal exercise treadmill tests and direct peak VO_2 assessments to volitional fatigue. Of the 83, 63 completed WFI sub-maximal exercise treadmill tests for comparison to directly measured peak VO_2 and historical estimations.

Results: Maximal heart rates were overestimated by the traditional 220-age equation by about 5 beats per minute ($p < .001$). Peak VO_2 was overestimated by the WFI maximal exercise treadmill and the historical WFI sub-maximal estimation by ~ 1MET and ~ 2 METs, respectively ($p < 0.001$). The revised 2008 WFI sub-maximal treadmill estimation was found to accurately estimate peak VO_2 when compared to directly measured peak VO_2.

Conclusion: Accurate assessment of cardiopulmonary capacity is critical in determining appropriate duty assignments, and identification of potential cardiovascular problems, for firefighters. Estimation of cardiopulmonary fitness improves using the revised 2008 WFI sub-maximal equation.

Background

Every 23 seconds a fire in the United States requires the services of a career or volunteer fire department [1]. Sudden cardiac death is the most common cause of on-duty death among firefighters and occurs at higher rates than those found in similar occupations, such as police and emergency medical services [2].

A joint task force of the International Association of Firefighters (IAFF) and International Association of Fire Chiefs developed the Fire Service Joint Labor Management Wellness-Fitness Initiative (WFI) in 1997. Revisions in the 1999 and 2008 WFI recognize the firefighter as the "most important asset" in the fire service, and its intent is to improve firefighter function, on-duty effectiveness, and overall quality of life, while reducing morbidity and mortality related to fire fighting [3]. A major component of the WFI is assessment of firefighters' cardiopulmonary capacity, with a stepmill test, sub-maximal, or a maximal exercise treadmill test. The WFI mandates that firefighters have a maximal exercise test at age 40 and every other year thereafter. The maximal exercise test is intended to measure peak VO_2 (measured as $ml/kg^{-1}{\cdot}min^{-1}$), which is an objective, clinical measure that defines the limits of cardiopulmonary function. Peak VO_2 reflects an individual's ability to increase their heart rate and stroke volume, and redirect oxygenated blood to muscles for work on demand. Exercising at levels beyond which the cardiopulmonary system can adequately supply oxygen (commonly termed the anaerobic or ventilatory threshold, or VT) involves progressively greater degrees of oxygen-independent muscle metabolism, which is dramatically less efficient than aerobic metabolism, and can compromise cardiovascular function [4].

Quantifying the energy demands of firefighting during fire suppression is difficult due to the inherent dangers of fire suppression tasks. Most efforts to define the arduous physical work demand requirements during firefighting have been focused on establishing the level of metabolic equivalents (METs) (1 MET ≈ 3.5 ml of O_2/kg/min) using simulated tasks. A MET is a multiple of the resting metabolic rate and is commonly estimated using standardized equations [4]. 10 METs is roughly equivalent to jogging a 10-minute mile; 14 METs is

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similar to many extended competitive activities such as running or rowing competitively, or bicycle racing at a high level [5]. The estimated METs proposed for firefighting range from 9.6 [6] to 14 [7] (a peak VO_2 range of 33.6 ml/kg^{-1} min^{-1}·to 49 ml/kg^{-1}·min^{-1}). Recent analysis of physical aptitude tests among firefighter recruits demonstrated that male recruits' average VO_2 requirement was 38.5 ml/kg^{-1}·min^{-1} (11 METs) to complete a timed simulated firefighting assessment course [8]. Measurement of functional capacity in 23 firefighters suggested that a mean of 41.54 ml/kg^{-1}·min^{-1} (11.9 METs) is required to complete standard fire suppression tasks while wearing personal protective equipment [9].

Firefighting work demands can be extreme and accurate assessment of cardiopulmonary status, as well as detection and treatment of any underlying cardiovascular disease, is critical to insure firefighter fitness for duty and prevent on-duty cardiac events or death. The 1999 WFI sub-maximal exercise test was found to overestimate true peak VO_2 in individual firefighters [10]. Concern about overestimation led to a revised equation for estimating peak VO_2 from sub-maximal exercise treadmill tests in the 2008 WFI.

Materials and methods

Given that previous sub-maximal exercise test results in the WFI were shown to overestimate peak VO_2, and that the WFI maximal exercise treadmill protocol has not been validated for accuracy in the literature, this study was undertaken to assess the validity of both the maximal and revised sub-maximal exercise treadmill peak VO_2 estimates in firefighters. Specifically, the present study tested the following comparisons: (a) estimated maximal heart rate (220 - age) to actual measured maximal heart rate; (b) WFI maximal exercise estimated peak VO_2 to directly measured peak VO_2; c) averaged pre-revision sub-maximal estimated peak VO_2 to revised sub-maximal estimated peak VO_2; and (d) directly measured peak VO_2 to revised WFI sub-maximal estimated peak VO_2.

Study Setting and Participants

The study setting was a medium-sized suburban fire department in the eastern region of the San Francisco Bay Area in northern California. This department serves approximately 163,000 citizens and covers 46 square miles. All firefighters (N = 105) assigned to suppression duties were recruited, including firefighters, firefighter/paramedics, firefighter/engineers, firefighter/captains and battalion chiefs. There were no women suppression firefighters in the department studied. This is consistent with national career firefighter statistics as women only represent approximately 4.5% of the fire service [11]. All testing took place during a five-week period between December 2008 and January 2009.

Inclusion criteria for participation required that each participant had successfully completed a WFI examination within the previous nine months and achieved a minimum of 10 METs (peak VO_2 of 35 ml/kg/min), on either a sub-maximal (using the pre-2008 equation), or maximal exercise treadmill test. Exclusion criteria included injury, illness, or scheduling conflicts that precluded testing during the study period. The final study population consisted of 83 male career firefighters from all suppression ranks in this department.

The study was conducted with approval of the University of California San Francisco Committee on Human Research. Signed informed consents were obtained and all testing was conducted during on-duty hours with the approval of the department and union local.

Testing occurred at an occupational health clinic where previous WFI examinations for this fire department had been conducted. A physician board certified in internal medicine and occupational medicine, and a nurse practitioner experienced in exercise testing, performed all treadmills and direct VO_2 measurements. Participants arrived on the day of scheduled testing with their assigned duty crew, with gym clothes and running shoes appropriate for completing a maximal exercise test.

Measurements

Data collection consisted of medical record abstraction for demographics, cardiovascular risk factors and exercise test information. Demographic characteristics included age, rank, and years of fire service. Definitions of cardiovascular risk factors were obtained from the American Heart Association, Adult Treatment Panel III (ATP III), The Seventh Report of the Joint National Committee on Prevention, Detection, Evaluation and Treatment of High Blood Pressure (JNC7), and the Centers for Disease Control and Prevention [12-15]. All serum samples were analyzed at the same hospital-based certified laboratory (Centers for Medicare and Medicaid Services Clinical Laboratory Improvements Amendments (CLIA)). Cardiovascular risk factors of the participants are summarized in Table 1.

Maximal Heart Rates

Maximal estimated heart rates were calculated as 220-age. Directly measured maximal heart rates were determined from the electrocardiogram at the point of volitional fatigue as determined by the firefighter and corroborated by the direct VO_2 assessment indicating that they had crossed the VT.

Maximal Exercise Treadmill with Direct Peak VO_2 Assessment

All 83 participants completed a maximal exercise test using the 2008 WFI Protocol with concurrent direct peak VO_2 measurements. Maximal exercise treadmill

Table 1 Participant Cardiovascular Risk Factor Profile - Maximal Exercise Treadmill-Peak VO_2 Assessment (n = 83)

Risk Factor	Mean, SD
Body Mass Index (kg/m^2)	28.2 (± 3.9)
Systolic BP	117 (± 10)
Diastolic BP	69 (± 7)
Total Cholesterol* (mg/dL)	197 (± 38)
HDL** (mg/dL)	47 (± 11)
LDL** (mg/dL)	126 (± 36)
Cholesterol/HDL Ratio	4.35 (± 1.17)
Triglycerides (mg/dL)	118 (± 70)

*-fasting

**- HDL - high density lipoprotein; LDL - low density lipoprotein

tests were considered complete when the firefighter indicated volitional fatigue (*n* = 83, see above), or if terminated by the testing physician due to concerns about cardiopulmonary distress (*n* = 0). The WFI protocol is a modified ramp protocol comprised of a 3-minute warm-up period at 3 mph - 0% grade, followed by fifteen 1-minute stages. Stage 1 begins at 4.5 mph and 0% grade, with the treadmill incline increasing 2% and speed increasing by 0.5 mph alternately in stages 2 through 15. The WFI maximal exercise treadmill estimates peak VO_2 based on the American College of Sports Medicine metabolic equation for running [16].

Peak VO_2 was obtained using the Cardio Coach CO_2™ VO_2 Fitness Assessment System, Model 9001-RMR (Korr Medical Technologies, Salt Lake City, Utah). The Cardio Coach CO_2™ is an economical, portable metabolic testing device that is feasible for use in a clinic and has been previously validated for measurement of peak VO_2 levels [17,18]. The Cardio Coach $CO_2$$^{TM\ is}$ a dual gas analyzer (O_2 and CO_2) that automatically calibrates to standard temperature and pressure, dry at the beginning of each testing cycle. The Cardio Coach CO_2™ measures heart rate using the Polar T-31 heart monitor (Polar, Inc., Lake Success, NY). Heart rate and VO_2 ($ml/kg^{-1}\cdot min^{-1}$), VCO_2 ($ml/kg^{-1}\cdot min^{-1}$), VE/VO_2, VE/VCO_2, VE in L/min, FeO_2%, Fe CO_2%, and respiratory exchange ratio are graphically reported every 15 seconds. The Cardio Coach CO_2™ uses the ventilatory equivalents method (Ve/VO_2) to detect VT (Korr Medical Technologies, 2009).

Revised Sub-maximal Exercise Treadmill Assessments

In the latter part of 2008, the WFI introduced a revised equation for estimating peak VO_2: peak $VO_2 = 56.981 + (1.242 \times TT) - (0.805 \times BMI)$, where TT is the test time required to achieve target heart rate, and BMI is Body Mass Index. The 2008 WFI calculates target sub-maximal heart rate (208 - (0.7 × age) × 0.85, whereas previous sub-maximal heart rates were based on (220-age) × 0.85 [3,19].

Of the 83 firefighters who volunteered for the maximal exercise treadmill tests and directly measured peak VO_2, 63 subsequently completely their annually scheduled WFI examination, which included a sub-maximal exercise treadmill test, within the subsequent four to eight weeks. These subsequent WFI sub-maximal exercise treadmill tests, using the revised equation, took place under identical conditions as the study WFI maximal exercise treadmill tests but without the direct VO_2 measurement. The sub-maximal test uses the WFI treadmill protocol (see above) but terminates 15 seconds after the firefighter reaches their target heart rate.

Pre-revision Sub-maximal Exercise Treadmill Assessments

Prior to the 2008 WFI revision there was no published equation for the estimation of peak VO_2 from the sub-maximal exercise treadmill. The estimated peak VO_2 was determined by duration of the test and stage achieved [19]. Between one and seven historical sub-maximal test results were available for each of the 63 participants, and were averaged to create comparative historical variables.

Procedure

Participant's height, weight and resting blood pressure was measured. A resting electrocardiogram (ECG) was completed, using the Welch-Allyn Schiller AT-10 6-Channel electrocardiograph/treadmill (San Diego, California). Upon completion of the resting ECG the Mason-Likar lead configuration was modified to accommodate the exercise treadmill [4]. The participant was then fitted with the appropriate 2-way non-rebreathable mask (Hans-Rudolph, Inc., Shawnee, Kansas). The mask completely covered the nose and mouth of the participant and was checked for air leaks to eliminate extraneous room air from affecting the interpretation of peak VO_2. A standing electrocardiogram was obtained and the treadmill was initiated. At test termination the firefighter recovered in the supine position. Available data from the maximal exercise treadmills is detailed in Table 2.

Statistical Analyses

Prior to all analysis all data were examined using stem and leaf plots and found to have normal distribution.

Table 2 Maximal Exercise Treadmill Data (n = 83)

	Minimum	Maximum	Mean, SD
Resting Systolic	102	164	122 (±10)
Resting Diastolic	60	100	73 (±8)
Resting Heart Rate	42	91	63 (±10)
Maximal Heart Rate	130	194	174 (±10)
Peak VO_2 Actual	26.3	69.5	43.6 (±9.1)
RER* - Peak Exercise	0.90	1.28	1.09 (± .07)

* - Respiratory Exchange Ratio

Dependent t-tests were conducted on all 83 participants to test for differences between:

1) Estimated maximal heart rate (220 - age) and directly measured maximal heart rate.
2) WFI maximal exercise treadmill estimated peak VO_2 and directly measured peak VO_2.

Additional dependent t-tests were conducted on the results of the 63 participants who subsequently performed a revised WFI sub-maximal exercise treadmill test for differences between:

1) Averaged pre-revision WFI sub-maximal exercise treadmill estimated peak VO_2 mean (converted to METs) to revised WFI sub-maximal exercise treadmill estimated peak VO_2 (converted to METs).
2) Directly measured peak VO_2 (converted to METs) to revised WFI sub-maximal exercise treadmill estimated peak VO_2 (converted to METs).

All dependent t-tests were two tailed, with $\alpha = 0.05$ used for statistical significance. Statistical analyses were performed using SPSS Version 15.0 (SPSS, Inc., Chicago, Illinois).

Results

There were 105 active suppression male career firefighters eligible for participation in the study. Of those, five were new hires who had not completed a WFI examination. Six firefighters chose not to participate; of the 94 choosing to participate 11 could not be scheduled for maximal exercise tests due to injury, illness or scheduling conflicts resulting in an $n = 83$ for this study. The participants' ages ranged from 26 to 57 years with a mean of 41.1; 94% of the participants were Caucasian, and 6% were Hispanic or African-American. The years of firefighting ranged from 2 to 34 with a mean of 15.6.

Maximal Estimates and Measurements

The traditional maximal heart rate estimation (220 - age) was significantly higher than measured maximal heart rate (178.6 vs. 173.6 with a mean difference of 4.96 beats/min, $p < 0.001$, 95% CI: 3.03, 6.90). Estimated peak VO_2 was significantly higher than directly measured peak VO_2 (47.7 vs. 43.6, with a mean difference of 4.06 ml/kg/min, (1.16 METs) $p < 0.001$, 95% CI: 2.88, 5.23).

Sub-maximal Estimates and Measurements

Within four to eight weeks of the maximal exercise treadmill tests 63 participants completed a sub-maximal exercise treadmill test (using the revised 2008 WFI equation). Their average age was 40.19 years (± 6.9) and average years of firefighting was 14.4 (± 6.8). All firefighter suppression ranks were represented in this subgroup. The subsequent examination allowed for comparison of the revised sub-maximal exercise treadmill peak VO_2 estimate to an averaged pre-revision (comparative historical variable) sub-maximal exercise treadmill peak VO_2 estimate and the recently obtained directly measured peak VO_2. For simplicity in reporting sub-maximal results all peak VO_2 results were converted to METs (peak VO_2/3.5).

A statistically significant difference was found between pre-revision sub maximal exercise treadmill peak METs mean estimates and revised sub-maximal peak METs estimates (14.81 vs. 12.58, with a mean difference of 2.23 METs, $p < 0.001$, 95% CI: 1.86, 2.59) These findings support previous research determining that WFI sub-maximal peak METs estimates prior to the 2008 revision were overestimated [10]. Revised sub-maximal treadmill METs estimates did not differ from directly measured maximal exercise treadmill METs, indicating that the revised 2008 estimating equation is a reasonable estimate of METs (12.64 vs. 12.58 with a mean difference of .07 METs, $p \leq .76$, 95% CI: -.39, .54) This represents additional validation of the accuracy of the new estimating equation [3]. All maximal and sub-maximal comparisons are summarized in Table 3.

Discussion

Fire departments often struggle to determine fitness for duty for their members who return from an injury or illness, prepare to embark on wildland strike teams, heavy rescue missions, or for daily work assignments. There are ongoing efforts to define minimally acceptable and safe fitness levels; levels that should be informed by the energy requirements needed during a firefighter's tour of duty. Maximum directly measured METs for the firefighters in this study ranged from 7.5 to 19.9, indicating that some participants might have a difficult time meeting the demands of the job while others appear adequately fit. Four different methods of cardiopulmonary assessment are compared here: direct measurement of peak VO_2, estimated peak VO_2 derived from a maximal exercise treadmill equation, historical average of pre-revision estimated peak VO_2 sub-maximal exercise treadmills, and estimated peak VO_2 derived from the revised (2008) sub-maximal exercise treadmill equation. Directly measured peak VO_2 is the most objective and considered the "gold standard" of the four methods [4].

The difference observed in maximum heart rate between directly measured maximum heart rate (while wearing a non-rebreathable mask), and a 220-age estimated maximum heart rate (part of the maximal exercise treadmill estimation equation) provides some explanation for the over-estimation. Estimated maximal

Table 3 Comparisons: Heart Rate, Peak VO_2, Estimated METs

	n	Mean	SD	SEM	95% CI Lower	95% CI Upper	t	d	Sig(2-tailed)
Estimated Max.									
HR: Actual Max.	83	4.96	8.87	.97	3.03	6.9	5.09	82	.00
HR									
Estimated peak VO_2: Direct measure peak VO_2	83	4.06	5.39	.59	2.88	5.23	6.85	82	.00
Pre-revision METs									
Est.: Revised METs estimate	63	2.23	1.46	.18	1.86	2.59	12.14	62	.00
Direct METs:									
Revised Sub-maximal METs estimate	63	.07	1.85	.23	-.39	.54	.31	62	.76

heart rates were about 5 beats per minute higher than those measured during peak exercise. Heart rates are a method used on the fire ground to evaluate a firefighters' capability to re-enter the fire scene. Using target heart rates that exceed true maximums, or percentages of estimated maximum heart rates that are inaccurate, could result in dangerous duty assignments.

Assessment of direct peak VO_2 and maximal exercise treadmill results indicate that the equation utilized by the WFI maximal treadmill over-estimates peak VO_2 by an average of 4.06 $ml/kg^{-1} \cdot min^{-1}$, or approximately 1 MET. If a firefighter's fitness level is less than optimal, or if they have underlying cardiovascular disease, this overestimation could lead to on-duty clearances that could prove compromising.

Revised sub-maximal exercise treadmill peak VO2 estimates were compared to averaged pre-revision historical sub-maximal exercise peak VO_2 estimates. The average overestimation of the historical mean was approximately 2 METs. This finding supports the Mier and Gibson report (2004) that the pre-revision WFI sub-maximal treadmill equation overestimated peak VO_2, and that those equation results should be used with caution for duty assignment decisions.

The comparison of directly measured peak VO_2 to the revised sub-maximal exercise treadmill peak VO_2 estimates (n = 63) found that there were no differences between the two assessment methods. When comparing revised WFI sub-maximal exercise treadmill peak VO_2 estimates to previous years of testing, or to reports in the literature, careful consideration must be given to which estimation method was used. The same task, measured with different estimating equations, can result in different results as demonstrated herein.

Limitations and Strengths

The limitations of our study include the self-selection bias of the participants, the limited gender and ethnic demographics of the group (all male, predominantly Caucasian), and the range in number of historical sub-maximal exercise treadmill VO_2 estimates, resulting in a less than ideal comparison group. While testing was completed within a four month period, it included the winter holiday season which may have had a seasonal influence on fitness behavior (resulting in an increase or decrease in exercise intensity). The composition of the sample is reflective of the department in terms of gender and ethnicity. There is an average four to eight week gap between the direct measure peak VO_2 and the sub-maximal exercise treadmill peak VO_2 assessment without any documentation of fitness behaviors. However, any fitness improvement on the part of firefighters in the interim would have directed the results towards the null.

The strengths of our study include the number of participants, their range in age, rank, firefighting experience, and their experience with the WFI protocol. The availability of seven years historical data can be viewed as a strength. Use of the mask to measure peak VO_2 was familiar to the participants as they routinely work with self-contained breathing apparatus. The ability to perform all testing components while on duty encouraged participation. There were no incentives offered for participation. All testing was completed in the same facility using the same equipment and personnel, thus increasing consistency of testing and inter-rater reliability.

