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Risk Factors Associated with Non-compliance with the Respiratory Protection Program among Firefighters

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Risk Factors Associated with Non-compliance with the Respiratory Protection Program among Firefighters

by

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DEDICATION

I dedicate this work to my family who has supported me through every stage of my life. To my father who demonstrated a framework and guidance on how to accomplish goals. To my mother who has continually been a source of positive energy. To my sisters who have always been by my side. To my loving wife who is a source of inspiration.

ACKNOWLEDGMENTS

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ABSTRACT

Introduction: Non-compliance with respiratory protection programs among firefighters may put them at increased risk of injury and illness from occupational exposures during fire extinguishing activities. This research aims to characterize respiratory protection practices among Florida firefighters. This information will allow better understanding of factors that are associated with non-compliance with respiratory protection guidelines.

Methods: Survey questionnaire was used to characterize Florida fire departments in this cross sectional study. Four hundred and seventy-seven surveys were administered to Florida firefighters both in person and electronically to collect information regarding firefighter knowledge and participation in their respective respiratory protection programs during the past twelve months. Survey questions were developed from the model set by the National Fire Protection Association which provides standards and regulations regarding firefighter protections. Collected data were used to produce summary statistics regarding firefighter department size, coverage area, and firefighter employment type. Further data analysis used Statistical Analysis Software to compute multinomial logistic regression analysis.

Results: The 477 respondents were 91% male with a mean age 39 years old (range 21-65 years). The majority of respondents, 76%, were non-smokers, 21% former smokers, and 3% current smokers. In regards to ethnicity, respondents were 77% Caucasian, 13% Hispanic, 3% African-

American, and 4% other. Most respondents were career firefighters, 97%, with less than ten years of experience, 44%, working in a fire department with at least 21 firefighters, 98%. Most respondents, 80%, had a written respiratory program in place. The most cited reason for not having implemented a written respiratory program was lack of knowledge related to the program. Multinomial logistic regression analysis of departments with response areas of at least 250,000 square miles produced a statistically significant 0.44 odds ratio for having a written respiratory program as compared to those with a less than 10,000 square miles response area.

Conclusion: Additional resources need to be given to Florida fire departments to ensure that all firefighters receive adequate respiratory protection in accordance with National Fire Protection Association guidelines. There is an association between fire departments with large response areas and non-compliance with respiratory protection guidelines in regards to: having a written respiratory program, the frequency of respiratory fit testing, and the frequency of medical fitness testing. This suggests that rural fire departments need additional resources to ensure fire fighters are adequately protected. Additional research should focus on why these differences exist in the rural fire departments. Respondents stating a lack of knowledge or no requirement for a written respiratory program suggest that future efforts should focus on respiratory protection education and training.

INTRODUCTION

The National Fire Protection Association (NFPA) estimates that there were 1,140,750 firefighters in the United States in 2013. These firefighters worked in an estimated 30,052 fire departments of which 4,448 were all or mostly career and 25,604 were all or mostly volunteer. The National Fire Department Census reports 477 registered fire departments in the state Florida of which 51.8% are career or mostly career and 48.2% are volunteer or mostly volunteer. From 2010 to 2012 the National Fire Incident Reporting System estimated 70,450 firefighter injuries annually of which 18.5% were characterized as due to an exposure to hazard.[6] Firefighters have to work in harsh conditions during fire extinguishing activities. To protect against these harsh conditions, the National Fire Protection Association has produced standards regarding firefighter activities that promote firefighter safety.

Firefighters are called in many different emergency situations where there is the potential for exposure to hazardous materials. These hazardous materials can become airborne and present threats as dusts, fumes, smoke, gas, aerosols, mists, and vapors. The respiratory system is vulnerable to these airborne hazards especially when they present in a size small enough to be inhalable (<100 μm). Research has shown that the smoke firefighters are exposed to during firefighting activities contains harmful inhalable particles.[2] These harmful particles create free radicals like carbon, hydrogen, and oxygen radicals that react with the airway to produce inflammation, fibrogenesis, and bronchopulmonary carcinogenesis.[2,10] Carbon-centered free radicals have been found to originate from wood fire and are known to specifically react within

the bronchopulmonary tree.[10] Additionally ultrafine particles (0.042-0.24 μm) inhaled through wildfire smoke were found to be potent producers of malondialdehyde a byproduct of lipid peroxidation and H_2O_2 responsible for DNA damage.[10]

The respiratory system injury due to occupational smoke inhalation can have both short and long-term adverse health implications. Studies have demonstrated that firefighters exhibit an inflammatory response after smoke inhalation. This inflammatory response results in increased sputum granulocytes, circulating cytokines, and circulating band cells.[17] These inflammatory changes post smoke inhalation exposure have been correlated with changes in spirometry testing. Multiple studies demonstrate decreases in both forced expiratory volume in 1 second (FEV1) and forced vital capacity (FVC) during spirometry testing.[9] These decreases in spirometry testing and inflammatory changes (sputum granulocytes) persisted up to 3 months post exposure.[5,9] All of these findings suggest that smoke inhalation can lead to both acute and long-term adverse health effects in firefighters.

To protect against smoke inhalation firefighters use respirators. One must keep in mind that independent of the respiratory concerns, fire extinguishing activities take place in a very stressful environment. The environment in which firefighters work requires strenuous physical exertion, awkward positioning, extreme heat, low visibility, loud noise, and psychological stress.[16] This creates significant physiological strain on all body systems but most directly on the cardiovascular and thermoregulatory systems. This strain can manifest itself by elevated core body temperature (hyperthermia), profuse sweating leading to a significant reduction in plasma volume (dehydration), decreased stroke volume, close to maximal heart rate (tachycardia),

alterations in blood electrolytes, and disabling fatigue.[16] Even with all of these stressors, using the actual respirator causes additional physiological strain on the body.

Studies on open circuit self-contained breathing apparatus (SCBA) type respirators demonstrate that there is added physiological stress from respirators due to increased airway resistance. When one uses a respirator there is increased physiologic dead space creating increased resistance especially during expiration. Inspiration is less affected due to assistance by the positive pressure systems within the respirator. The increased expiratory resistance reduces tidal volume resulting in hypoventilation thus reducing oxygen consumption. This occurs during a time when the body physiologically requires more oxygen as a result of the increased physiologic demand.[8] Additionally the actual mechanical weight of the respirator increases the physiological demand of the body. Much effort has been dedicated to characterization of the increased physiological demands during fire extinguishing activities. This information would better assist risk stratification during medical fitness assessment for firefighters. Unfortunately due to the very nature of the fire extinguishing environment and the great physiological demands it has been a difficult task.[7]

Still respirators do help protect workers from the adverse health effects due to the occupational hazard of smoke inhalation. Both the Occupational Health and Safety Administration (OSHA) and the NFPA have produced standards and regulations regarding respiratory protection. Per OSHA 29 C.F.R. §1910.134 and NFPA Standards (1404, 1500, 1582, 1981, 1986, 1989) when atmospheric contamination against agents responsible for occupational diseases is not able to be prevented by accepted engineering control measures, appropriate respirators provided by the employer should be used. Additionally when a workplace or an

employer requires respirator use, the employer must maintain a written respiratory protection program. The written respiratory protection program outlines the following: procedures for selecting the proper respirator, medical evaluation for those employees required to use respirators, annual procedures for fit testing, procedures for proper respirator use, procedures for respirator maintenance, training on respirator use, training on respirator hazards, and procedures to evaluate the effectiveness of the respiratory program.[14]

Even the best respiratory protection program imaginable that includes all OSHA and NFPA guidelines would be imperfect. One of the most concerning aspects of a respiratory protection program is that non-compliance at any level may put firefighters at increased risk of injury and illness due to inhalation exposure. A survey of 281,776 private sector employers requiring respirator use showed that only 132,348 (47%) of employers evaluated medical fitness for respirator use. An additional 13,598 (5%) did not know about the requirement for medical fitness assessment prior to respirator use. Of those implementing medical fitness assessments, the modality of assessment was variable. The largest portion representing 62,893 employers (48%) used questionnaire with follow-up physical examination, 40,520 (31%) used physical examination only, 14,388 (11%) used questionnaire only, and 12,683 (10%) used other modalities. These variabilities existed even though the requirements from national organizations like the Occupational Safety and Health Administration and the Mine Safety and Health Administrations which these employers follow are not variable and in fact are both explicit and clear. [18]

OBJECTIVE

The purpose of this research is to collect information regarding respiratory protection programs for Florida firefighters. Collected information will characterize practices, knowledge, and surveillance related to the respiratory protection programs. The primary goal is to identify risk factors for non-compliance with existing respiratory protection programs.

METHODS

The study design is a cross-sectional survey of Florida fire departments in the Tampa area. The survey consisted of 21 questions that collected information regarding firefighter knowledge and participation in their respective respiratory protection programs during the previous 12 months. It was administered to 477 Florida firefighters both in person (44) and electronically (433). In addition to collection of information regarding respiratory practices, basic demographic information was obtained regarding respondent firefighters and their respective fire departments. Survey questions were developed from the model set by OSHA and the NFPA which provides standards and regulations regarding firefighter protections. Additional input was received from a consultant with previous experience with a Florida fire department and faculty from the University of South Florida College of Public Health.