Clinical Implications

Firefighters who have been tested using earlier estimation equations may require careful explanation as to a noticeable drop in test results when using the revised 2008 WFI equation. Participants are likely to be disappointed to see a reduction in their "fitness level" when they have not changed their patterns, nor workout habits, between testing cycles. Again, if a fire fighter falls into the lower fitness categories, or has underlying cardiovascular disease, inaccurate estimates could contribute to cardiac compromise.

Conclusions

In order to protect firefighters from potentially life-threatening cardiac situations it is imperative that exercise testing results are accurate, whether the test is being used for duty assignment or part of a comprehensive risk assessment. The results from the revised sub-maximal exercise treadmill estimation equation appear to accurately reflect directly measured peak VO_2 results. WFI maximal treadmill peak VO_2 estimates should be interpreted with caution, especially as they appear to over-estimate METs by an average of 1. Given the potential for over-estimation of fitness, providers who make fitness-for-duty assessments should consider the energy requirements of the job, any underlying cardiovascular risk factors, and the method of testing used when recommending return to, or continuation of, duties. These findings support the continuation and further expansion of reliable exercise testing of firefighters, within the context of a cardiovascular disease prevention program such as the WFI.

Performing measured peak VO_2 and maximal exercise treadmill tests can be challenging for fire departments to accomplish due to limited resources. The 2008 WFI sub-maximal exercise treadmill test can be safely administered outside of a medical setting using tools that are often available within the fire department (treadmill, stopwatch, and Polar heart monitor). Disadvantages of the sub-maximal treadmill test are the limited means for assessing underlying cardiovascular conditions, and the inability to determine maximal cardiovascular performance directly. However, the revised 2008 sub-maximal treadmill peak VO_2 estimation equation is a valid tool to assess interim progress in cardiovascular training programs.

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Authors' contributions
All of the authors contributed substantially to the conception, design, data acquisition and analysis, manuscript drafts and revisions of this study. Each has given final approval for publication.

Competing interests
Dr. Drew-Nord and Dr. Nord own the occupational medicine practice where this research was conducted and contract with various fire agencies to provide WFI services. This relationship was determined to represent no conflict of interest by the Institutional Review Board of the University of California, San Francisco. The remaining authors declare that they have no competing interests.

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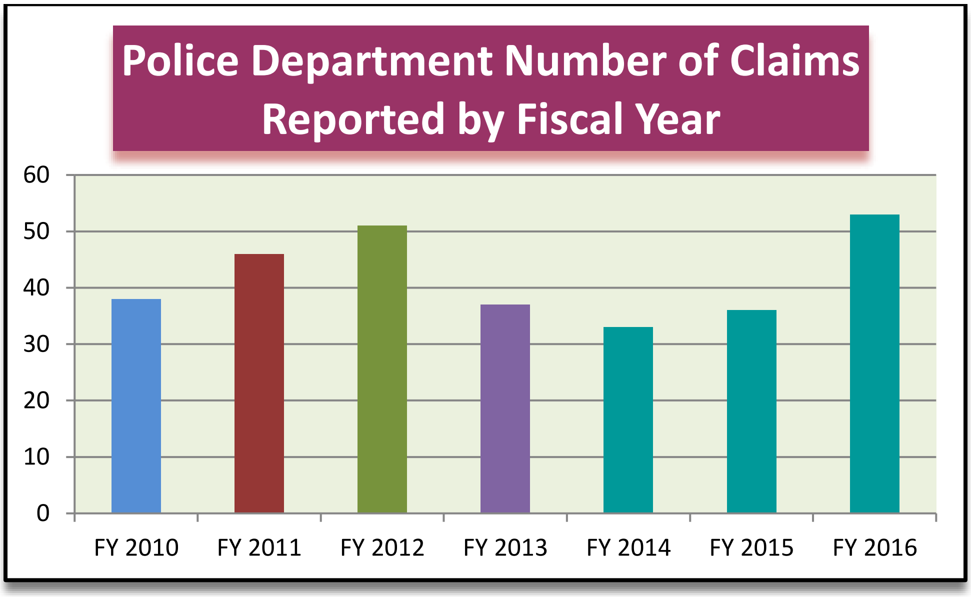
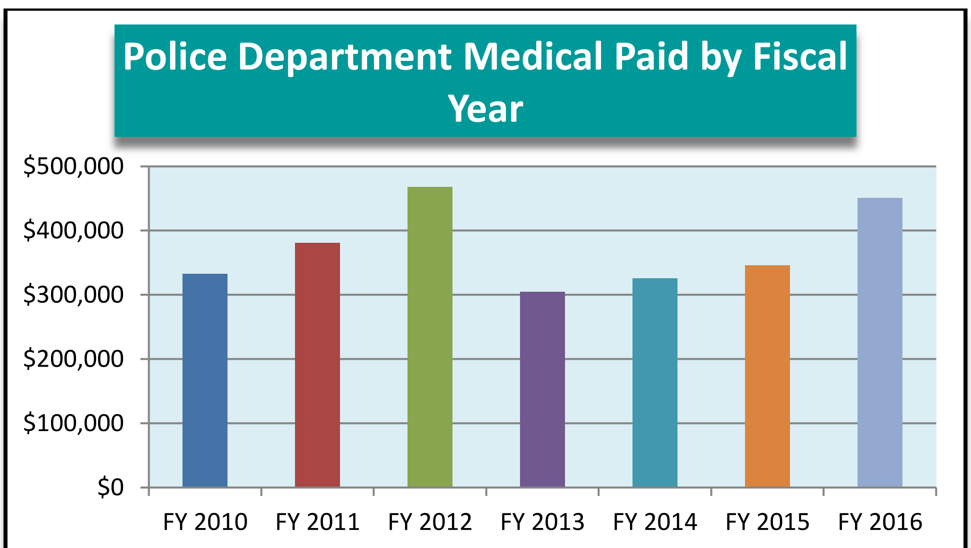
Program Effectiveness

Case Study – Clovis Police Department

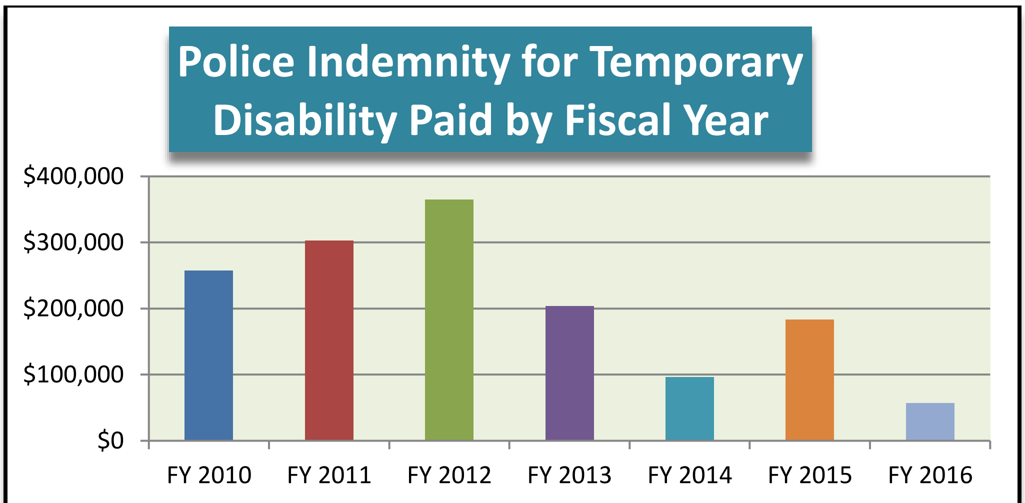
Clovis Police Department

In 2008, the Clovis Police Department suspended their health screening and fitness testing program. As illustrated below, the number of claims increased until 2012 when Pinnacle Training Systems began a wellness program for these officers.





There has been a 50% reduction in total dollars paid from 2012-2016.



Despite the increase in the number of claims in 2016 and the medical dollars paid per fiscal year (the first increase since 2012), the total number of dollars paid and the dollars paid for temporary disability is still lower since the implementation of our program. This demonstrates the effectiveness of a well implemented program. While claims might increase in any given year, fit officers will return to work more quickly than those who are unfit reducing indemnity dollars paid. The Clovis Police Department has implemented a non-voluntary, incentivized, yet potentially punitive MOU for officers based on their overall health and fitness levels. Since the implementation of this program, the culture within the department has changed and more officers are motivated to engage in healthy behaviors. Furthermore, 4 officer's lives have been saved due to identifying abnormal EKG rhythms.

Based on the cost of the program and the total dollars paid since 2012 to 2016, the return on investment for this department is 17.5:1

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Original Contribution

The Association of Aerobic Fitness With Injuries in the Fire Service

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The aim of the present study was to understand the risk of injury in relation to fitness in a retrospective occupational cohort of firefighters in Tucson, Arizona, from 2005 to 2009. Annual medical evaluations and injury surveillance data were linked to compare levels of aerobic fitness in injured employees with those in noninjured employees. The individual outcomes evaluated included all injuries, exercise-related injuries, and sprains and strains. Time-to-event analyses were conducted to determine the association between levels of fitness and injury likelihood. Fitness, defined by relative aerobic capacity ($\mathrm{VO}_{2\mathrm{max}}$), was associated with injury risk. Persons in the lowest fitness level category ($\mathrm{VO}_{2\mathrm{max}}$ <43 mL/kg/minute) were 2.2 times more likely (95% confidence interval: 1.72, 2.88) to sustain injury than were those in the highest fitness level category ($\mathrm{VO}_{2\mathrm{max}}$ >48 mL/kg/minute). Those with a $\mathrm{VO}_{2\mathrm{max}}$ between 43 and 48 mL/kg/minute were 1.38 times (95% confidence interval: 1.06, 1.78) more likely to incur injury. Hazard ratios were found to be greater for sprains and strains. Our results suggest that improving relative aerobic capacity by 1 metabolic equivalent of task (approximately 3.5 mL/kg/minute) reduces the risk of any injury by 14%. These findings illustrate the importance of fitness in reducing the risk of injury in physically demanding occupations, such as the fire service, and support the need to provide dedicated resources for structured fitness programming and the promotion of injury prevention strategies to people in those fields.

aerobic capacity; fire service; injury

Abbreviation: $\mathrm{VO}_{2\mathrm{max}}$, relative aerobic capacity.

The work demands for fire service employees are well documented as requiring considerable physical abilities. In 1992, Sothmann et al. (1) recommended that these workers have a relative aerobic capacity ($\mathrm{VO}_{2\mathrm{max}}$) between 38 and 42 mL/kg/minute in order to meet the measured workload demand for firefighters while also maintaining a reserve capacity to respond to other unanticipated events. Since then, most fire departments have adopted minimum fitness standards, often emphasizing aerobic capacity as a definitive measure of overall fitness. Standard fitness assessments for the general population typically have a set of norms that are scaled to age and sex, and results can range from poor to superior (2).

Opportunities for injury in the fire service are diverse. Persons with higher aerobic capacities should be able to consume more oxygen than those with lower aerobic capacities, and their bodies are likely to be more efficient at circulating oxygen to all systems and producing energy. Persons in the top levels of a fitness spectrum may not be as susceptible to microtraumas and may recover better from injury than their less-fit counterparts (3–9). Hence, those with higher $\mathrm{VO}_{2\mathrm{max}}$ should have a lower potential for fatigue and subsequent injury. Conversely, a high fitness level may also be an indicator that a person has an increased risk of injury, as these persons likely have greater exposure time to exercising hazards. In some fire departments, exercise has been shown to be the leading activity associated with on-duty injuries (10).

The objectives of the present study were to establish and understand the relationship between fitness status and the risk of injury in a 5-year occupational cohort of career fire service members. We hypothesized that firefighters deemed to be on the lower end of the fitness spectrum would be more susceptible to injury than their more fit colleagues.

MATERIALS AND METHODS

Population description, data sources, and years

As previously described (10), the present study includes data from commissioned employees of a medium-sized metropolitan fire department in the southwestern United States. Briefly, the fire department operates 21 fire stations and responds to nearly 520,000 permanent residents (with seasonal increases nearing 720,000 residents). Like many other municipal fire departments, this fire department requires an annual physical examination to assess fitness levels and provide medical clearance for each commissioned employee. Between 2005 and 2009, data for this study were obtained from 2 sources: physical assessments from annual clinic visits and department injury surveillance reports. The present study included all commissioned (noncivilian) employees of the fire department who were employed at some point in time during the study period. Approval for and oversight of the use of human subjects was provided by the University of Arizona's Institutional Review Board.

Physical fitness measures

Information collected from annual exams included anthropometric measures (e.g., height, weight, body fat percentage), $\mathrm{VO}_{2\mathrm{max}}$, muscular strength, muscular endurance, and flexibility. Aerobic capacity can be defined as the highest rate at which oxygen can be taken up and utilized by the body during rigorous exercise (11). Aerobic capacity is expressed as a rate that is referenced in either absolute terms (L/minute) or by relative measures (mL/kg/minute) to account for individual size variations. In this study, we refer to studied relative aerobic capacity. $\mathrm{VO}_{2\mathrm{max}}$ was categorized into 3 levels of fitness, using the 25th and 50th percentiles as the cutoff points between the "less fit" (<43 mL/kg/minute) and "high fit" (>48 mL/kg/minute) aerobic capacity categories, respectively. The use of a percentile as the cutoff was also used in 1999 by Lee et al. (12), who studied the relationship between cardiorespiratory fitness and cardiovascular disease in a large observational cohort of men. In addition, the 25th percentile closely relates to the recommended minimum level of aerobic capacity (42 mL/kg/minute) suggested by Sothmann et al. (1) that has been adopted by the National Fire Protection Association and most municipal fire departments in the United States (including those in this study's population). The 50th percentile was chosen as the cut off for the high fit designation because of the distributional characteristics of the population's data and to remain in accordance with current annual physical assessment methods used by the department. Neither age nor sex was directly considered when assigning aerobic fitness levels, as fire departments institute a minimum standard for aerobic fitness to help ensure that all commissioned fire personnel are capable of performing the myriad of critical job tasks and responses regardless of age or sex. Maximum aerobic capacity was estimated using the submaximal incremental treadmill protocol developed by Gerkin et al. (13) and guidelines suggested by the Wellness Fitness Initiative of the International Association of Fire Fighters and the International Association of Fire Chiefs (14). In brief, each participant is hooked up to a heart rate monitor and made to walk on a standard treadmill. The treadmill's speed and incline are increased at prespecified time points until the subject's target heart rate is reached and $\mathrm{VO}_{2\mathrm{max}}$ can be estimated. Direct measurement of $\mathrm{VO}_{2\mathrm{max}}$ using oxygen and carbon dioxide analyzers and monitoring of electrocardiogram output is generally limited to specific indications because of its higher cost.

Injury defined

Injuries that occurred on the job were recorded either if they were reportable to the Occupational Safety and Health Administration or if they were deemed nonreportable but were documented internally because of the potential for the injury to progress to the point of requiring an insurance claim (e.g., due to cumulative or repeated trauma). It should be noted that field personnel work 24-hour shifts. For the purposes of these analyses, reported injuries known to be only internally documented incidents with no loss of function or ability to perform duties (by review of injury report details) were excluded. In addition, cardiac events (e.g., stroke, heart attack), along with heat exhaustion, stress, and other medical issues, were excluded from injury analysis. These events were considered more likely to be indicative of an underlying set of symptoms, conditions, or diseases than to be related to an injury sustained on the job.

Statistical analyses

Data from annual physical examinations and injury surveillance reports were merged utilizing unique identifiers, which enabled a direct comparison of persons with and without injury. Quantitative methods, notably time-to-event regression models, were used to evaluate the relationship between aerobic fitness and injury. Analyses were conducted for 3 separate injury outcomes: 1) any recorded injury; 2) injuries resulting from physical exercise; and 3) any reported sprain or strain.

For time-to-event (i.e., first injury) analyses, cumulative incidence was estimated using the life table and Kaplan-Meier methods, which allow for censoring (i.e., no injury). Incidence rates were assessed with respect to established fitness measures. These levels were set using methods similar to those used for establishing aerobic fitness levels (as previously explained); however, in this case, sex was taken into account for measures of body fat percentage, grip strength, and flexibility. The time-to-event analysis utilized repeated measures in which each time point (observation) corresponded to a person's annual medical examination until the occurrence of injury or censoring. This method accounted for variable observation periods because some employees were introduced later in the study period (e.g., new employees), whereas others dropped out (e.g., retired, transferred), and it enabled a single person to contribute time at risk to each of the fitness levels based on his or her most recent physical assessment. Survival analyses were completed using Cox proportional hazard regression models. Statistical analyses were conducted using Stata software, version 11.2 (StataCorp LP, College Station, Texas).

Table 1. Mean Values of Person-Level Descriptive Statistics, Tucson, Arizona, 2005–2009

Variable	No.	Mean	Minimum Mean	Maximum Mean	Mean Difference
VO_{2max}, mL/kg/minute	782	49.6	43.6	55.8	12.2
Resting heart rate, beats per minute	797	62.9	57.2	69.2	12.0
Total grip strength, lbs[a]	797	229.5	211.4	247.5	36.1
Flexibility, inches[b]	782	5.8	4.5	7.0	2.5
% body fat	790	18.3	15.4	20.9	5.5

Abbreviation: VO_{2max}, relative aerobic capacity.
[a] 1 lb = 0.45 kg.
[b] 1 inch = 2.54 cm.

RESULTS

At the end of each calendar year from 2005 to 2009, there were between 577 to 694 commissioned employees within this metropolitan fire service. During that time period, 799 employees underwent at least 1 physical examination and follow-up until their first injury event or censoring. On average, the clinic database accounted for approximately 87% of the workforce population, and the mean age was 39.2 (standard deviation, 9.6) years. Table 1 displays select summary fitness measures of the study population across the study period. The mean for VO_{2max} for the overall population across time was 49.6 mL/kg/minute, with a 12.2-unit difference between the minimum and maximum mean values. In total, 773 injuries were reported (Table 2). There were 357 persons who sustained at least 1 injury of any type, 174 who sustained at least 1 exercise-related injury, and 294 who sustained at least 1 sprain or strain injury. The median lengths of follow-up were 2.5, 3.2, and 2.8 years, respectively. A previous descriptive analysis of this population (for the years 2004–2009) demonstrated that 67% of all injuries were sprains and strains, and that number increased to 89% among exercise injuries. Thirty percent of all injuries were reported to have resulted in lost time on the job (10).

Kaplan-Meier analyses (data not shown) indicated that the incidence rate for injury decreased and the median time to injury increased with increasing age (stratified into 10-year categories) ($P < 0.001$). There were no significant differences identified between sexes; however, women accounted for only 5% of the study population (as is common for the fire service (15)). Increases in body fat percentage were related to increased incidence rate, driven most notably by those in the highest tier (>36% body fat).

Table 3 displays the general summary characteristics of the incidence of injury outcomes for VO_{2max} levels and repeated measures modeling. Log-rank tests indicated that there were statistically significant increases in incidence rate with a decline in VO_{2max} for each of the 3 injury outcomes. In addition, persons with lower VO_{2max} levels were likely to sustain any injury sooner than were those who were more fit, as indicated by a median time to injury of 2.24 years in level III (least fit category) compared with 4.07 years for level I (most fit category; $P < 0.001$).

Table 2. Annual Frequency of Injury Outcomes, Tucson, Arizona, 2005–2009

Year	No. of Employees	No. of Recorded Injuries	No. of Sprains and Strains	No. of Exercise-related Injuries[a]
2005	577	128	84	30
2006	625	148	100	50
2007	659	174	120	62
2008	694	199	128	81
2009	667	124	89	45

[a] Of all exercise-related injuries, 85.2% were sprains and strains.

Cox proportional hazard modeling

Results from Cox proportional hazards models are presented in Table 4. The dependent variables in these models utilized time to first injury as a function of fitness. The hazard ratios for fitness are shown with respect to 2 modeling strategies: 1) VO_{2max} adjusted for age and sex and 2) VO_{2max} adjusted for other measures of fitness (i.e., resting heart rate, grip strength, flexibility, body fat percentage, number of continuous sit-ups and push-ups, age, and sex). With a hazard ratio of 0.959 for all injuries, a 1-mL/kg/minute increase in VO_{2max} decreased the risk of injury 0.041 times ($P < 0.001$). The amount of work needed to complete a given task in relation to the amount of energy expended during 1 minute of seated rest is referred to as the metabolic equivalent of task. For VO_{2max}, a single metabolic equivalent of task is approximately 3.5 mL/kg/minute. Thus, these results suggest that improving one's aerobic capacity by 1 metabolic equivalent of task would reduce the risk for any injury by approximately 14%.