Prior to initiation of the research efforts, the study was approved by the Institutional Review Board through the University of South Florida Research Integrity and Compliance. The study was found to meet both University of South Florida and Federal Exemption requirements regarding the documentation of informed consent per federal regulations 45 C.F.R. § 46.101(b) and 45 C.F.R. § 46.117 (c). Data collected from the survey contain no personally identifying characteristics of any participating firefighters or fire departments and were only used for the purpose of research. Once obtained, the data were stored on a secure computer located at the Center for Environmental and Occupational Risk Analysis and Management.

Collected data were used to produce summary statistics regarding firefighter and fire department demographic information related to gender, age, ethnicity, firefighter type, service years, department size, and department response area. Further data analysis was performed using Statistical Analysis Software to compute multinomial logistic regression.

RESULTS

There were 477 respondents who completed the survey questionnaire. Table 1: Firefighter Respiratory Protection Survey Results displays the results from the survey questionnaire. The demographic information obtained regarding respondent firefighters and their respective fire departments is displayed in Figures 1-8. Figure 1: Firefighter Gender Distribution and Figure 2: Firefighter Age Distribution show that overall the respondents were 91% male with a mean age 39 years old (range 21-65 years). Figure 3: Firefighter Smoking Status demonstrates that 76% of respondents were non-smokers, 21% former smokers, and 3% current smokers. Figure 4: Firefighter Ethnicity Distribution shows that respondents were 77% Caucasian, 13% Hispanic, 3% African-American, and 4% other. Figure 4A: Ethnicity Response Other Classification further characterizes the responses for the Other ethnicity. Respondent firefighters who completed their surveys online were able to enter free text responses regarding the Other ethnicity. The 21 Other responses were further subdivided as follows: 24% (5) were Asian, 14% (3) American, 14% (3) Mixed, 14% (3) Native American, 14% (3) White, 10% (2) American Indian, 5% (1) All Races, and 5% (1) Other. Figure 5: Firefighter Career Type and Figure 7: Fire Department Size show that most respondents were career firefighters, 97%, working in a fire department with at least 21 firefighters, 98%. Figure 6: Firefighter Service Years shows that 45% of respondents had less than ten years of experience as a firefighter while 55% had greater than ten years of experience. Figure 8: Fire Department Response Area shows that the majority of fire

departments included in the survey, 63%, worked in fire departments with a service area of less than 10,000 square miles.

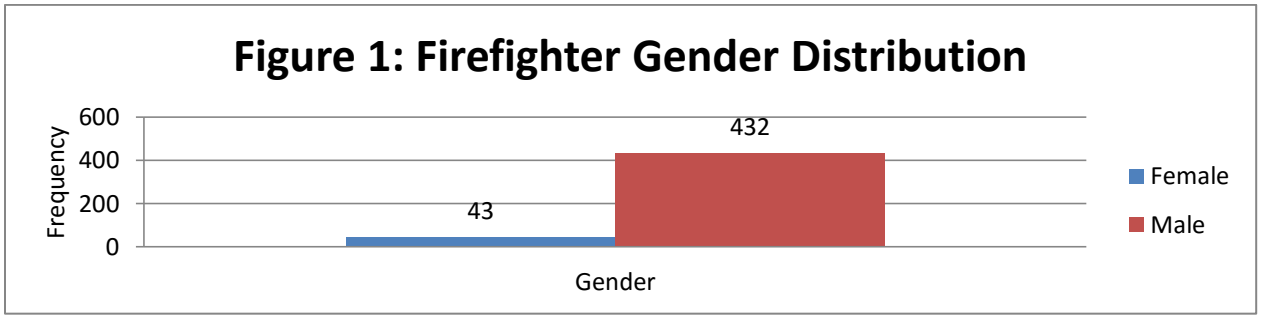

Figure 1: displays the gender distribution of respondent firefighters

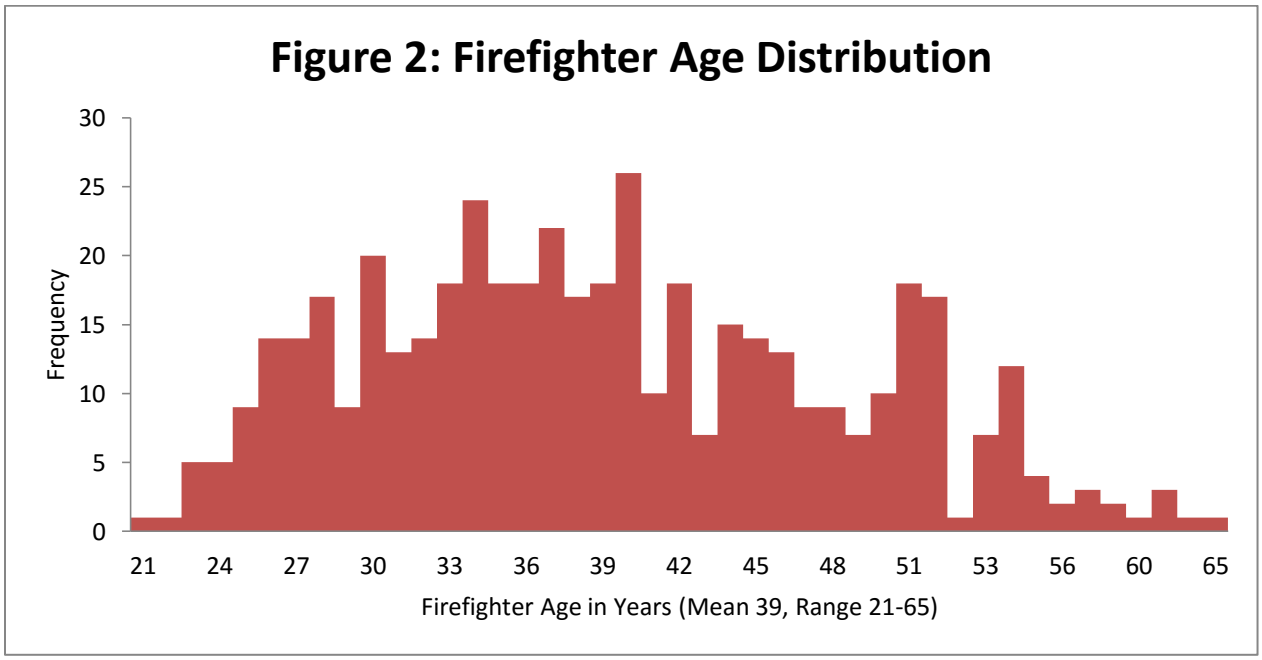

Figure 2: displays the age distribution of respondent firefighters

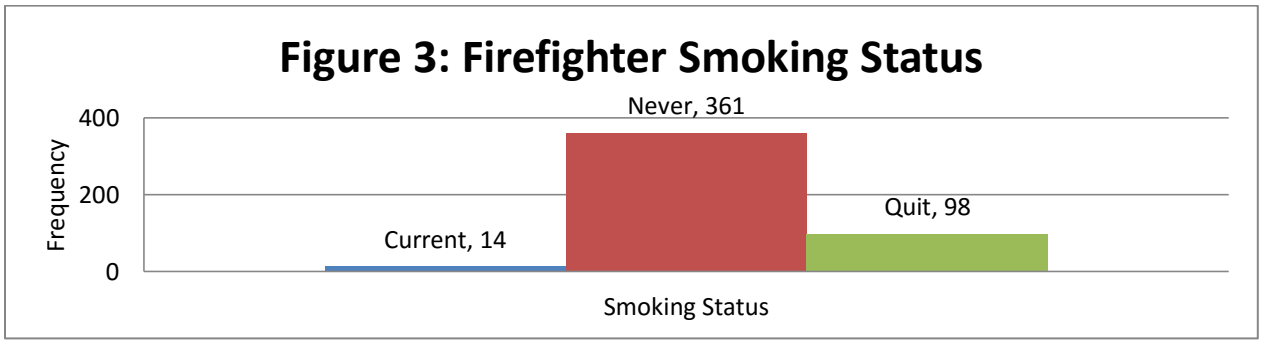

Figure 3: displays the smoking status of respondent firefighters

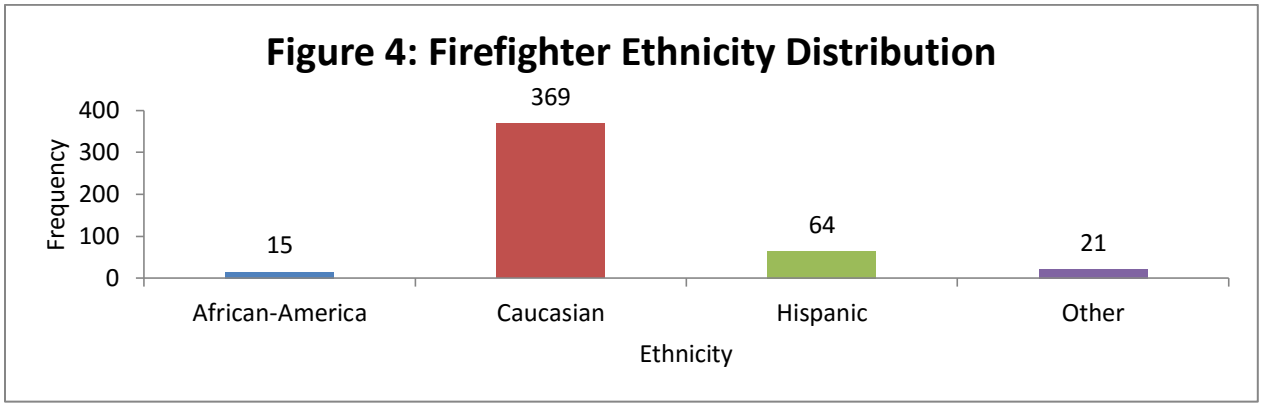