Table 5 shows the relationship between the categorical levels of aerobic fitness (VO_{2max}) for the repeated measures analyses. For each injury outcome, persons with a lower fitness status (e.g., level III) had a higher hazard ratio for injury than did those in the most-fit category. For example, persons with a VO_{2max} between 43 and 48 mL/kg/minute (level II) were 1.38 times more likely to sustain any injury than were those in the top category of VO_{2max} (>48 mL/kg/minute). The risk of injury increased with decreasing fitness level, as those with a VO_{2max} less than 43 mL/kg/minute (level III) were 2.2 times more likely to have any injury than were those in the top VO_{2max} fitness category. The hazard ratios were also found to

Table 3. Time-to-Event Summary Statistics Between Fitness Levels and Injury Outcomes, Tucson, Arizona, 2005–2009

Fitness Level[a]	Injury Type								
	All Injuries			Physical Exercise			Sprains and Strains		
	IR[b]	No. at Risk	Years at Risk[c]	IR	No. at Risk	Years at Risk	IR	No. at Risk	Years at Risk
I	17.5	460	921	7.3	532	1116	12.2	482	996
II	21.1	287	442	7.2	332	541	17.2	312	483
III	29.9[d]	235	338	13.3[d]	263	407	25.1[d]	242	355

Abbreviation: IR, incidence rate.
[a] The relative aerobic capacity for each level was as follows: I, >48 mL/kg/minute; II, 43–48 mL/kg/minute; and III, <43 mL/kg/minute.
[b] Incidence rate per 100 person-years.
[c] Contributed time at risk (person-years).
[d] Statistical significance ($P < 0.05$) between levels using log-rank test for equality of survival functions.

be greater when the event outcome was restricted to time to first reported sprain or strain.

Effect modification

To assess the potential of effect modification of the relationship by age, a simple age-stratified analysis was completed for all injury outcomes, as well as for sprains and strains. Age proved to be a significant modifier of $\text{V}O_{2max}$ ($P < 0.001$). Table 6 presents the crude hazard ratios for the all-injury model and the sprain and strain model in relation to age (<30 and ≥30 years of age) and overall, stratified by aerobic fitness level. For both outcome types, the risk of injury among those with decreased $\text{V}O_{2max}$ was higher in persons younger than 30 years of age than in those 30 years of age or older. Thirty years of age was chosen as our demarcation value primarily based on incidence rates resulting from the Kaplan-Meier analysis described above. In addition, persons 30 years of age or younger had a consistently increased incidence rate, regardless of the injury type. Our previous descriptive study of injury distributions demonstrated that firefighters (median age, 31 years) sustained the most injuries (30.7%), with lower injury rates for engineers, paramedics, captains, etc. (10). Given the strong relationship between age and rank and the results from Kaplan-Meier estimates, it seemed suitable to use 30 years of age as our cutoff value for assessing potential effect modification.

DISCUSSION

In the present study, we sought to better understand the association between levels of aerobic fitness and the incidence of injury using a retrospective occupational cohort. The findings were consistent with our original hypothesis that lower fitness levels, as defined by $\text{V}O_{2max}$, would be associated with increased risk of injury. Furthermore, these increased risks were modified by age, with a larger association between fitness level and subsequent injury in those 30 years of age or younger. The reduction in injury risk was significant for all injuries, sprains and strains, and physical exercise injuries. These findings are especially noteworthy considering that one third of work-related injuries in this population resulted from exercise activities (10), further indicating the need for fitness programs with improved structure and management relevant to the high physical demands of the job.

A number of studies have assessed the relationship between various measures of fitness and the performance of a given task, with varying results. However, in contrast to our present study, few studies have focused on assessing the association among fitness, performance, and injury risk.

Two published studies have demonstrated an increase in injuries associated with fitness or the implementation of fitness programs (9, 16). After a baseline treadmill test to assess $\text{V}O_{2max}$, participants of the Aerobic Center Longitudinal Study had their physical activity levels assessed over a

Table 4. Cox Proportional Hazard Models for Assessing Aerobic Fitness and Risk of Injury, by Injury Type, Tucson, Arizona, 2005–2009

Injury Outcome	Model					
	$\text{V}O_{2max}$[a]			$\text{V}O_{2max}$ Full Model[b]		
	No. of Observations	HR	95% CI	No. of Observations	HR	95% CI
All[c]	716	0.959	0.946, 0.972	710	0.953	0.939, 0.968
Exercise-related	718	0.960	0.941, 0.979	714	0.953	0.933, 0.973
Sprains and strains	718	0.952	0.937, 0.967	712	0.947	0.932, 0.963

Abbreviations: CI, confidence interval; HR, hazard ratio; $\text{V}O_{2max}$, relative aerobic capacity.
[a] Adjusted for sex and age.
[b] Includes independent variables: resting heart rate, grip strength, flexibility, % body fat, number of sit-ups performed, number of push-ups performed, age, and sex.
[c] There were fewer subjects in this category because of lacerations that occurred during the first clinic visit, which precluded follow-up for those subjects.

Table 5. Hazard Ratios[a] for Injuries by Levels Aerobic Fitness in Repeated Measures Modeling, Tucson, Arizona, 2005–2009

Vo_{2max} Level[b]	All Injuries (n = 716)		Exercise Injuries (n = 718)		Sprains and Strains (n = 718)	
	HR	95% CI	HR	95% CI	HR	95% CI
I		Referent		Referent		Referent
II	1.38	1.06, 1.78	1.20	0.81, 1.77	1.61	1.21, 2.13
III	2.22	1.72, 2.88	2.53	1.76, 3.64	2.63	1.98, 3.50

Abbreviations: CI, confidence interval; HR, hazard ratio, Vo_{2max}, relative aerobic capacity.
[a] All models were adjusted for sex and age.
[b] The relativeaerobic capacity for each level was as follows: I, >48 mL/kg/minute; II, 43–48 mL/kg/minute; and III, <43 mL/kg/minute.

12-month period (16). Increased risk of musculoskeletal injury was associated with increases in cardiorespiratory fitness (as measured by a treadmill test), as well as increases in the amount of reported weekly physical activity. Stratified analyses by physical activity type suggested that the association between cardiorespiratory fitness and musculoskeletal injury was potentially driven by unmeasured intensity levels of exercise. After instituting a new fitness program among United States Air Force service members to increase fitness and participation in fitness-related activities, the mean relative Vo_{2max} increased significantly (6.04 and 3.24 mL/kg/minute among men and women, respectively) over 3 years of the program (9). The number of injuries also increased during that time, which was likely a result of increased participation in exercise activities with no embedded injury prevention program.

Two studies failed to find an association between fitness and injuries. During an 8-week basic military training regimen, musculoskeletal injuries were assessed in relation to baseline body composition (or body mass index), aerobic fitness (determined by the time participants took to run 3,000 meters), health assessment measures, and age (17). Significant associations were observed at a univariate level between injury and a variety of variables, including age greater than 23 years, increased body mass index, slow run times, and dysfunction of back or lower limbs. Multivariate logistic regressions showed no relationship between injury and aerobic fitness level; however, increased body mass index, minor back and lower limb dysfunctions, and mental dysfunctions were predictive of injury. In a study of manual material handlers, McSweeney et al. (18) found no difference between exercisers and nonexercisers in terms of the likelihood of reporting an injury. However, the authors noted that increased or regular exercise was likely to reduce absenteeism occurrence and duration. In another study among male material handler employees at 3 separate facilities, no association was observed between injury occurrence and absolute aerobic capacity; however, a significant increase in injury risk was related to a decreased Vo_{2max}, in addition to increased body fat percentage (19). It is important to note that none of the studies described above used repeated measures of fitness, unlike the present study. The added strength of being able to capture time-series data for the population increased statistical power of our study and our ability to control for confounding effects both within and across cohort members.

Table 6. Age-Stratified Hazard Ratios[a] for All Injuries and Sprains and Strains by Fitness Level, Tucson, Arizona, 2005–2009

Fitness Level by Injury Type[b]	Total		Age <30 Years		Age ≥30 Years	
	HR	95% CI	HR	95% CI	HR	95% CI
All injuries						
I		Referent		Referent		Referent
II	1.38	1.06, 1.78	2.28	1.41, 3.71	1.15	0.85, 1.57
III	2.22	1.72, 2.88	3.43	2.10, 5.58	1.86	1.36, 2.53
Sprains and strains						
I		Referent		Referent		Referent
II	1.61	1.21, 2.13	2.27	1.32, 3.90	1.40	1.00, 1.95
III	2.63	1.98, 3.50	4.48	2.63, 7.64	2.10	1.49, 2.96

Abbreviations: CI, confidence interval; HR, hazard ratio.
[a] All models were adjusted for sex and age within the strata.
[b] The relative aerobic capacity for each level was as follows: I, >48 mL/kg/minute; II, 43–48 mL/kg/minute; and III, <43 mL/kg/minute.

Results from our study indicated that there was a modification of injury risk based on age of the person. In particular, younger employees (30 years of age or younger) with a VO_{2max} below that of the high fit group (i.e., VO_{2max} <48 mL/kg/minute) had a higher risk of injury than did their older, less fit counterparts. This effect modification may be due to changes in job rank (and presumably job duties and exposure to external conditions) with increasing age in firefighters. Typically, younger personnel hold the rank of firefighter, whereas promotion or career progression tends to lead into ranks of paramedic, engineer, and captain. For most emergency responses, firefighters are the first to enter an emergency scene and are thus subject to greater hazards, known and unknown emergent threats, and time-limiting stresses. One exception includes the risks to which paramedics are exposed during calls involving advanced life support. Nevertheless, the hazard profile and exposure risk for those with the rank of firefighter can be considered greater than those of their team counterparts (e.g., engineer, captain, chief).

Limitations

Although injury events that occurred before the first observed clinic visit were removed to avoid left-censoring bias (a product of data merging), there was no knowledge of previous injury history. In addition, analyses were restricted to the first specified injury event; therefore, recurrent injuries were not assessed. Future studies on recurrent injuries should enhance the understanding of injuries in this population by differentiating between the risks of repeated injuries (i.e., the same injury type suffered multiple times by a person) and those of the repeatedly injured (i.e., persons who suffer from multiple injury types). The data assessed for this study also did not permit evaluation of intrinsic factors, such as central motor control (i.e., balance), skeletal abnormalities, alignment of joints, and ligamentous laxity (3–5, 20–29). Ideally, inclusion of these factors would improve future studies (30–32), as intrinsic risk factors each influence local anatomy and biomechanical limitations.

Although VO_{2max} is linearly related to heart rate and energy expenditure, it is an indirect measurement of an person's maximal capacity to do work aerobically (33). In the present study population, VO_{2max} was estimated using a submaximal test protocol that was previously validated and has been used widely in the fire service (13). Two recent studies, however, have indicated the potential for submaximal tests to overestimate true aerobic capacity (34, 35). If true, any overestimation of VO_{2max} should not influence the regression modeling because the potential bias would be nondifferential. Of note, the distribution of VO_{2max} values in our study is considered higher than that in the general population. Standard fitness assessments classify midrange ("good") aerobic fitness at 40 years of age to be 35–38 mL/kg/minute for women and 42–45 mL/kg/minute for men (2). The notion that firefighters are more fit than the general population is supported by the characteristics of this study's firefighting population, who had an average age of 39 years and a mean VO_{2max} of 49.6 mL/kg/. These differences are likely due to the use of an employed population and the active nature of the job. As previously mentioned, the cutoff values established for the aerobic fitness levels in these analyses were based on the range of distributions within this active population in addition to methods used in other research.

When compared with the results from a previous study that described exercise-related injuries, which accounted for one third of all reported injuries, as the most common (10), the present findings may appear somewhat counterintuitive. It was not clear if the injuries sustained during exercise periods were the result of overexposure (i.e., fit people exercising too intensely or for too long while on duty) or if the types of exercises being completed were not appropriately structured and evaluated in an effort to minimize the chances for overexertion. The present study's results regarding increased risks of injury among those deemed less fit suggests that the structure and management of exercise within the fire service needs to be considered more intently and that employees without a physical training background should not necessarily be left to exercise without some level of appropriate programming, training, and oversight. Most professional fire departments promote or require some level of exercise among their employees in an effort to assure their ability to complete job tasks with high physical demands (e.g., rescues). Persons in the fire service, much like the majority of the general population, can benefit from exercise instruction and from resources aimed at maintaining or improving their functional fitness levels, thus reducing the potential injury loss. Given the limited financial and personnel resources, a challenge for all fire departments (and similar occupational settings) will be determining the best measures for assessing each component of functional fitness that are 1) consistent and reliable and 2) feasible for implementation.

Conclusions

Findings from the present study provide empirical evidence that lower fitness levels are associated with increased risks of injury among career fire service employees. Furthermore, these increased risks were modified by age, which is likely due to the fact that rank, job task, and risk profile are often associated with age in this population. As injuries continue to be of relevant health concern in the fire service, the contribution of fitness to the likelihood of injury is significant. Given that injuries are often the result of a multitude of factors and the efficiency of every response activity in the fire service is dependent on the health and fitness of those responders, comprehensive and multifaceted solutions need to be devised, applied, and distributed in order to prevent further injury loss.

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Firefighter Fitness: Improving Performance and Preventing Injuries and Fatalities

Denise L. Smith, PhD

Abstract
Firefighting is dangerous work. Each year, approximately 80,000 firefighters are injured and about 100 firefighters lose their lives in the line of duty. Firefighters face multiple dangers in the course of their work; they encounter toxic fumes, dangerous products of combustion, high radiant heat loads, and a chaotic work environment. Despite the myriad dangers, the leading cause of line-of-duty death among firefighters is sudden cardiac event, accounting for approximately 45% of duty deaths. Firefighting requires high levels of aerobic fitness, anaerobic capacity, and muscular strength and endurance; however, data suggest that many firefighters do not possess high aerobic or anaerobic capacity. Furthermore, many firefighters are overweight and have one or more modifiable risk factors for cardiovascular disease. The safety of the public and the health and safety of firefighters would be enhanced if firefighters followed well-designed fitness programs to improve overall health and fitness.

Introduction

Firefighters perform strenuous work in hostile, chaotic, and unpredictable conditions. Thus, firefighting is widely recognized as dangerous work. In 2009, there were 1.35 million fires in the United States, resulting in 3,010 civilian deaths, 17,050 civilian injuries, and an estimated total property loss of $12.5 billion (25). There are approximately 1.2 million firefighters in more than 30,000 departments providing local communities with protection from fire and other hazards. Roughly 29% of the U.S. Fire Service is made up of career, paid firefighters, while the remaining 71% are volunteer firefighters (25).

Firefighters are a unique occupational group, and they face multiple dangers in the course of their work; firefighters encounter toxic fumes, dangerous products of combustion, high radiant heat loads, and a chaotic work environment. In addition to hazards encountered at the scene of a fire, firefighters also perform rescues, extrications, emergency medical system (EMS) calls, and respond to natural disasters and hazardous materials spills. Attesting to the dangerous nature of the job, approximately 80,000 firefighters are injured on the job each year. More than 40% of the injuries occur on the fireground, despite the fact that firefighters spend a very small percentage of their time engaged in fire suppression activities. When expressed relative to the type of call they are responding to, approximately 23 to 25 firefighters are injured per 1,000 fires, whereas only 0.6 to 0.7 injuries occur per 1,000 non-fire emergencies (24).

Firefighting also results in approximately 5.7 firefighter fatalities per 100,000 structure fires (13). A retrospective study, performed between 1995 and 2004, revealed that 1,006 firefighters had died in the line of duty during that period. Approximately 45% of those fatalities were the result of cardiovascular events. While most people recognize that firefighting is dangerous, many believe that fire or the products of combustion account for most of the fatalities in the Fire Service. As seen in Figure 1, the percentage of fatalities attributed to sudden cardiac events far outnumbers the deaths due to burn or asphyxiation on a consistent basis.

Physical Demands of Firefighting

Firefighting involves a unique set of stressors (Fig. 2). Firefighters perform strenuous muscular work; they must climb stairs and ladders, carry and use heavy tools, often above their head or in awkward positions, and they may be called upon to perform difficult rescue operations. Firefighters work in dangerous environments; they encounter extreme temperatures, toxic smoke (including carbon monoxide and hydrogen cyanide), and chaotic conditions that include loud noise and low visibility. Further, this work must be done with time urgency and is often performed under the psychological stress of knowing that civilians are

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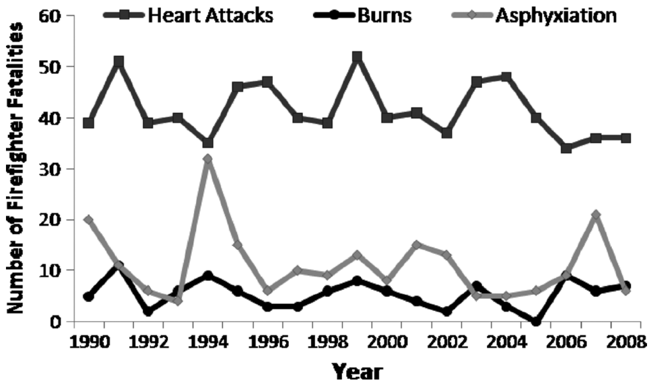

Figure 1: Firefighter casualty statistics from 1990 to 2008. Based on data from The National Fire Protection Association (NFPA).

in imminent danger. Additionally, firefighters must perform their work while wearing personal protective equipment (PPE), equipment that is necessary to protect the firefighter but that also imposes a considerable physiological burden because of its weight, insulative properties, and restrictiveness. The unique set of stressors that are encountered during firefighting results in substantial physiological strain, particularly to the thermoregulatory and cardiovascular systems.

Physiological Strain of Firefighting

Considering the work that is done and the environment in which it is performed, firefighting is among the most arduous work that humans undertake. Not surprisingly then, firefighting affects every system of the body. Figure 3 summarizes some of the major effects of firefighting on the body.

While firefighting results in significant physiological strain affecting nearly every system of the body, statistically the greatest risks to the firefighter come from the cardiovascular and thermal strain associated with firefighting. Strenuous firefighting activities lead to near maximal heart rates (HR) that can remain elevated for extended periods of time (1,38). Stroke volume decreases following strenuous firefighting activity (38). Firefighting may result in high blood pressures that quickly drop below resting values following cessation of work (21).

Firefighting is associated with profuse sweating and hence a decrease in plasma volume. A 15% reduction in plasma volume has been reported after 18 min of strenuous firefighting drills (38). The decrease in plasma volume contributes to the reduction in stroke volume noted above and leads to hemoconcentration. Hemoconcentration causes a change in blood electrolytes and increases blood viscosity (39). Platelet number increases (more than can be explained by hemoconcentration) and platelet aggregability increases following firefighting activity (41).

Given that firefighters wear heavy, insulative PPE that often weighs in excess of 22 kg and are called upon to perform strenuous muscular work in very hot environments, it is no surprise that firefighting leads to thermal strain. Challenges to the thermoregulatory system include elevated core temperature (hyperthermia) and dehydration. Hyperthermia and dehydration are very serious problems in the Fire Service because these twin challenges can hasten the onset of fatigue and limit work time, add to cardiovascular strain, lead to fatal heat illnesses (including heat stroke), impair cognitive function, and increase the risk of injury.

Core temperature increases rapidly but does not reach drastically high levels during short-term firefighting. Periods of 18 to 20 min of firefighting have been reported to cause an average increase in body temperature of 1.5 to 2.5°F (21,40). Prolonged firefighting or repeated evolutions of training would cause greater elevations in body temperature. Firefighting, like other strenuous activity, leads to fatigue. The fatigue may be due to neural, metabolic, or muscular factors and is likely hastened by work in the heat. Fatigue can impair the firefighting mission and may increase susceptibility to injury.

Performance Requirements

Firefighting requires high levels of aerobic fitness, anaerobic capacity, and muscular strength and endurance. Additionally, given the detrimental effects of excess body fat, firefighters also should possess an appropriate body composition. Several studies have attempted to quantify the aerobic

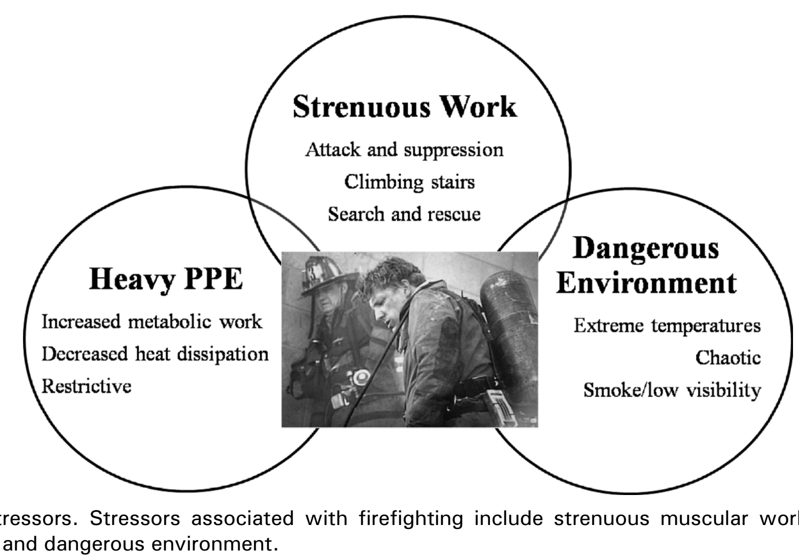

Figure 2: Unique job stressors. Stressors associated with firefighting include strenuous muscular work, heavy personal protective equipment (PPE), and a hot and dangerous environment.

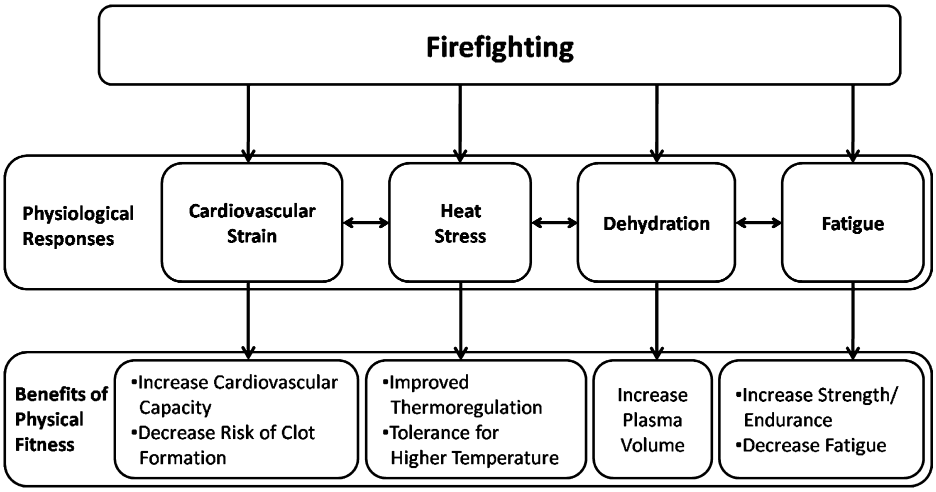

Figure 3: Primary physiological responses to firefighting and the benefits of physical fitness. Firefighting results in considerable physiological strain. A well-designed fitness program provides multiple benefits and helps prepare the firefighter for the demands of firefighting.

requirements of firefighting. A limitation to all of these studies is that they "simulate" firefighting activity. Further, the work that must be performed varies greatly based on the work assignment (*e.g.*, officer, venting, advancing a charged hose line, performing a rescue). Studies have reported the estimated oxygen consumption associated with firefighting to range between 33.6 and 49.0 $mL \cdot kg^{-1} \cdot min^{-1}$ (17,26,28,44). Sothmann and colleagues (1990) devised a simulated set of firefighting drills that took approximately 9 min to complete (44). The participants had an average $\dot{V}O_{2max}$ of 39.9 $mL \cdot kg^{-1} \cdot min^{-1}$ and worked at approximately 76% of their $\dot{V}O_{2max}$ to complete the simulated drills (44). To validate a minimum $\dot{V}O_{2max}$ requirement, the researchers recruited another group of firefighters ($\dot{V}O_{2max}$ range 26–51 $mL \cdot kg^{-1} \cdot min^{-1}$) and had them perform the fire-suppression drills. Seven of 10 firefighters with a $\dot{V}O_{2max}$ of 33.5 to 41.0 $mL \cdot kg^{-1} \cdot min^{-1}$ were able to successfully complete the drills within the allotted time. All participants with a $\dot{V}O_{2max}$ greater than 41 $mL \cdot kg^{-1} \cdot min^{-1}$ were able to complete the fire-suppression activities within the acceptable timeframe. Based on research findings, the National Fire Protection Association (NFPA) Standard on Occupational Medical Programs for Fire Departments recommends that firefighters have a minimal aerobic capacity of 42 $mL \cdot kg^{-1} \cdot min^{-1}$ (metabolic equivalent of task score, 12) (31).

Firefighters also must have a high anaerobic capacity to perform certain job tasks. Strenuous firefighting relies on anaerobic energy sources (in addition to aerobic sources) and high lactate values (6–13 mmol) have been reported following demanding firefighting simulations (2,17,26).

Muscular strength and endurance also are important to meet the physical demands placed on firefighters. Muscular strength and endurance are necessary for forcible entry, advancing the fire hose, chopping tasks, and victim rescues. Sothmann and colleagues (2004) have sought to validate minimally acceptable standards for muscular strength and endurance necessary to successfully perform firefighting tasks (43). Participants completed a simulated set of firefighting tasks and a battery of tests of physical abilities. The researchers found that physical ability tests (hose drag/high rise pack carry, arm lift, and muscle endurance) combined to significantly predict performance time on the simulated firefighting tasks. Rhea and colleagues (2004) investigated the relationship between several fitness scores and job performance (assessed by performance time on a simulated hose pull, dummy drag, stair climb, and hose hoist) (34). These authors reported high correlations between measures of muscular strength, muscle endurance, anaerobic performance, and performance times.

Fitness Profile of U.S. Firefighters

Given the heterogeneous nature of the U.S. Fire Service, it is difficult to get an accurate, generalizable assessment of the "typical" firefighter. Firefighter fitness profiles are likely to vary greatly depending upon region of the country, career or volunteer status, the age of the firefighter, and the hiring, medical, and fitness policies of the department.

Aerobic Capacity

Despite the physically demanding aspects of the job, several studies have reported that firefighters do not possess above-average aerobic capacity. Again, caution must be used when interpreting the literature because many articles report fitness values on a small number of firefighters, from a single department or small group of departments. Furthermore, many of the aerobic fitness values reported in the literature are based on submaximal exercise tests. In general, reported aerobic fitness values for firefighters range from 35 to 56 $mL \cdot kg^{-1} \cdot min^{-1}$ (9,35,37,49). An early study that randomly sampled 150 firefighters from a large metropolitan city found that aerobic capacity significantly decreased from the 20- to 25-yr-old group (47.7 $mL \cdot kg^{-1} \cdot min^{-1}$) to the 30- to 35-yr-old group (37.9 $mL \cdot kg^{-1} \cdot min^{-1}$) and from the 35-yr-old group to the 40- to 45-yr-old group (31.5 $mL \cdot kg^{-1} \cdot min^{-1}$). In each case, however, the firefighters' aerobic capacity was similar to that predicted for sedentary individuals (37). In contrast, Davis and colleagues (2002) studied a small municipal fire department on the West Coast and found that firefighters in the 20- to 29-yr age group had an aerobic capacity of 55.9 $mL \cdot kg^{-1} \cdot min^{-1}$ and that the oldest group, 50–59 yr, had an oxygen uptake of 40.4 $mL \cdot kg^{-1} \cdot min^{-1}$ (9). In every decade-group, the firefighters' aerobic capacity was higher than age-predicted values (9). While it is tempting to hope that the improvements in aerobic capacity cited in the more recent study reflect positive changes relative to fitness patterns among the Fire Service, other evidence suggests that firefighters possess modest aerobic capacity (7,9,49). A study of over 100 recruit firefighters in a metropolitan fire department found that recruit firefighters entered the fire service with an aerobic capacity of 35 $mL \cdot kg^{-1} \cdot min^{-1}$ (9). Encouragingly, the study went on to document a 28% increase in aerobic capacity following a 16-wk fitness program.

Muscular Strength and Endurance

In general, firefighters have high levels of muscular strength and endurance (2,9,29,34,35,43). Muscular strength and endurance are necessary to perform common firefighting activities, such as carrying ladders, advancing charged hose lines, and using heavy equipment. Firefighters rely on upper- and lower-body strength to perform their jobs. Further, core muscular strength also may serve to reduce the incidence of injuries (48). The high level of strength reported in the fire service also may reflect cultural values within the Fire Service.

Obesity

There is considerable evidence of a high prevalence of obesity among U.S. firefighters (7,12,16,42,46,50). Clark and colleagues (2002) investigated the body mass index (BMI) and health status of a group of municipal firefighters and reported that 80% of the firefighters were overweight or obese and that there was a significant increase in systolic blood pressure, diastolic blood pressure, cholesterol, and triglycerides as firefighters increased in fatness category (7). Conversely, $\dot{V}O_{2max}$ and METS decreased with increasing fatness (7). A study involving a large group of career firefighters (N = 332) found that at baseline testing, 53% of firefighters were overweight (BMI between 25 and 29.9), with an additional 35% classified as obese (BMI $\geq$ 30). Additionally, obese firefighters were more likely to have hypertension and low levels of high-density lipoprotein-cholesterol (42). A study of more than 100 career and volunteer firefighters with no known history of cardiovascular disease, stationed throughout Illinois, found an average BMI of 28.1 and that 75% of the participants had a BMI greater than 25 (12). Furthermore, Fahs and colleagues (2009) reported that increased BMI was associated with increased arterial stiffness (12). In addition to the high prevalence of overweight and obesity in the Fire Service, there is evidence that firefighters are getting heavier over time. Soteriades *et al.* (2005) found that over a 5-yr follow-up period, the prevalence of obesity increased from 35% to 40%, and the proportion of firefighters with extreme obesity increased fourfold (from 0.6% to 2.4%) (42).

Cardiovascular Risk

Most studies that have compared the overall cardiovascular mortality of firefighters with the general public have found that firefighters do not have an increased risk for cardiovascular death, except in instances where the careers of firefighters included significant time on the job before the use of respiratory protection (11). Studies in Boston, Connecticut, New Jersey, San Francisco, Seattle, Edmonton/Calgary and Florida all have found no association between cardiovascular mortality and occupation (3,10,14,18,27,30,36,47). Similarly, a recent review found that firefighters have similar risk profiles for obesity, hypertension, and hyperlipidemia compared with the general population (11).

Mismatch Between Fitness Demands and Fitness Profiles

Given that so much of a firefighter's time is sedentary, perhaps it is not surprising that they do not differ from the general population in fitness, obesity, or other cardiovascular risk factors. However, considering that their work is punctuated by periods of intense activity, these risk profiles may explain why sudden cardiac events are the leading cause of line-of-duty deaths among firefighters; essentially, there is a mismatch between the fitness and health requirements of strenuous firefighting and the current fitness profile of the U.S. Fire Service.

Fitness Recommendations

Current standards **recommend** that firefighters participate in a fitness program (22,32), but it is the responsibility of each individual department to determine whether to institute a fitness program. The NFPA 1583 Standard recommends a program that is positive, nonpunitive, and does not set fitness standards. Of the 440 firefighter fatalities investigated by the National Institute of Occupational Safety and Health (NIOSH) during the period from 1995 to 2004 (44% of fatalities during that period; 440 of 1,006), 39% of the departments offered a voluntary fitness program, but only 8% had mandatory participation (33).

Cardiovascular events are by far the leading cause of line-of-duty deaths among firefighters. Additionally, cardiac events are disproportionately related to fire suppression activities, with firefighters having a 10- to 100-fold increased risk of experiencing a fatal cardiac event after fire suppression versus normal duties at the station (23). Thus firefighters should have a high level of cardiovascular fitness in order to improve performance and decrease the risk of on-the-job fatalities associated with strenuous activity. Additionally, nearly 80,000 firefighters are injured each year, with a large percentage of these injuries occurring during fireground operations. Clearly, fitness has an important role to play in preparing firefighters for the strenuous activity they encounter during firefighting activity. Appropriate fitness programs can enhance overall health, improve performance, and lessen the risk of firefighter injury or fatality. Firefighters and the public they serve will benefit from more fitness programming in the Fire Service.

Fitness Prescription for Firefighter Health and Safety

Firefighting is strenuous physical work and places considerable strain on the body. In order to meet the unique physical demands of firefighting and to perform firefighting in a safe manner, firefighters must be physically fit. Like soldiers and elite athletes, firefighters should be physically prepared to meet the unique physical challenges they face. Figure 3 depicts the direct ways in which a fitness program can mitigate against the physiological strain of firefighting.

Fitness prescriptions for firefighters must meet certain criteria in order to adequately serve the U.S. Fire Service. Prescriptions need to address the unique and specific physiological demands of firefighting. This is difficult to accomplish because of the current diversity in fitness and health status of firefighters. Fitness prescriptions must recognize the unique structure and culture of volunteer and career fire departments. These prescriptions also must include individual and progressive programs to meet the individual needs of low-fit to highly-trained firefighters.

Aerobic Training

Aerobic training provides several health benefits, including improved body composition, serum lipids, glucose metabolism, and maximal aerobic capacity (20). While moderate-intensity aerobic exercise (50%–70% HR_{max}) is widely recommended for health benefits, research suggests that higher-intensity aerobic exercise training may promote weight loss and cardiovascular improvements to a greater extent (8). Given the physical demands of firefighting, and the high proportion of line-of-duty deaths attributed to cardiac events, it is essential that a training program for firefighters include endurance training.

Sprint Interval Training (SIT)

SIT is a type of high-intensity interval training (HIT) that is designed to improve endurance, increase anaerobic threshold, and improve maximal performance. This type of training has been shown to be effective at increasing aerobic capacity (6), improving endurance capacity when working at 80% of aerobic capacity (4), enhancing aerobic metabolism (19), and increasing muscle glycogen content and the maximal activity of citrate synthase (5). Given the effectiveness and efficiency of these workouts and the degree to which they mimic actual energy expenditure during an emergency, it is reasonable to include SIT in exercise prescriptions for firefighters. However, given the high intensity of the workouts and the heterogeneity of fitness levels in the Fire Service, it may be prudent to initiate exercise programs at a lower intensity and increase progressively.

Functional Training

Functional training targets movements that are necessary for activities of daily living (45). Functional training utilizes full-body, dynamic movements to increase muscular strength and endurance as well as aerobic capacity using equipment such as medicine balls, physioballs, and exercise bands to provide resistance. This type of exercise mimics the high-intensity demands of firefighting. In fact, functional training workouts have been gaining popularity among progressive Fire Departments. CrossFit workouts are now embraced by many members of the Fire Service.

Resistance Training

Resistance training increases muscle mass and function. Muscle strength and endurance routinely have been found to predict performance on simulated firefighting activities and are unquestionably important for firefighters. Additionally, resistance training is associated with a decreased risk of all-cause mortality, the development and maintenance of lean muscle mass, and enhanced glucose metabolism (15,20). Resistance training should be part of every firefighter's fitness program. Not only will it improve work capacity, it is likely to provide protection against injuries, especially muscular strains, on the fireground.

Lifestyle Modifications

There must be a cultural change within the U.S. Fire Service in order to improve fitness and decrease injuries and cardiac events. Changes should include a fitness program designed to improve aerobic capacity, muscle strength and endurance, and functional capacity. The fitness program and a sound dietary plan also should seek to promote healthy weight for firefighters. The development of a social support system with adequate leadership and incentives should promote healthy lifestyle changes. Each individual firefighter and Fire Department must set short- and long-term goals that are realistic and measureable as well as easy to implement within the constraints of space, equipment, and other duties.

Conclusion

Firefighting is strenuous and dangerous work with a unique set of stressors. In order to meet the physical demands of firefighting, firefighters must be physically fit. Firefighters who possess high levels of cardiovascular and muscular fitness are better able to serve the public by performing their job more effectively. Fit firefighters have increased mobility, energy, and endurance, allowing them to better perform job duties efficiently and safely, and fit firefighters also are less likely to jeopardize the safety of their fellow firefighters or the public they serve.

The safety of the public and the health and safety of firefighters would be greatly enhanced if firefighters followed well-designed fitness programs to improve overall health and fitness. Exercise scientists can play an important role in enhancing firefighter's fitness, thereby improving public health and safety. Specific fitness programs that meet the needs of a broad range of individuals within the Fire Service must be developed that are tailored to the specific job requirements that firefighters face. These fitness programs should be geared toward improving health, safety, and performance. In order to be adopted, these programs must be sensitive to the diverse needs in the Fire Service.

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ARTICLE

Cardiovascular Strain of Firefighting and the Risk of Sudden Cardiac Events

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[1]Health and Exercise Sciences, Skidmore College, Saratoga Springs, NY; [2]University of Illinois Fire Service Institute, Champaign, IL; [3]Department of Environmental Health, Harvard TH Chan School of Public Health, Boston, MA; [4]Occupational Medicine, Cambridge Health Alliance/Harvard Medical School, Cambridge, MA

SMITH, D.L., J.P. DEBLOIS, S.N. KALES, and G.P. HORN. Cardiovascular strain of firefighting and the risk of sudden cardiac events. *Exerc. Sport Sci. Rev.*, Vol. 44, No. 3, pp. 90–97, 2016. *Approximately 45% to 50% of line-of-duty deaths in the fire service are caused by sudden cardiac deaths, which most often occur during or shortly after firefighting duties. We present a theoretical model linking the cardiac, vascular, and hematological responses of firefighting to the triggering of sudden cardiac death in susceptible individuals.*

Key Words: firefighting, cardiac, vascular, coagulatory, cardiovascular disease, sudden cardiac death.

Key Points

- The leading cause of duty-related death within the fire service is a sudden cardiac event, accounting for approximately 50% of line-of-duty deaths.
- Sudden cardiac events are much more likely to occur after firefighting activities than other duties and may be the result of primary arrhythmias or myocardial infarction.
- Firefighting leads to significant cardiovascular strain, including alterations in cardiac function, vascular function, and hemostasis.
- Most firefighters recover from the stress of firefighting without incident. However, the cardiovascular strain of firefighting may trigger a cardiovascular event in firefighters with an underlying disease.
- Increased cardiac work, vascular dysfunction, tissue ischemia, and a procoagulatory state may be important causal links that increase the risk of sudden cardiac events in the vulnerable firefighter.

Editor's note: Go online to view the Journal Club questions in the Supplemental Digital Content: see http://links.lww.com/ESSR/A19.

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INTRODUCTION

Firefighters respond to multiple types of emergencies, such as fires, vehicle/machinery accidents, medical calls, calls for public assistance, technical rescue, and hazardous materials spills to protect the communities they serve. However, statistics show that firefighting (*i.e.*, those activities directly related to fire suppression) results in the greatest risk of injury or fatality (8). Firefighting activities often are conducted in immediately dangerous to life or health conditions that may expose firefighters to extreme environmental temperatures and to multiple chemical and particulate hazards. These conditions necessitate that firefighters wear heavy, insulated, and restrictive personal protective equipment (PPE). Hence, it comes as no surprise that firefighting results in high levels of cardiovascular strain.

Fire service statistics reveal that despite all the acute traumatic risks that firefighters face (*e.g.*, burn injuries, smoke inhalation, structural collapse), by far, the leading cause of line-of-duty death is cardiac related. In fact, approximately 45% to 50% of all firefighter duty–related fatalities are caused by sudden cardiac death (SCD) — a proportion that is relatively stable and stubbornly high. This point is highlighted in Figure 1, which compares SCD with fatalities from burns and asphyxiation since 1990. The number of cardiac fatalities seems to be trending downward during the past 10 years. This encouraging trend may be caused by efforts by the International Association of Firefighters, the International Association of Fire Chiefs, and the National Volunteer Fire Council, all of which have undertaken rigorous campaigns to increase medical evaluations and to promote firefighter wellness and fitness. However, as the numbers indicate, considerable work remains to further reduce cardiac fatalities in the US Fire Service (Fig. 1).

Importantly, sudden cardiac events are disproportionately more likely to occur during or after a firefighting activity than other duties. Although firefighters spend a small percentage of their time (1%–5%) engaged in fire suppression activities, more

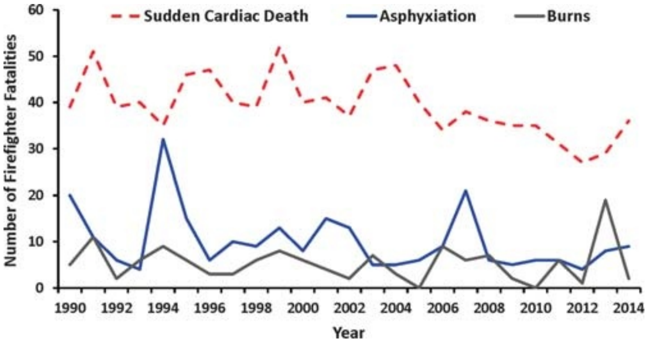

Figure 1. Line-of-duty deaths by major cause since 1990.

than 30% of cardiac fatalities occur during or shortly after firefighting activity, resulting in a 10 to 100 times greater risk of sudden cardiac events after firefighting versus station duties (19). Furthermore, there are approximately 17 to 25 duty-related nonfatal cardiovascular events (heart attacks and strokes) for every fatal event (8,15).

Cardiac events are devastating for individual firefighters and their families, but because firefighting relies on a coordinated team effort, duty-related cardiac events also can jeopardize job performance and the safety of other firefighters and may compromise the ability of firefighters to protect civilians during emergencies. Cardiac injuries likewise often will require significant time away from the fire department at significant cost and burden to the local fire department. Hence, there is an important public safety concern about cardiovascular events in the fire service. We recently have published a review that proposed a theoretical model highlighting the interaction of occupational, medical, and behavioral risk factors in contributing to underlying cardiovascular disease (CVD) (coronary heart disease (CHD) and/or structural heart disease) and where the strenuous duties of firefighting may trigger a cardiovascular event (Fig. 2) (32). In the current review, we extend the previous model by detailing results of translational research documenting the cardiovascular strain of firefighting and further highlighting the potential mechanisms by which cardiovascular responses to firefighting may lead to pathophysiologic changes that can trigger fatal arrhythmias or myocardial infarction, thus leading to a sudden cardiac event (Fig. 3).

FACTORS AFFECTING THE CARDIOVASCULAR STRAIN OF FIREFIGHTING

Firefighting involves performing a complex series of physically demanding tasks under psychologically stressful conditions within arduous environments. As depicted in Figure 3, the cardiovascular strain of firefighting results from multiple interacting factors including 1) sympathetic nervous system activation; 2) the strenuous physical work (aerobic and anaerobic); and 3) exposure to environmental conditions and pollutants contained in fire smoke.

Sympathetic Nervous System Activation

Sympathetic nervous activation begins with the alarm and continues throughout a fire call. The sudden sounding of an alarm increases psychological/mental stress, activating the sympathetic nervous system. While on the call, sympathetic activation continues because the fire scene is a dynamic cluttered environment in which fire behavior can change rapidly and where loud noises, time urgency, and potential danger produce powerful sympathetic arousal. Several studies have shown a fivefold to sevenfold risk of sudden cardiac events *during alarm response* versus nonemergencies (19,20). The increased relative risk of a cardiac event during this period can be attributed largely to sympathetic arousal and a putative surge in catecholamines because there is not yet exposure to the fire environment or the requirements for large amounts of physical work.

Physical Work

Structural firefighting requires a combination of static work and aerobic exertion, such as stair and ladder climbing (while

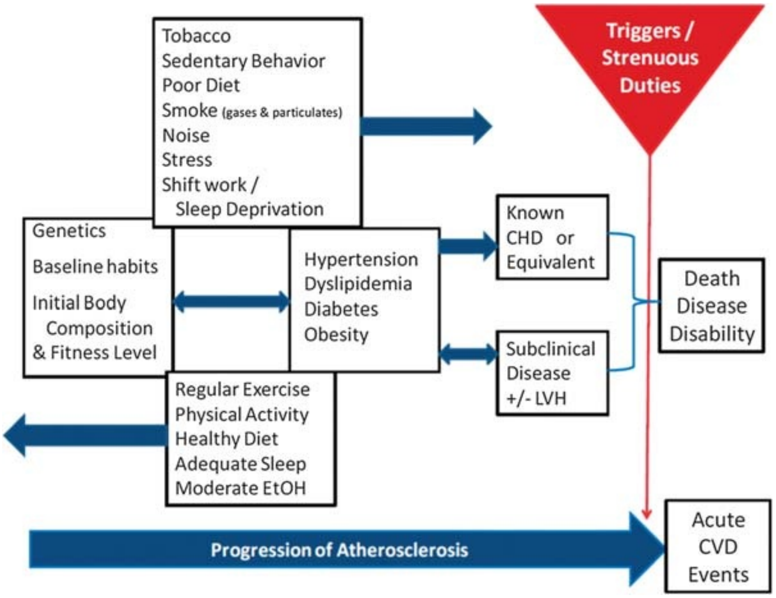

Figure 2. Theoretical model of occupational, medical and behavioral risk factors that contribute to sudden cardiac events following firefighting activities. Note that there is overlap between occupational and lifestyle risk factors. Arrows indicate that factors can be associated with progression or regression of risk factors and subclinical disease. EtOH, alcohol; CHD, coronary heart disease; LVH, left ventricular hypertrophy; CVD, cardiovascular disease. (Reprinted from (32). Copyright © 2011 Wolters Kluwer Health. Used with permission.)

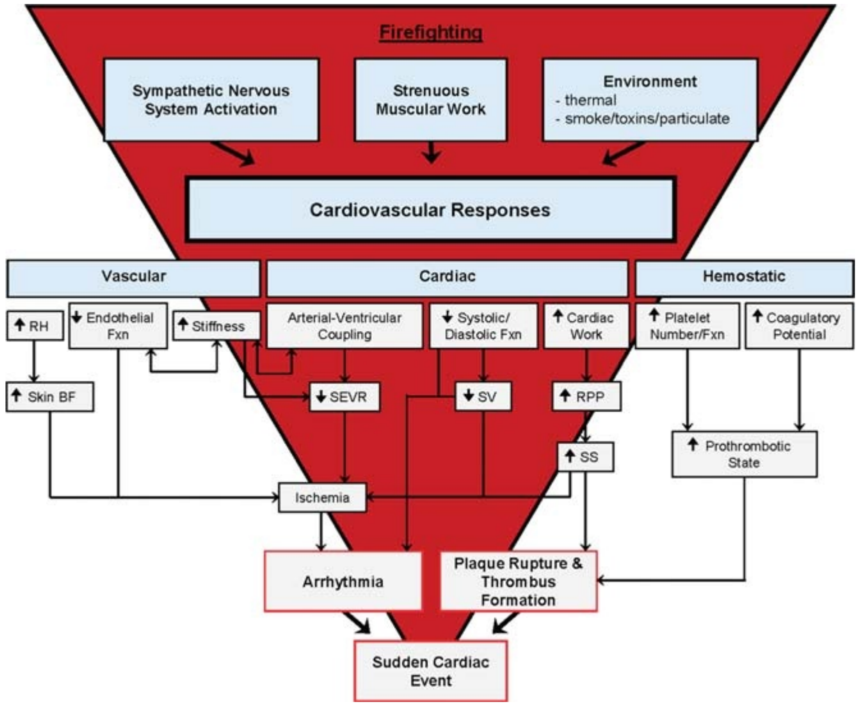

Figure 3. Theoretical interplay between cardiac, vascular, and hemostatic responses to firefighting and sudden cardiac events in susceptible individuals. RH, reactive hyperemia; BF, blood flow; Fxn, function; SEVR, sub-endocardial viability ratio; SV, stroke volume; RPP, rate pressure product; SS, shear stress.

carrying heavy equipment), forcible entry, victim search and rescue, building ventilation, and fire attack and suppression. Although it is known that different firefighting tasks require different levels of energy expenditure, firefighting often results in oxygen consumption of greater than of 40 $mL \cdot kg^{-1} \cdot min^{-1}$ (24). The strenuous work of firefighting is performed while wearing heavy (≥25 kg) and fully encapsulating PPE that provides range-of-motion restrictions, heavy insulation, and limited breathability and adds to the metabolic demands of firefighting. In addition, firefighters perform a great deal of upper body work (lifting and carrying heavy equipment, hose movement and control, chopping, ceiling overhaul), and upper body work (such as wood chopping or snow shoveling) leads to an exaggerated blood pressure response and an increased cardiac work and is associated with an increased risk of a sudden cardiac event (12).

Environmental Conditions

Radiant heat from a fire adds considerably to the heat stress experienced by firefighters. We have reported an increase in core temperature (T_{co}) of approximately 1.5°C after short-term (≤20 min) firefighting activity (30), and the rate of T_{co} change increased with subsequent firefighting activities (17). Both heat stress and dehydration exacerbate cardiovascular strain associated with heavy work (9).

Although firefighters regularly use self-contained breathing apparatus to protect their airways while operating inside the structure, firefighters routinely are exposed to fire smoke (outside of the structure and during overhaul/cleanup operations), which contains toxic and asphyxiant gases such as carbon monoxide, hydrogen cyanide, hydrogen sulfide, and particulate matter among a myriad of other chemicals (5). When inhaled, carbon monoxide reduces the availability of oxygen, thus, potentially resulting in tissue hypoxia. Tissue hypoxemia caused by carbon monoxide and other asphyxiants (*e.g.*, hydrogen cyanide, hydrogen sulfide) may lead to myocardial ischemia in susceptible individuals. Fire smoke also contains particulate matter associated with the promotion of arrhythmias, decreased heart rate variability, and increased blood pressure (23). Such particulates also may increase the formation of free radicals leading to activation of proinflammatory and prothrombotic pathways that may cause endothelial dysfunction and increased blood coagulability.

CARDIOVASCULAR RESPONSES TO FIREFIGHTING

Firefighting operations are complex, and no fire scene is identical to another. The magnitude of the cardiovascular strain is affected by the fuel that is burning (*e.g.*, heat release rate, products of combustion), the size of the fire (amount of fuel involvement), dimensions and layout of the structure, the resources (human and equipment) that are available to fight the fire, the tactics that are used (*e.g.*, interior, exterior, or combination attack), and the firefighter's assigned task. For example, a firefighter who is responsible for operating the pump on the engine at a small fire would have a different level of cardiac strain than a firefighter who is performing search and rescue activities on the interior of a large structure during fire suppression activities. The following sections detail research efforts to characterize systematically the effects of firefighting on the various components of the cardiovascular system — the heart, vasculature, and hemostatic system.

Cardiac Responses

During strenuous fire suppression activities, heart rates (HR) increase and rise to maximal or near maximal levels and T_{co} increases rapidly (18,29). Studies that have focused on long-term firefighting activities that require more than 1 cylinder of air (supporting heavy firefighting work for approximately 12–16 min) have shown that the rate of increase in T_{co} is augmented in later bouts of activity, further exacerbating cardiovascular strain and leading to higher HR (17). HR responses to firefighting vary tremendously depending on the type of work the firefighter is doing and multiple other factors (ambient temperature, length of time engaged, fitness level, etc.). Furthermore, firefighters' HR vary throughout a given emergency because of the intermittent nature of the work (17).

Although HR is the most frequently documented cardiovascular variable because of its ease of measurement, alterations in other cardiac variables are likely even more important to describe the cardiovascular risk associated with firefighting. We have reported a 35% reduction in stroke volume (seated position) after three short bouts of strenuous firefighting activity that lasted a total of approximately 20 min (29). More recently, we performed a full echocardiographic examination (supine position) before and after a 3-h training period that included multiple training evolutions/drills, each lasting approximately 15 to 30 min (11). The firefighting training resulted in near maximal HR (mean, 192 ± 15 beats min^{-1}) and an increase in T_{co} from 37.1 ± 0.5°C to 38.9 ± 0.6°C. Echocardiographic measurements were obtained within 30 min of firefighting, and mean HR had decreased to 90 ± 13 beats min^{-1} at the time of measurement. In this study, we found a 13% reduction in stroke volume (11). Furthermore, the repeated bouts of training resulted in significant reductions in left ventricular diastolic size and volume, transmitral flow velocities, mitral E/A (the ratio of passive ventricular filling to active atrial filling of the ventricle), and left ventricular shortening fraction and ejection fraction. The changes in left ventricular function observed in this study may reflect changes in preload after the firefighting activity. However, there is some evidence that intrinsic systolic and diastolic function also may be depressed after firefighting activity. TDI-E′, an indicator of rate of ventricular relaxation, decreased by 19% when measured at the lateral wall but was unchanged when measured at the septal wall (11). The decline in the lateral wall TDI-E′ is a marker of lusitropic function that is less load dependent than other measures of diastolic function. Although the clinical significance of the cardiac changes presented above are not fully comprehended, it is important to consider these changes in the context of overall cardiovascular function, especially given that these results were noted in apparently healthy firefighters with no known CVD. Indeed, this study found that, in addition to decreased left ventricular function, there was a decrease in systemic arterial compliance (11). These findings raise the possibility that arterial-ventricular coupling may be altered with firefighting and reinforces the importance of investigating vascular function after firefighting.

Vascular Responses

The myocardium and vasculature work together in a concerted effort to deliver blood to body tissues. Changes in vascular function and/or the interaction between the myocardium and the vasculature may lead to tissue ischemia/hypoxia, precipitating a sudden cardiac event. We have conducted several studies to investigate the effects of firefighting activities and heat stress on the vasculature and its function.

Yan *et al.* (35) reported changes in arterial-ventricular coupling after repeated bouts of firefighting during a 3-h period of live-fire training in a group of young (28 ± 1 yr) firefighters. Arterial-ventricular coupling was measured on the right common carotid artery using wave intensity analysis, a hemodynamic index in which changes in blood pressure and blood flow provide insights into cardiovascular stress (25). In response to live-fire training, wave 1 amplitude, an indicator of cardiac contractility, was reduced by approximately 28%, suggesting that systolic function decreased (35). In a laboratory study designed to further investigate the role of heat stress in changing arterial-ventricular coupling, Smith *et al.* (26) examined 11 young (22 ± 3 yr) men before and after a 100-min exercise/rest treadmill task (alternating 20-min walk/20-min rest in structural firefighting PPE) and found a nearly 32% increase in wave 2 amplitude. This measure of end-systolic/early-diastolic ventricular function from wave intensity analysis indicates increased afterload on the myocardium after heat stress (26).

We also have examined the influence of firefighting on vascular structure and function. Fahs *et al.* (6) examined the acute effects of live-fire training drills on arterial stiffness and limb blood flow in a group of 69 male firefighters (mean age, 28 ± 1 yr). After 3 h of live-fire training, hemodynamic proxies (wave reflection time and augmentation index) influenced by aortic stiffness increased by approximately 3%. Despite a possible increase in aortic stiffness, a concomitant increase in peripheral forearm vascular conductance (80%) and hyperemia (32%) also were observed (6). It is suggested that the unique combination of thermal, metabolic, psychological, and mental stress that occurs with firefighting activities might explain the increased aortic stiffness and forearm blood flow.

As a follow-up to live-fire studies, Lefferts *et al.* (22) conducted a laboratory-based study to isolate the influence of thermal stress on vascular and central hemodynamic changes. Controlling for hydration status, Lefferts *et al.* (22) reported that exercise-induced moderate heat stress (T_{co} of 37.8 ± 0.1°C caused by treadmill walking in firefighting PPE) did not change aortic stiffness (pulse wave velocity, pre: 5.0 ± 0.1 $m \cdot s^{-1}$ vs post: 4.9 ± 0.1 $m \cdot s^{-1}$; $P = 0.698$). However, Lefferts *et al.* (22) did find alterations in myocardial work demands (rate-pressure product increased by 37%) and an indirect proxy of coronary perfusion (subendocardial viability ratio (SEVR) reduced by about 27%). After a short 18-min bout of live-fire activity, Horn *et al.* (18) found a larger increase in rate-pressure product (80%–95%) and similar reductions in SEVR (30%–35%). These results, although they must be interpreted cautiously given limitations with SEVR, suggest a potential mismatch between myocardial oxygen demand and supply, which may result in ischemia during strenuous work in the heat. This potential mismatch may be more pronounced after firefighting activities than exercise-induced heat stress.

Thus, firefighting activity and heat stress may result in vascular dysfunction and arterial-ventricular uncoupling as evidenced by increased central arterial stiffness, decreased vascular function, and a myocardial oxygen supply-demand mismatch. A potential linkage between vascular alterations and the risk of SCD may be related to firefighters' individual characteristics. We have found increased arterial stiffness in a group of obese (≥29.5 $kg \cdot m^{-2}$) and overweight (25.9–29.4 $kg \cdot m^{-2}$) firefighters compared with lean (<25.9 $kg \cdot m^{-2}$) firefighters, where carotid artery β stiffness was greatest in the obese group compared with the overweight and lean groups (5.9 ± 0.3, 5.1 ± 0.3, and 4.9 ± 0.3, respectively) (7). Furthermore, we also have examined vascular changes in older firefighters (40–60 yr) before and after firefighting activity and found that reactive hyperemia, a measure of microvascular blood flow, and pressure-controlled arterial stiffness (central pulse wave velocity/aMAP) increased significantly after firefighting (21). The cause of increased vascular stiffness after firefighting is not known. The increased central vascular stiffness observed after firefighting activities could be a compensatory mechanism to counteract the profound skin vasodilation in an attempt to facilitate blood flow to the heart and brain or it could reflect a detrimental response to the stressors encountered during firefighting. Additional studies are necessary to better understand the cause and consequences of arterial stiffness and to elucidate what populations of firefighters who, through underlying disease or CVD risk factors, may have a greater risk of experiencing acute vascular changes that may result in SCD.

Because changes in vascular function may be caused by reactive oxygen species or prostaglandin production, we had conducted studies that used antioxidant supplementation or aspirin. We have investigated the effect of vitamin C supplementation on vascular responses to firefighting in young healthy firefighters and found that 2 g of vitamin C did not affect measures of vascular stiffness or microvascular function (6). We also have investigated the effect of aspirin supplementation on vascular changes associated with firefighting in older subjects and found that 2 wk of aspirin supplementation did not affect microvascular (reactive hyperemia) or macrovascular (arterial stiffness/central blood pressure) responses to firefighting (21).

Collectively, research has shown that firefighting and exercise-induced heat stress lead to vascular alterations, specifically, reduced vascular reactivity/endothelial function (6) and increased central arterial stiffness (7,22), which may play roles in arterial-ventricular uncoupling in response to firefighting activity and heat stress (26,35). The uncoupling of the arterial-ventricular system may explain the oxygen supply-demand mismatch observed after firefighting and exercise-induced heat stress (22), leading to ischemia. Increased arterial stiffness after firefighting may be detrimental because of increased cardiac work (increased afterload) or impaired vascular function (compromised vasodilation), and this effect is likely more pronounced in individuals with underlying CVD. Furthermore, overweight/obese and older firefighters may be at increased risk for abnormal vascular responses associated with firefighting and heat stress because the vasculature of these persons is stiffer at rest without the external influence of occupational stressors (7).

Hemostatic Responses

Firefighting leads to an increase in blood pressure and sweating. Accordingly, we have documented a decrease of approximately 15% in plasma volume after an 18-min bout of firefighting (30). In turn, this resultant hypovolemia decreases central venous pressure, causes hemoconcentration, and increases blood viscosity.

Firefighting likewise seems to disrupt hemostatic balance. We conducted a large study (N = 114) to examine the acute effects of firefighting on platelet number and function. Live-fire firefighting drills (~18 min) caused a modest change in T_{co} (0.7°C) and a peak HR of 167 beats min^{-1} and resulted in increased platelet number and decreased platelet closure time (increased aggregation) in young (29 ± 8 yr) apparently healthy firefighters (31). In a follow-up study, we evaluated the effects of firefighting activities on platelets, coagulation, and fibrinolytic activity and documented the extent to which these variables recovered 2 h after completion of the firefighting activity in young (25 ± 5 yr) apparently healthy firefighters (27). Platelet number, platelet activity, and coagulatory potential increased immediately after firefighting, and many variables (platelet function, activated partial thromboplastin time (aPTT) and factor VII) continued to reflect a procoagulatory state even after 2 h of recovery. Fibrinolysis also was enhanced immediately after firefighting but returned to baseline values 2 h after firefighting. Research with athletes has similarly indicated that strenuous physical activity acutely increases platelet number and platelet activation (4) and leads to a hypercoaguable state that is normally offset by simultaneous increases in fibrinolysis (16). This hypercoaguable state persists longer into the postactivity recovery period than does the increase in fibrinolysis, potentially reflecting a "vulnerable period" after strenuous exercise (16). In situations of abnormal hemostatic balance, the exercise-induced procoagulatory state may result in increased incidence in cardiovascular events during and immediately after strenuous physical activity. These data support the hypothesis that firefighting leads to a hemostatic imbalance that is primarily prothrombotic during the recovery period from firefighting activities.

INDIVIDUAL CHARACTERISTICS AND UNDERLYING CVD RISK

As we have summarized in a previous review (32), individual factors may mediate the magnitude of the cardiovascular strain of firefighting. Although firefighting results in significant cardiovascular strain, most firefighters recover from firefighting activities with no untoward event. However, the cardiovascular strain of firefighting interacts with an individual's health and fitness status to determine whether responses to the strain of firefighting are limited to transient physiologic disruptions or result in the activation of pathophysiologic pathways that may lead to sudden cardiac events (32). Underlying cardiovascular health status is determined largely by the prevalence of cardiovascular risk factors. As shown in the Table, such risk factors greatly increase the risk of cardiac death in the fire service, with smoking, hypertension, diabetes, and old age all associated with a greatly elevated risk. However, the greatest risk was associated with previous CHD diagnosis (32). In addition, low fitness also likely contributes to the increased risk of sudden cardiac events (2) because fit individuals can do more work at the same level of cardiovascular strain or they experience less strain at the same level of work. Unfortunately, there is substantial evidence that firefighters often lack high levels of fitness and a large pecentage are overweight or obese (2,7,32).

A potential linkage between vascular alterations and the risk of SCD also may be related to individual factors, including obesity. Obesity (body mass index (BMI), ≥30 $kg \cdot m^{-2}$) is a global epidemic affecting all members of society, including first responders. In the fire service, obesity has been found to increase the relative risk of an on-duty coronary heart disease fatality threefold (32). Obesity is a well-established risk factor for CVD and has been associated with reduced arterial function and increased aortic blood pressures (10). We examined the influence of body weight on vascular structure and function in a group of 110 firefighters (30 ± 8 yr). Firefighters were evenly

TABLE. Relative risk of cardiovascular outcome by risk factor in firefighters

	On-Duty CHD Fatalities, OR (95% CI) (20)	Non-CHD Cardiovascular Retirements, OR (95% CI) (16)	CHD Retirements, OR (95% CI) (16)
Current smoking	8.6 (4.2–17)	2.5 (1.2–5.1)	3.9 (2.5–6.2)
Hypertension	12 (5.8–25)	11 (6.1–20)	5.4 (3.7–7.9)
Obesity, BMI ≥30 $kg{\cdot}m^{-2}$	3.1 (1.5–6.6)	3.6 (2.0–6.4)	1.4 (0.96–1.93)
Cholesterol ≥5.18 $mmol{\cdot}L^{-1}$ (200 $mg{\cdot}dL^{-1}$)	4.4 (1.5–13)	1.1 (0.51–2.24)	2.4 (1.6–3.6)
Diabetes mellitus	10.2 (3.7–28)	7.7 (2.9–20)	13 (6.1–28)
Prior diagnosis of CHD	35 (9.5–128)	NA	30 (9.1–96)
Age ≥45 yr	18 (8.5–40)	26 (13–51)	63 (35–111)

BMI, body mass index; CHD, coronary heart disease; CI, confidence interval; diabetes mellitus, defined as random blood glucose level more than 8.3 $mmol{\cdot}L^{-1}$ (150 $mg{\cdot}dL^{-1}$), previous diagnosis, or receiving insulin or hypoglycemic medications; hypertension, defined as resting blood pressure of 140/90 mm Hg or higher, previous diagnosis of hypertension, or receiving antihypertensive therapy; OR, odds ratio. (Reprinted from (32). Copyright © 2011 Wolters Kluwer Health. Used with permission.)

divided into tertiles according to BMI (<25.9, 25.9–29.4, and ≥29.5 $kg{\cdot}m^{-2}$). We found increased arterial stiffness in the obese (≥29.5 $kg{\cdot}m^{-2}$) and overweight (25.9–29.4 $kg{\cdot}m^{-2}$) firefighters compared with that in lean (<25.9 $kg{\cdot}m^{-2}$) firefighters (7). Furthermore, carotid artery β stiffness was greatest in the obese group compared with the overweight and lean groups (5.9 ± 0.3, 5.1 ± 0.3, and 4.9 ± 0.3, respectively). However, measures of endothelial function did not differ by BMI classification (7).

We also have investigated the effect of obesity on coagulatory response to acute firefighting activity (28). An 18-min bout of live-fire training caused a significant increase in coagulatory and fibrinolytic markers, including an overall shift toward a procoagulatory state, as evidenced by a decrease in aPTT and an increase in platelet activity. We also found that obese firefighters exhibited lower baseline levels of fibrinolytic activity (lower tissue plasminogen activator and higher plasminogen activator inhibitor-1), which is consistent with previous literature. However, contrary to our hypothesis, we did not detect an increase in baseline coagulatory measures in obese firefighters nor did we find a greater coagulatory response among obese firefighters. Additional research is necessary to better understand how age, body composition, fitness, and cardiovascular risk factors affect vascular-hemostatic balance after firefighting because it is known that the vascular-hemostatic responses to exercise differ between healthy individuals and those with underlying CVD or CVD risk factors (34).

TRIGGERING A CARDIOVASCULAR EVENT

Atherosclerosis and structural heart changes, such as left ventricular hypertrophy (LVH), generally develop during a period of many years — even decades. Although CVD may progress with or without symptoms for many years, a plaque rupture or arrhythmia can lead to the rapid onset of severe symptoms and even SCD. Understanding what precipitates, or triggers, such an event is of interest to researchers, clinicians, and those involved in health policy.

Classic studies have temporally linked heavy physical exertion/strenuous work (such as running or snow shoveling) to the onset of acute cardiovascular events, with the risk being concentrated among individuals who are unaccustomed to such levels of exertion (1,12). Sympathetic nervous activation caused by emotional stress, such as excitement and frustration/anger, also is associated with triggering cardiovascular events in individuals with known CHD (32). In addition, environmental conditions such as elevated levels of air pollution have been shown to be associated with increased rates of sudden cardiac events among susceptible individuals (23).

Although a series of complex pathophysiological processes are involved in SCD, pump failure usually caused by terminal cardiac arrhythmias is ultimately the cause of death. Terminal arrhythmias may be caused by a primary electrical conduction problem (primary arrhythmia) or as complications of plaque rupture and thrombus formation that causes a myocardial infarction. SCD can be caused by many underlying conditions; however, a very large percentage of SCD is caused by CHD (*i.e.*, atherosclerosis) and/or cardiomegaly/LVH (13,36).

Firefighting as a Trigger for Sudden Cardiac Events

The work of a firefighter is characterized by long periods of low-intensity work, such as inspection, chores, and public education, unpredictably punctuated by episodes of strenuous work. During these intense intervals, firefighting activity involves heavy muscular work and requires high levels of oxygen consumption. Thus, during firefighting, multiple stressors may function independently or more likely synergistically to precipitate acute CVD events among susceptible firefighters (32).

Multiple studies have provided compelling evidence that firefighting activities can trigger cardiovascular events in susceptible firefighters (19,20). These studies found highly elevated and remarkably consistent odds for SCD and other acute CVD events during emergency firefighting activities compared with nonemergency duties. The largest of these studies (19) investigated line-of-duty deaths (n = 449) attributed to CHD between 1994 and 2004 and found that, although firefighting (*i.e.*, active fire suppression) represents between 1% and 5% of a firefighter's annual working time, firefighting accounted for more than 30% of line-of-duty CHD deaths. This resulted in a relative risk of SCD during fire suppression of roughly 10 to 100 times the risk encountered during nonemergency duties (19).

The aforementioned physiological disruption and cardiac strain associated with firefighting do not normally pose a significant risk in healthy individuals. However, in susceptible individuals, the stress of firefighting can serve as a trigger for SCD. Most sudden cardiac events are likely caused by myocardial infarctions in individuals with CHD or fatal arrhythmias in individuals with CHD or cardiomegaly/LVH.

Coronary Heart Disease

Studies that have examined autopsy findings of firefighters who suffered SCD have found that roughly 90% of victims had evidence of coronary atherosclerosis (13,20). CHD is characterized by atherosclerotic plaque in the arterial wall, which is preceded by endothelial dysfunction as the onset of the atherosclerotic process. As the plaque progresses, it results in stenosis and can cause ischemia. Death from a myocardial infarction frequently involves the rupture of vulnerable plaque, exposing blood to underlying connective tissue that is highly thrombotic. Platelets begin to adhere to the vessel and aggregate to each other to form a plug. Ultimately, this may result in the formation of an occlusive thrombus that causes a myocardial infarction.

Firefighting leads to increased shear stress that may increase the risk of plaque rupture. Furthermore, firefighting increases platelet number and activity and leads to a procoagulatory condition that may make thrombus formation more likely. Thus, although most firefighters recover from the cardiovascular strain of firefighting without incident, an individual with underlying atherosclerotic plaque, especially vulnerable plaque, is at a greatly increased risk of plaque rupture and thrombus formation during firefighting activity.

Cardiomegaly/LVH

Cardiomegaly (increased heart size and mass) and LVH (increased wall thickness and mass) are structural abnormalities that increase the risk of SCD caused by arrhythmia. LVH is a powerful predictor of cardiovascular morbidity and mortality in population-based studies (3), and there is a strong graded association between left ventricular mass and increased cardiovascular risk (14). LVH is frequently associated with fatal arrhythmias (33). Research has found that the increased risk associated with LVH is independent of other factors such as age, sex, smoking status, diabetes, and serum cholesterol. In a majority of cases, LVH is typically a result of hypertension with or without obesity and/or CHD. Obstructive sleep apnea, which also is commonly associated with hypertension and obesity, is another risk factor for LVH. In cases of firefighting SCD, CHD and LVH are frequently comorbid (13,20,36). Myocardial fibrosis is thought to be an important mediator of increased risk of SCD associated with LVH, although the precise mechanisms by which LVH causes cardiovascular morbidity and mortality are not fully understood. However, vascular changes, such as increased arterial stiffness, altered wave reflections and arterial-ventricular uncoupling may lead to the development of LVH.

A recent retrospective study found that cardiomegaly/LVH is a frequent cause of SCD in the general public and is highly associated with obesity and death at a younger age than CHD (33). There is mounting evidence that LVH/cardiomegaly is common among US firefighters and plays a major role in CVD events in the fire service. Kales *et al.* (20) conducted a case-controlled investigation of on-duty CHD fatalities and found evidence for LVH in 76% of the CHD deaths where the autopsy results were available. Subsequently, a larger follow-up case-fatality study was conducted to compare firefighters succumbing to on-duty CHD fatalities with firefighters suffering nonfatal CHD events leading to retirement. Among the fatalities, LVH/cardiomegaly was mentioned in summary reports of almost 60% of the available autopsies (13). In addition, Yang *et al.* (36) studied younger (<45 yr) firefighters and found a greater than 100-g difference in heart weight among SCD cases compared with trauma fatality controls. Furthermore, approximately 66% of cardiac cases had evidence of cardiomegaly (heart weight, >450 g), and this conveyed a fivefold increase in relative risk of SCD. These studies provide convincing evidence that LVH/cardiomegaly plays a role in a large percentage of firefighter fatalities.

As illustrated in Figure 3, firefighting may lead to several cardiac and vascular changes that increase the risk of arrhythmia, particularly in individuals with underlying vascular dysfunction and/or structural heart abnormalities. Obviously, firefighting leads to increased cardiac work. Furthermore, our research suggests that firefighting also leads to increased arterial stiffening and decreased arterial compliance. The combination of increased cardiac work and decreased arterial compliance may lead to ischemia that could provoke an arrhythmia, particularly in individuals with underlying CHD and/or structural heart changes that include myocardial fibrosis, which likely increases susceptibility to electrical abnormalities.

CONCLUSIONS

The proposed model suggests that the cardiovascular strain associated with firefighting may trigger a sudden cardiac event in a susceptible person through several biological pathways. Increases in shear stress may cause rupture of vulnerable plaque, resulting in thrombus formation and the occlusion of coronary arteries, which may be exacerbated by hypercoagulability that is known to increase the risk of thrombotic events. Alternately, acute risks encountered during firefighting activities may increase the risk of fatal arrhythmias. Ischemia (caused by an increase in myocardial oxygen demand that exceeds myocardial supply) may result in electrical, mechanical, and biochemical dysfunction of the cardiac muscle. Exposure to environmental conditions (such as gaseous and particulate toxicants in smoke) also may increase susceptibility to arrhythmias (23), particularly in those with LVH and other forms of cardiomegaly or in the context of ischemia.

Additional research is necessary to better understand how individual characteristics affect the cardiovascular responses to firefighting and the precise mechanisms by which firefighting leads to an increased risk of fatal arrhythmias and plaque rupture. Additional research also is needed to identify the types of physical fitness training programs that provide the greatest potential for reducing the risk of sudden cardiac events in the fire service. Firefighters accept great risks to protect their communities. Exercise professionals have a unique opportunity to help improve the health of this remarkable occupation, which is so important to our public safety.

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REVIEW Open Access

Prostate cancer in firefighting and police work: a systematic review and meta-analysis of epidemiologic studies

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Abstract

Objectives: We conducted a systematic review and meta-analysis to evaluate potential associations between firefighting and police occupations, and prostate cancer incidence and mortality.

Methods: Original epidemiological studies published from 1980 to 2017 were identified through PubMed and Web of Science. Studies were included if they contained specific job titles for ever/never firefighting and police work and associated prostate cancer risk estimates with 95% confidence intervals (CI). Study quality was assessed using a 20-point checklist. Prostate cancer meta-risk estimates (mRE) and corresponding 95% CIs were calculated for firefighting and police work separately and by various study characteristics using random effects models. Between-study heterogeneity was evaluated using the I^2 score. Publication bias was assessed using Begg's and Egger's tests.

Results: A total of 26 firefighter and 12 police studies were included in the meta-analysis, with quality assessment scores ranging from 7 to 19 points. For firefighter studies, the prostate cancer incidence mRE was 1.17 (95% CI = 1.08–1.28, I^2 = 72%) and the mortality mRE was 1.12 (95% CI = 0.92–1.36, I^2 = 50%). The mRE for police incidence studies was 1.14 (95% CI = 1.02–1.28; I^2 = 33%); for mortality studies, the mRE was 1.08 (95% CI = 0.80–1.45; I^2 = 0%). By study design, mREs for both firefighter and police studies were similar to estimates of incidence and mortality.

Conclusion: Small excess risks of prostate cancer were observed from firefighter studies with moderate to substantial heterogeneity and a relatively small number of police studies, respectively. There is a need for further studies to examine police occupations and to assess unique and shared exposures in firefighting and police work.

Keywords: Firefighters, Police, Occupation, Prostate cancer risk, Incidence, Mortality, Meta-analysis, Systematic review, Epidemiology

Background

Prostate cancer is one of the most commonly diagnosed cancers in men worldwide but its etiology remains poorly understood [1–5]. The only established risk factors for prostate cancer are older age, positive family history of prostate cancer, and African-American ethnicity [1, 2, 4, 5]. There is some evidence linking prostate cancer to differences in socioeconomic status, increased height, increased obesity, reduced physical activity, and active smoking and alcohol use [3, 5–10]. There is growing evidence that occupation may be a risk factor, and previous studies have shown increased risks associated with employment in agriculture/farming, management and administration, rubber production, metal work, and transportation [11–13]. Some studies have also suggested associations between prostate cancer risk and employment in protective services occupations [11, 12, 15–17].

Protective services occupations include firefighting, police, military, and other groups (eg. security guards). Previous epidemiological studies have demonstrated consistent associations between firefighting and different

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types of cancer, with some evidence for prostate cancer [14]. In 2007, the International Agency for Research on Cancer (IARC) classified firefighting as "possibly" carcinogenic to humans (IARC Group 2B) [16]. IARC's evaluation was based on evidence from 42 epidemiological studies, including two previous meta-analyses on firefighting and cancer [14, 18]. Based on studies published at the time, IARC evaluated multiple cancer sites and identified statistically significant increased risks of prostate cancer, testicular cancer, and non-Hodgkin lymphoma [16]. Since the IARC evaluation, 11 new studies have been published that included assessments of prostate cancer risk in firefighters. Relatively less is known about prostate cancer risk in police occupations, as this group is often understudied and findings have been inconsistent [11, 12, 15, 19, 20].

Only one meta-analysis, published over a decade ago, focused on firefighting and cancer risks that included prostate cancer [14]. This study found a significant association with prostate cancer incidence (summary risk estimate: 1.28, 95% CI: 1.15–1.43) based on evidence from 6 cohort studies [14]. Recently, a narrative review examined cancer risk in police work. Eight studies reported on prostate cancer risk in police work, with mixed findings [15]. The objective of the present systematic review and meta-analysis was to evaluate the quality of the epidemiological evidence on firefighting and police employment in association with prostate cancer incidence and mortality, and to conduct a quantitative synthesis. Based on the availability of epidemiologic literature, this meta-analysis focused on firefighting and police work, and not protective services as a whole.

Material and methods

Search strategy

A search was conducted on PubMed and Web of Science to identify epidemiological studies published between January 1980 and December 2017 in English or French about employment in firefighting and police occupations, and risk of prostate cancer. Various combinations of MeSH terms were used to search for studies that included firefighter and police occupations (firefighting OR firefighter OR fire fighter OR fire OR police OR police officer OR policeman OR policemen) and that reported on associations with prostate cancer risk (prostate OR prostate neoplasm OR neoplasm OR cancer). Cited references in individual papers and review papers that resulted from the search were used to identify any additional studies.

Inclusion criteria

To be included in the meta-analysis, articles must have reported results for original case–control or cohort studies that contained specific job titles related to ever/never firefighting and police work and that examined associated prostate cancer incidence and/or mortality using any type of relative risk estimator (hazard ratio (HR), odds ratio (OR), relative risk (RR), standardized mortality ratio (SMR), or standardized incidence ratio (SIR)) with corresponding 95% confidence intervals. Reviews, meta-analyses, editorials, and experimental studies were excluded. For any articles with overlapping study populations, only the most recently published study with prostate cancer incidence and/or mortality results was included. Furthermore, studies were excluded if reported risk estimates were only based on internal comparisons between different occupational groups rather than based on comparisons to the general population. Titles and abstracts were initially screened for eligibility, and for those eligible, full-text articles were reviewed.

Data extraction

Information on author(s), date of publication, title, country of study, study design, number of cases/deaths and controls/non-cases, data collection method, effect sizes and 95% CIs for prostate cancer, and covariates was extracted from and tabulated for each study included in the meta-analysis. Effect sizes and 95% CIs recorded from included studies were for ever vs. never firefighter or police employment in models that were adjusted for the maximum number of potentially confounding variables.

Quality assessment

The quality of each study included in the meta-analysis was independently assessed by two authors (JS and MP) using a modified quality assessment checklist by Downs and Black [21]. Checklist items that were irrelevant to observational studies were omitted, resulting in a maximum of 20 achievable points for reporting (9 points), external validity (2 points), internal validity (bias and confounding) (8 points), and power (1 point) [21]. Any disagreement of ratings was discussed and a consensus was arrived at mutually or by consulting a third author, if earlier consensus could not be reached.

Statistical analysis

Reported ORs, HRs, RRs, SIRs, and SMRs were considered as RRs in meta-analyses and used in forest plots. A random effects model was used to calculate meta-risk estimates (mREs) in all meta-analyses due to potential variance in effect sizes between the included studies. mREs were calculated separately for firefighting and police occupations and prostate cancer risk. mREs were calculated for subgroups based on the following characteristics: incidence versus mortality, study design (i.e. cohort versus case–control, and administrative linkage-based studies, defined as large studies that used multiple linked administrative databases, e.g. census data and tumour registries.

For each mRE, heterogeneity was evaluated using the I^2 statistic. The I^2 statistic is a percentage that describes the variation between studies that is not due to chance [22]. Two-sided *p*-values for the I2 statistic were reported. Ninety-five percent confidence intervals for the I2 statistic were calculated to address small numbers of included studies ($N < 5$) in some subgroup meta-analyses. In addition, the Galbraith plot was used to visualize if individual studies fell within or outside of the 95% confidence region. Studies outside of the 95% confidence region can contribute to high heterogeneity. These studies were removed in sensitivity analyses to evaluate the impact of decreased heterogeneity on mREs [23].

Begg's test and Egger's test were used to assess publication bias. Begg's test uses the correlation between ranks of effect sizes and variances, whereas Egger's test uses a funnel plot to plot the effect estimates against sample size [24, 25]. All statistical analyses were performed using STATA version 14.2 (StataCorp LLC, College Station, USA).

Results

The literature search resulted in 366 unique studies published in English or French. Based on the screening of titles and abstracts, 318 (87%) were excluded due to non-observational/non-human studies, missing job titles, missing effect estimates for prostate cancer, duplicate studies, or irrelevancy to the objective of this meta-analysis. Of the remaining 48 studies that were obtained in full text, 17 were excluded because they did not include reports of relative risks for prostate cancer with 95% CIs, had overlapping study populations, or were studies of military workers. As a result, 31 unique studies were included (Fig. 1).

Of these, 24 were cohort and seven were case–control studies. Nineteen studies only included investigations of firefighters (Table 1) and five focused on police workers (Table 2); seven contained investigations of both firefighters and police workers (Table 3). In all studies that included firefighters ($N = 26$), there were 5712 incident cases of prostate cancer and 428 deaths from prostate cancer. In all studies that included police workers ($N = 12$), there were 1510 incident cases and 49 deaths. The characteristics of each included study are summarized in Tables 1 (firefighters), 2 (police workers), and 3 (both). Covariates included in the risk estimates selected from each of the seven case–control studies are shown in Additional file 1: Table S1.

Of all the firefighter studies, 2 pairs of studies (Ma et al., 2005 & Ma et al., 2006; Demers et al., 1992 & Demers et al., 1994) [26–29] examined the same respective populations but reported on different prostate cancer outcomes (incidence and mortality). In the meta-analyses of prostate cancer incidence and mortality in firefighters, respective results from both pairs of studies were retained and used. Two studies [30, 31] published results for both prostate cancer incidence and mortality, and each estimate was used [31, 32]. For the police studies, [28, 29] reported on the same populations with different outcomes of incidence and mortality, and each estimate was used. Each incidence and mortality outcome was used only in their respective categories and not included together for any meta-risk estimates.

Quality assessment

The overall quality assessment of all 31 included studies ranged from 5 to 19 points (Table 4). Scores were similar for firefighter, police, and firefighter and police studies across the different quality assessment categories. The mean score for reporting was 6 out of 9, based on clear

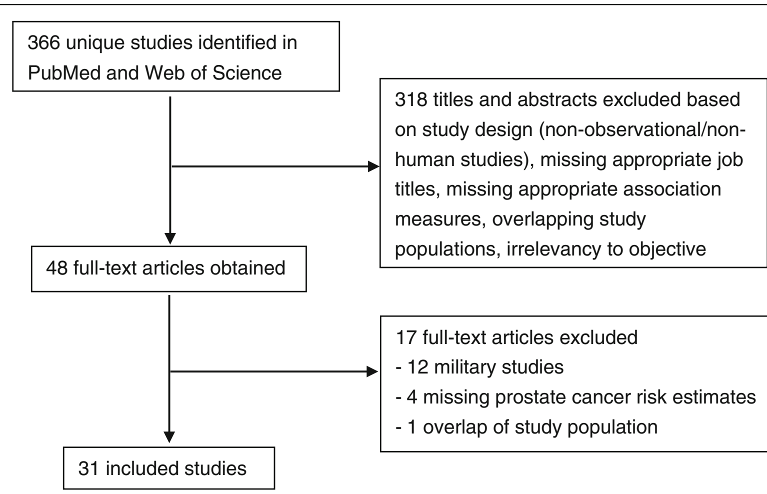

Fig. 1 Descriptive flow chart of study selection in this meta-analysis

Table 1 Characteristics of included studies on firefighting and prostate cancer risk (*N* = 19)

Author/ Year	Location of Study	Study Design	Incidence or Mortality	Follow-up period	Number of Cases/ Deaths	Cohort Size/Total Number of Cases[a]	Prostate Cancer Risk Estimates for Ever versus Never Employment[b]
Glass et al. 2016 [63]	Australia	Cohort	Incidence	1980–2011	478	30, 057	SIR 1.31, 95% CI 1.19–1.43
Brice et al. 2015 [64]	France	Cohort	Mortality	1979–2008	17	10, 829	SMR 0.54, 95% CI 0.31–0.86
Daniels et al. 2014 [32]	USA	Cohort	Incidence; Mortality	1950–2009	1261 cases 282 deaths	29, 993 29, 993	SIR 1.03, 95% CI 0.98–1.09; SMR 1.09, 95% CI 0.96–1.22
Pukkala et al. 2014 [17]	Denmark, Finland, Iceland, Norway and Sweden	Cohort (linkage)	Incidence	1961–2005	660	16, 422	SIR 1.13, 95% CI 1.03–1.22
Ahn et al. 2012 [65]	Korea	Cohort	Incidence	1996–2007	9	33, 416	SIR 1.32, 95% CI 0.60–2.51
Ma et al. 2006 [27]	USA	Cohort	Incidence	1981–1999	209	34, 796	SIR 1.10, 95% CI 0.95–1.42
Ma et al. 2005 [26]	USA	Cohort	Mortality	1972–1999	21	34, 796	SMR 1.08, 95% CI 0.67–1.65
Baris et al. 2001 [66]	USA, USA	Cohort	Mortality	1925–1986	31	7, 789	SMR 0.96, 95% CI 0.68–1.37
Bates et al. 2001 [67]	New Zealand	Cohort	Incidence	1977–1995	11	4, 221	SIR 1.08, 95% CI 0.50–1.90
Tornling et al. 1994 [31]	Sweden	Cohort	Incidence; Mortality	1951–1986	28 cases 14 deaths	1, 116 1, 091	SMR 114, 95% CI 76–165; SMR 121, 95% CI 66–202
Aronson et al. 1994 [68]	Canada	Cohort	Mortality	1950–1989	16	5, 373	SMR 132, 95% CI 76–215
Giles et al. 1993 [69]	Australia	Cohort	Incidence	1980–1989	5	2, 865	SIR 2.09, 95% CI 0.67–4.88
Guidotti 1993 [70]	Canada	Cohort	Mortality	1927–1987	8	3, 328	SMR 146.1, 95% CI 63.1–287.9
Beaumont et al. 1991 [33]	USA	Cohort	Incidence	1940–1982	8	3, 066	RR 0.38, 95% CI 0.16–0.75
Grimes et al. 1991 [71]	USA	Cohort	Mortality	1969–1988	4	205	PRR 2.6, 95% CI 1.4–5.0
Vena & Friedler 1987 [72]	USA	Cohort	Mortality	1950–1979	5	470	SMR 0.71, 95% CI 0.23–1.65
Tsai et al. 2015 [73]	USA	Case–control (linkage)	Incidence	1988–2007	1397	3, 996	OR 1.45, 95% CI 1.25–1.69
Kang et al., 2008 [74]	USA	Case–control (linkage)	Incidence	1986–2003	577	285, 964	SMOR 1.05, 95% CI 0.88–1.24
Krstev et al. 1998 [75]	USA	Case–control	Incidence	1986–1989	12	981	OR 3.34, 95% CI 1.13–9.91

[a]cohort size represents the total sample size in only cohort studies, and the total number of cases is only applicable to case–control studies
[b]HR – hazard ratio, SIR – standardized incidence ratio, SMR – standardized mortality/morbidity ratio, RR – relative risk, PRR – proportionate risk ratio, OR – odds ratio, NR – not reported

and detailed reporting of aims/hypotheses, outcomes measures, participant information, confounder information, and loss to follow-up. Studies were generally found to be externally valid, and there was minimal bias. Studies of firefighters had higher scores for confounding factors than studies of police workers. Only one study reported a power calculation making it difficult to evaluate this category.

Table 2 Characteristics of included studies on police work and prostate cancer risk (*N* = 5)

Author/Year	Location of Study	Study Design	Incidence or Mortality	Follow-up Period	Number of Cases/Deaths	Cohort Size/Total Number of Cases[a]	Prostate Cancer Risk Estimates for Ever versus Never Employment[b]
Vena et al. 2014 [19]	USA	Cohort	Mortality	1980–2005	31	3, 424	SMR 1.18, 95% CI 0.80–1.67
Gu et al. 2011 [76]	USA	Cohort	Incidence	1976–2006	104	2, 234	SIR 0.88, 95% CI 0.72–1.07
Finkelstein 1998 [20]	Canada	Cohort	Incidence	1964–1995	85	22, 197	SIR 1.16, 95% CI 0.93–1.43
Forastiere et al. 1994 [77]	Italy	Cohort	Mortality	1973–1991	7	3, 868	SMR 0.77, 95% CI 0.31–1.50
Bouchardy et al. 2002 [78]	Switzerland	Case–control	Incidence	1980–1993	129	9, 126	OR 1.20, 95% CI 1.00–1.50

[a]cohort size represents the total sample size in only cohort studies, and the total number of cases is only applicable to case–control studies
[b]HR – hazard ratio, SIR – standardized incidence ratio, SMR – standardized mortality/morbidity ratio, RR – relative risk, OR – odds ratio

Firefighter and prostate cancer meta-analyses

There were significantly elevated prostate cancer risks for firefighting occupations for incidence outcomes, cohort studies, and administrative linkage-based studies. For incidence studies, the mRE was 1.17 (95% CI: 1.08–1.28; I^2 = 72%, 95% CI: 55–82%, *p*-value <0.001; 19 studies) (Fig. 2); for mortality studies, it was 1.12 (95% CI: 0.92–1.36; I^2 = 50%, 95% CI: 0–76%, p-value = 0.04; 10 studies) (Fig. 3). In cohort studies, the prostate cancer mRE was 1.14 (95% CI: 1.03–1.26; I^2 = 67%, 95% CI: 46–80%, *p*-value <0.001; 18 studies) (Additional file 2: Figure S1). The meta-analysis of case–control studies resulted in an mRE of 1.27 (95% CI: 0.95–1.69; I^2 = 78%, 95% CI: 53–90%, *p*-value <0.001; 6 studies) (Additional file 3: Figure S2). The mRE for census or administrative linkage-based studies was 1.19 (95% CI: 1.06–1.34; I^2 = 61%, 95% CI: 0–85%, *p*-value = 0.04; 5 studies) (Additional file 4: Figure S3).

Police work and prostate cancer meta-analyses

There were significantly elevated prostate cancer risks for police occupations by incidence outcomes and in case–control studies. The mRE for prostate cancer incidence studies was 1.14 (95% CI: 1.02–1.28; I^2 = 33%, 95% CI: 0–74%, *p*-value = 0.16; 9 studies) (Fig. 4) while the mRE for prostate cancer mortality studies was 1.08 (95% CI: 0.80–1.45; I^2 = 0%, 95% CI: 0%–90%, *p*-value = 0.62; 3 studies) (Fig. 5). The mRE for case–control studies was higher compared to the mRE for cohort studies (case–control studies: mRE = 1.22, 95% CI: 1.03–1.44; I^2 = 0% (95% CI 0%–85%, p-value = 0.42; 4 studies) (Additional file 5: Figure S4) versus cohort studies: mRE = 1.10, 95% CI: 0.96–1.26; I^2 = 37%, 95% CI: 0–79%, p-value = 0.15; 7 studies) (Additional file 6: Figure S5). There were no administrative linkage-based studies of police workers and prostate cancer risk.

Table 3 Characteristics of included studies on both firefighting and police work and prostate cancer risk (*N* = 7)

Author/Year	Location of Study	Study Design	Incidence or Mortality	Follow-up Period	Number of Cases/Deaths	Cohort Size/Total Number of Cases[a]	Prostate Cancer Risk Estimates for Ever versus Never Employment[b]
Sritharan et al, 2017b*	Canada	Cohort (linkage)	Incidence	1991–2011	165 firefighters; 325 police	1,100,000 1,100,000	HR 1.17, 95% CI 1.01–1.36; HR 1.22, 95% CI 1.09–1.36
Zeegers et al. 2004 [11]	Netherlands	Cohort (linkage)	Incidence	1986–1993	709 firefighters; 693 police	58, 279 58, 279	RR 0.59, 95% CI 0.05–6.33; RR 1.62, 95% CI 0.62–4.27
Demers et al. 1994 [28]	USA	Cohort	Incidence	1974–1989	66 firefighters; 28 police	2, 447 1, 878	SIR 1.40, 95% CI 1.10–1.70; IDR 1.10, 95% CI 0.70–1.80
Demers et al. 1992 [29]	USA	Cohort	Mortality	1945–1989	30 firefighters; 11 police	4, 546 3, 676	SMR 1.34, 95% CI 0.90–1.91; SMR 1.02, 95% CI 0.51–1.82
Sritharan et al. 2017a [79]	Canada	Case–control	Incidence	1995–1998	38 firefighters; 35 police	1, 737 1, 737	OR 1.67, 95% CI 0.94–2.95; OR 1.15, 95% CI 0.66–1.99
Sritharan et al. 2016 [80]	Canada	Case–control	Incidence	1994–1997	53 firefighters; 12 police	760 760	OR 0.73, 95% CI 0.53–1.01; OR 0.82, 95% CI 0.41–1.63
Sauve et al. 2016 [12]	Canada	Case–control	Incidence	2005–2009	26 firefighters; 45 police	1, 937 1, 937	OR 1.72, 95% CI 0.88–3.37; OR 1.60, 95% CI 1.00–2.40

[a]cohort size represents the total sample size in only cohort studies, and the total number of cases is only applicable to case–control studies
[b]HR – hazard ratio, SIR – standardized incidence ratio, SMR – standardized mortality/morbidity ratio, RR – relative risk, IDR – incidence density ratio, OR – odds ratio
*manuscript submitted and currently being revised for publication

Table 4 Quality assessment of included firefighter and police studies

Quality Assessment Category	Maximum Attainable Score	Studies on firefighters (n = 19)		Studies on police workers (n = 5)		Studies on both firefighters and police workers (n = 7)		All studies (n = 31)
		Range	Mean	Range	Mean	Range	Mean	Mean
Reporting	9	4–9	6.0	1–8	5.4	4–8	6.1	5.9
External Validity	2	1–2	1.8	0–2	1.6	1–2	1.6	1.7
Internal Validity: Bias	4	3–4	3.8	3–4	3.8	4	4	3.8
Internal Validity: Confounding	4	2–4	3.2	1–4	2.8	3–4	3.6	3.2
Power	1	0	0	0	0	0–1	0.1	0.0
Total	20	10–19	14.8	5–18	13.6	12–18	15.4	14.6

Between-study heterogeneity

There was high heterogeneity (72%) for the meta-analysis of all 19 firefighter incidence studies. As a sensitivity analysis, the Galbraith plot was used and one study [33], appeared outside of the 95% confidence region. Removal of this study resulted in a minimal change in heterogeneity (72 versus 69%, respectively). For the meta-analysis of the 10 mortality studies, there was moderate heterogeneity (50%). High heterogeneity was observed for the six case–control studies (78%), 18 cohort studies (67%) and the five administrative linkage-based studies (61%). When plotting these subgroups using the Galbraith plot, no studies appeared outside of the 95% confidence region.

For police studies, heterogeneity ranged from none to moderate. Moderate heterogeneity was observed for the nine incidence studies (33%) and seven cohort studies (37%), but no heterogeneity (0%, 95% CI: 0–90%) was observed for the mortality (three studies) and case–control (four studies) subgroups. I^2 values of 0% are biased and imprecise, likely because of the small number of studies in these subgroups (n < 5) [34]. Using the Galbraith plot, none of the police studies appeared outside of the 95% confidence region.

Publication bias

There was no evidence of publication bias according to Begg's test (p = 0.86) and Egger's test (p = 0.11) for the meta-analysis of all 19 firefighter incidence studies. No publication bias was evident for the 9 police incidence studies (Begg's test: p = 0.60, Egger's test: p = 0.68). There were also no statistically significant findings for

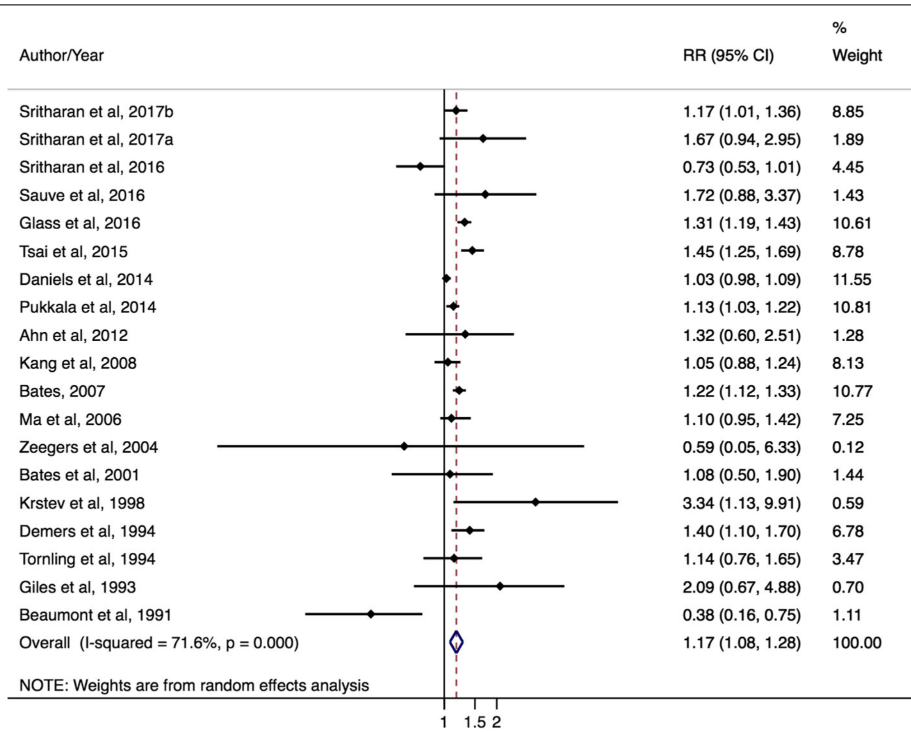

Fig. 2 Forest plot and mRE of all included prostate cancer incidence studies on firefighters

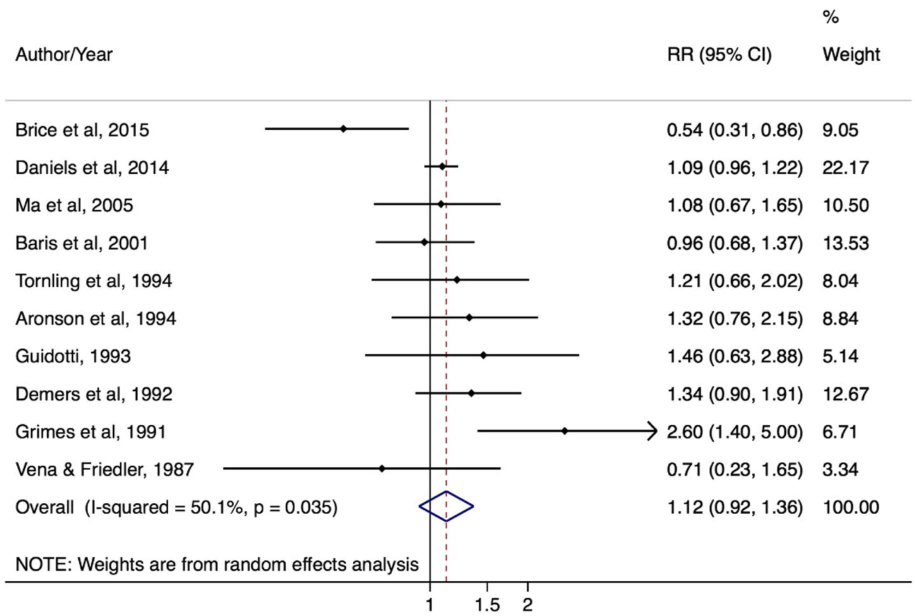

Fig. 3 Forest plot and mRE of all included prostate cancer mortality studies on firefighters

publication bias for mortality studies, case–control, cohort, and administrative linkage-based studies.

Discussion

In this meta-analysis of 31 epidemiological studies of protective services workers, nearly identical and small statistically significant excess risks of prostate cancer were found for ever working in firefighting and police work. Statistically significant and borderline prostate cancer mREs were found for firefighters in separate evaluations of incidence studies, cohort studies, and administrative linkage studies, as well as in each meta-analysis of police worker incidence studies and case–control studies. Most studies were of average quality, with opportunities for improvement in reporting and study power assessment. As expected, case–control studies compared to cohort studies generally had more information on variables that can act as potential confounders of the firefighter/police work and prostate cancer associations. All case–control studies reported prostate cancer risk estimates that were adjusted for age;

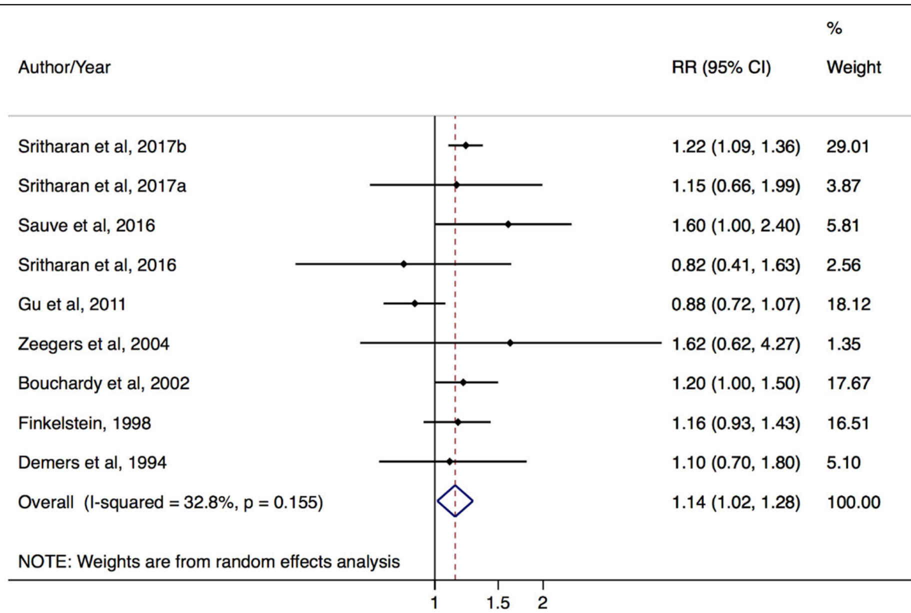

Fig. 4 Forest plot and mRE of all included prostate cancer incidence studies on police workers

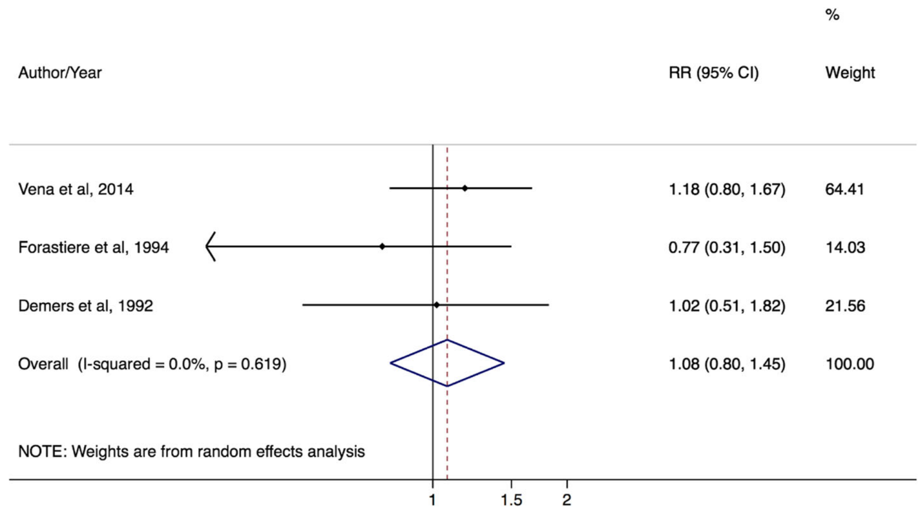

Fig. 5 Forest plot and mRE of all included prostate cancer mortality studies on police workers

most were also adjusted for ethnicity. Fewer case–control studies adjusted risk estimates for family history of prostate cancer and potentially confounding variables such as socioeconomic status, physical activity, height, obesity, active smoking, and alcohol consumption. Overall, findings from this meta-analysis support positive associations found between prostate cancer risk and firefighting in the epidemiological literature, and indicate a potential relationship with police work as well.

There are a few hypotheses that may explain why employment in protective services occupations could be associated with increased prostate cancer risk. Firefighting and police jobs are inherently dangerous occupations that involve stressful, and, at times, life-threatening, situations with exposure to multiple hazards [14–16]. Psychological stressors can influence biological processes and lead to decreased immune function, increased pro-inflammatory cytokine secretion, and cancer progression [15]. Shift work, which is common in protective services work, was significantly associated with increased prostate cancer risk in a recent meta-analysis of eight case–control and cohort studies [35]. Firefighters are also exposed to toxins released by fire and smoke including benzene, 1,3-butadiene, formaldehyde and at times can be exposed to other compounds such as radiation, diesel exhaust, asbestos, metals (arsenic and cadmium), and PAHs [14, 16, 27]. The chemical reactions during combustion and the age and type of building or material on fire can contribute to exposure to these compounds [16]. Police work involves fewer chemical exposures compared to firefighting, although exposure to ionizing radiation from radar devices is a concern for overall cancer risk [11, 12]. Firefighters and police workers may also be exposed to air pollution on the job, as ambient concentrations of ultrafine particles and NO_2 have been previously linked to prostate cancer risk [36, 37]. Of the described chemical exposures, only x and gamma radiation, arsenic compounds, and cadmium compounds have been linked to prostate cancer by IARC based on limited evidence in non-occupational settings. However, IARC has classified benzene, ionizing radiation, diesel exhaust, asbestos, arsenic compounds, cadmium compounds, and air pollution as all Group 1 carcinogens, based on evidence for other cancer sites [38]. There is a need to further examine these chemical exposures in both firefighting and police work to understand if these exposures are involved in prostate cancer risk.

Evaluating potential associations between shift work and prostate cancer is an active area of ongoing research [39–41]. Shift work can disrupt the body's endogenous circadian rhythm (sleep-wake cycle) and contribute to increased susceptibility to acute and chronic diseases. However, the biological mechanisms that may be involved in prostate and other cancers have not been established [18, 42]. One hypothesis is that night shift work can lead to decreased melatonin, which can then lead to continuous testosterone production, influencing the growth and differentiation of prostate cancer cells [16]. In addition, decreased sunlight exposure in night shift workers reduces the production of vitamin D, thereby compromising the effects of vitamin D on suppressing the production of prostate cancer cells [16].

Psychological stress also has been linked to cancer progression, but there is limited evidence for how this impacts cancer promotion [43]. Firefighting and police work involve constant stressors that can potentially affect cancer progression, particularly prolonged stress over years of employment in these jobs [44]. A recent study on stress at work and cancer outcomes found that the highest prevalence of stress at work was reported among firemen when compared to other types of occupations [45].

Another factor that may influence our meta-analysis results is prostate cancer screening. Although prostate specific antigen (PSA) testing varies across different countries and within countries, it is believed that protective services workers have frequent and better access to health resources compared to other workers, including access to cancer screening [32]. In North America, for example, firefighters are provided with health information and recommendations on what to consider when completing a health examination with their primary physician, including recommendations for prostate cancer screening [46]. However, it is up to each fire department to disseminate this information and ultimately up to each firefighter to request screening from their primary physician. In this meta-analysis we found slightly lower mortality mREs compared to incidence mREs for firefighters and police officers. As increased screening of prostate cancer leads to the identification of more early stage cases (increased incidence), this may be indicative of a screening effect. However, the mREs for both incidence and mortality were so similar that it was difficult to attribute these differences to screening. Also, prostate cancer screening may not be of high importance in firefighting compared to other cancers (ex. brain, bladder, and colon) and health conditions that have been consistently associated with firefighting. We evaluated study estimates based on different follow-up periods defined as pre-PSA period (prior to 1990 before the PSA test was introduced), during the introduction of PSA testing (early 1990s), and after the introduction of PSA testing (late 1990s and onwards). Although we included studies from different nations, most of the studies were North American so we loosely defined the time periods based on North America. We identified a number of pre-PSA period firefighter studies and observed a meta-risk estimate of 1.26 (95% CI 0.96–1.67) for these studies. For firefighter studies that had follow-up periods during and after the introduction of PSA testing, we observed a meta-risk estimate of 1.13 (95% CI 1.02–1.25). It was challenging to define firefighter study follow-up periods as post PSA testing (late 1990s onwards) since most of these studies had follow-up periods that overlapped the early 1990s when PSA testing began. We identified only a few firefighter studies that had later follow-up periods (late 1990s and early 2000s) and observed a meta-risk estimate of 1.58 (95% CI 1.09–2.29) for these studies. Overall, we observed an elevated risk for firefighter studies that were conducted before the introduction of PSA testing, and a statistically significant elevated risk for firefighter studies that took place during and after the introduction of PSA testing. These findings may be representative of the increased screening that took place over this time period. We attempted to evaluate police studies as well but were limited as almost all included police studies had follow-up periods overlapping periods with and without PSA testing.

Our findings of a slight excess risk of prostate cancer in firefighting and police services should be cautiously interpreted. As expected, there was considerable heterogeneity between studies, particularly in subgroup meta-analyses of police workers and prostate cancer risk that involved small numbers of studies. This makes it challenging to interpret mRE values with precision [34]. Heterogeneity was likely due to differences in study design and populations studied, follow-up years, occupational exposure assessment and job coding, and adjustment of relative risk values for known or potential covariates. Specifically, there were differences in how the study populations were defined, in terms of paid or unpaid work, full time vs. part time, and eligible employment duration. Some heterogeneity may also be attributed to different follow-up periods in each study, especially those overlapping the pre and post PSA era. The variation in age distribution across included studies could also contribute to heterogeneity based on differences in how studies stratified by age. Some studies had relatively younger populations than other studies and we observed a similar elevated meta-risk estimate for these younger population studies as we did for the overall estimates Publication bias was also considered, but was not recognized as a significant factor as a majority of the included studies were cohort designs. The cohort studies generally looked at multiple cancer sites as outcomes, so it is unlikely that publication bias would have been of concern based on solely prostate cancer results.

A major strength of this meta-analysis is that it was the first to assess prostate cancer risk in both firefighting and police work, replete with subgroup analyses and assessments of study quality, heterogeneity, and publication bias. This meta-analysis captured all previously and newly published studies since the IARC evaluation of firefighting in 2007, and also quantitatively evaluated prostate cancer risk in police studies which had not been done before. Firefighting and police work should be priority areas for investigation because these occupations frequently involve exposure to multiple chemical, biological, physical, and psycho-social hazards. Exposure to some hazards may be associated with increased risk of prostate cancer, although the strength and consistency of associations varies across studies and there are substantial research gaps. Altogether, this research can be used to help identify opportunities for further research on occupation and prostate cancer risk.

Other occupations of interest with respect to prostate cancer risk are military workers. While we initially sought to include military studies in this meta-analysis, they were ultimately not included because these studies were primarily based on specific historical events (ex. Gulf war) or internal comparisons between military groups [47–62]. This made it difficult to compare findings to other studies that did not focus on single events or that compared workers to the general population. Future assessments can separately consider military studies.

Conclusions

Overall, the slight excess risks of prostate cancer in firefighting and police services found in this meta-analysis of 31 studies were generally robust to subgroup analyses by outcome (incidence and mortality) and study design. Our findings are important as they show the importance of prostate cancer incidence and mortality among protective services workers, and as this is the first meta-analysis to include both firefighting and police work and prostate cancer risk. The observed findings suggest that screening may not entirely explain our findings, but further investigation into actual screening rates and screening behaviours in firefighting and police work is warranted. Also, further investigations should be designed to assess specific exposures such as benzene, radiation, diesel exhaust, arsenic and cadmium compounds, PAHs, asbestos, and air pollution which are involved in firefighting. Little evidence on how they may relate to prostate cancer risk has been accrued. There is also a need for future studies to examine prostate cancer risk in police work given the small number of police workers published to date. By addressing these important issues in future studies, there will be better understanding on prostate cancer risk in firefighting and police work.

Additional files

Additional file 1: Table S1. Covariates adjusted for in firefighter and police case–control studies (DOCX 12 kb)

Additional file 2: Figure S1. Forest plot and mRE of all included cohort studies on firefighters. (DOCX 285 kb)

Additional file 3: Figure S2. Forest plot and mRE of all included case–control studies on firefighters. (DOCX 137 kb)

Additional file 4: Figure S3. Forest plot and mRE of all included administrative linkage-based studies on firefighters. (DOCX 153 kb)

Additional file 5: Figure S4. Forest plot and mRE of all included cohort studies on police workers. (DOCX 175 kb)

Additional file 6: Figure S5. Forest plot and mRE of all included case–control studies on police workers. (DOCX 117 kb)

Abbreviations

CI: Confidence Interval; HR: Hazard Ratio; IARC: International Agency for Research on Cancer; mRE: Meta-risk Estimate; OR: Odds Ratio; PSA: Prostate Specific Antigen; RR: Relative Risk; SIR: Standardized Incidence Ratio; SMR: Standardized Mortality Ratio

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Data availability statements

All data generated or analyzed during this study are included in this published article.

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Authors' contributions

The corresponding author, JS, is the main contributor in the design and conceptualization of the study, analysis and interpretation of the data, drafting the work and revising content critically, final approval of the work to be published. MP contributed to the design and conceptualization of the study, analysis and interpretation of the data, drafting and revising the work critically, and final approval of the version to be published. PD contributed to the conceptualizing and design of the study, acquisition and interpretation of the data, drafting the work and revising content critically, and final approval of the work to be published. SH and DC contributed to the design and interpretation of the work, drafting and revising content critically, and final approval of the version to be published. MEP contributed to the design and conceptualization of the study, interpretation of the data, drafting and revising the work critically, and final approval of the version to be published.

Ethics approval and consent to participate

Not Applicable.

Consent for publication

Not Applicable.

Competing interests

The authors declare that they have no competing interests.

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Risk of Cancer Among Firefighters in California, 1988–2007

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Abstract

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

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

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

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

Keywords

cancer; firefighters; occupation; registry; risk

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INTRODUCTION

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

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

Studies have found that firefighting is significantly associated with an increased risk for developing the following cancers: colorectal [Vena and Fiedler, 1987; Burnett et al., 1994; Baris et al., 2001; Daniels et al., 2014], lung [Pukkala et al., 2014; Daniels et al., 2015], melanoma [Howe and Burch, 1990; Sama et al., 1990], prostate [Grimes et al., 1991; Demers et al., 1994; LeMasters et al., 2006], testis [LeMasters et al., 2006; Ma et al., 2006], urinary bladder [Vena and Fiedler, 1987; Sama et al., 1990; Ma et al., 2006], kidney [Burnett et al., 1994; Delahunt et al., 1995; Daniels et al., 2014], brain [Grimes et al., 1991; Demers et al., 1992; Aronson et al., 1994; Ma et al., 2006], myeloma [LeMasters et al., 2006], non-Hodgkin lymphoma [Burnett et al., 1994; Figgs et al., 1995; Golden et al., 1995], and leukemia [Morton and Marjanovic, 1984; Golden et al., 1995; Baris et al., 2001; Daniels et al., 2015]. In recognition of these cancer risks, as of 2015, a total of 33 states cover firefighters for one or more cancers under workers' compensation as a result of presumption legislation [International Association of Fire Fighters, 2015]. In 20 of these states, the language in the presumption legislation contains broad or nonspecific language that can be interpreted to cover any cancer experienced by a firefighter. In the other 13 states, only certain specific cancers are covered, most commonly leukemia (12 states), brain cancer (10 states), bladder cancer (9 states), non-Hodgkin lymphoma (9 states), and gastrointestinal cancer (8 states).

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

MATERIALS AND METHODS

California Cancer Registry (CCR)

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

Firefighter Definition

To identify all cancer cases among firefighters, the I&O narrative fields were extensively searched for key words consistent with firefighting. The identified I&Os were coded using 1990 Bureau of Census (BOC) codes. Occupation codes used to indicate a career in firefighting are 413, 416, and 417. All firefighters with these codes were selected regardless of industry. The BOC manual states that the 417 code includes firefighters, fire chief's aides, smoke jumpers, forest-fire fighters, and crash-crew men [U.S. Department of Commerce, 2000]. Their main duties are to control and extinguish fires that threaten life, property or environment, fire prevention, emergency medical service, hazardous material response, search and rescue, and disaster management [U.S. Department of Commerce, 2000]. A total of 29 search terms (e.g., firefighter, fire crew worker) were used to identify and code individuals as BOC code 417.

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

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

Exclusion Criteria

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

Selection of Cases and Control Cancers

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

Data Analysis

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

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

RESULTS

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

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

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

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

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

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

DISCUSSION

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

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

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

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

Comparison With Another Large Firefighter Study and a Meta-Analysis

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

Commonly Observed Increased Cancer Risks Among Firefighters

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

Comparison With Bates [2007]

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

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

Firefighters of Other Race/Ethnicity

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

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

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

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

Prostate Cancer

The prostate is a hormone-regulated gland (i.e., testosterone). Chemicals, such as pesticides, cadmium, Bisphenol A (BPA), or PCB, have been shown to be endocrine disruptors [Diamanti-Kandarakis et al., 2009] that interfere with androgen metabolism. This disruption elevates the bioavailability of androgen which can initiate prostate cancer. The increased prostate cancer risk could also be due to an increased frequency of prostate cancer screening among firefighters as compared to the general population. Such a screening effect is supported by a recent study showing a lack of a positive dose-response relationship between fire-fighting exposure and prostate cancer incidence and mortality [Daniels et al., 2015].

Melanoma

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

Esophageal Cancer

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

Limitations

This study has several limitations. First, using other cancer cases as controls may bias our findings towards the null if the selected control cancers are related to firefighting exposures. To minimize this bias, we did a comprehensive literature review of cancers found to be elevated among firefighters. Cancers that consistently showed very weak or no association with firefighters were selected as control cancers. Second, I&O data were missing for approximately 50% of cancer cases in CCR. Individuals in the CCR dataset who had unknown I&O were more likely to be older and of Hispanic descent compared to the CCR cases meeting study eligibility. Ascertainment bias would be present if the proportion of firefighters who were ascertained by the CCR varied across the different cancers. However, the California cancer presumption law enacted in 1982 and amended periodically can award compensation and benefits to any firefighter diagnosed with any cancer within 10 years of their last day worked [William Dallas Jones Cancer Presumption Act, 2010]. It should be noted that the employer can challenge the firefighter's compensation filing on the basis of an insufficient latency period (i.e., 10 years or less), or if the employer can prove that the association between the cancer and firefighting has been examined scientifically and shown not to exist [Heald, 2005]. Since firefighters can presume that any cancer was caused by work, it is unlikely that ascertainment bias was introduced. Third, because I&O recording is not standardized, I&O data obtained may not be the longest-held job, but rather the current job. It is reassuring that findings based on large representative samples of U.S. workers found moderate to high correlation between current and longest-held job [Gomez-Marin et al., 2005; Luckhaupt et al., 2013], indicating that current job may be an acceptable surrogate for longest-held job. Fourth, those who worked as volunteer firefighters may have been classified as non-firefighters in our analyses because it is unlikely that volunteer firefighting was captured as the longest-held job. Conversely, some individuals with the designation of firefighter in this study may not have been involved in firefighting. The former misclassification of fire-fighting exposure may have biased the estimates towards the null, and it's not clear how the latter misclassification would bias our findings. Fifth, CCR does not have information on smoking, alcohol consumption, obesity, workplace exposures, length of employment, and actual job duties. Although many cancers of interest are influenced by lifestyle factors, this study was not able to adjust for these potential confounders. Recent studies found that firefighters working in the central region of the United States were less likely to smoke [Haddock et al., 2011], but have high rates of heavy and binge drinking on their off-duty days [Haddock et al., 2012]. Any differences in lifestyle factors could have biased our estimates in either direction. Sixth, due to small sample sizes, we were unable to examine blacks, Hispanics, and Asians separately. Finally, this study did not adjust for multiple comparisons and some findings may have arisen due to chance. Nevertheless, it is reassuring that many of the findings from this study are similar to those of previous studies.

Strengths

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

CONCLUSION

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

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TABLE I

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

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

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

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

TABLE II

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

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

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

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

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

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

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

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

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

TABLE III

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

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

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

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

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

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

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

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

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

[d] Firth bias-correction applied.

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

TABLE IV

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

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

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

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

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

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

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

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

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