Figure 4: displays the ethnicity distribution of respondent firefighters

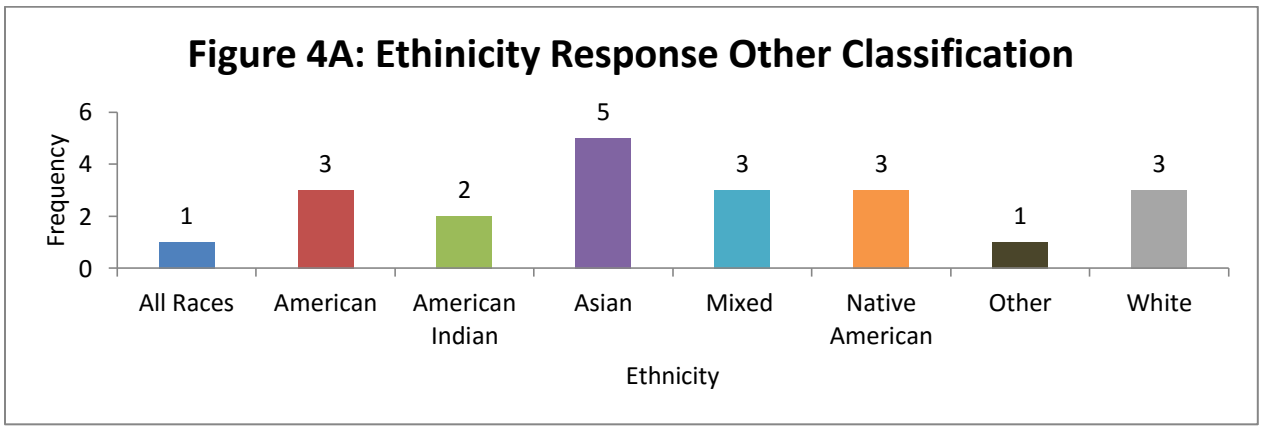

Figure 4A: displays the breakdown of free text responses for respondents selecting Other for ethnicity

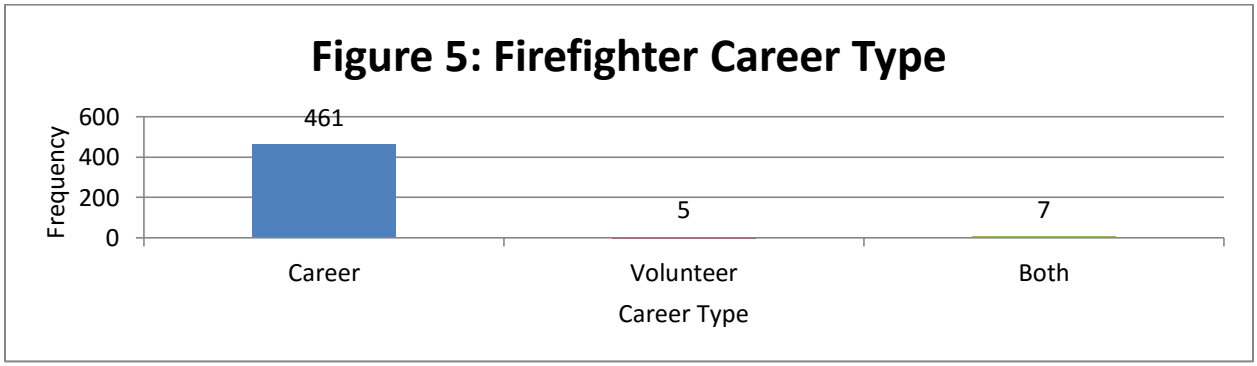

Figure 5: displays the different career types of respondent firefighters

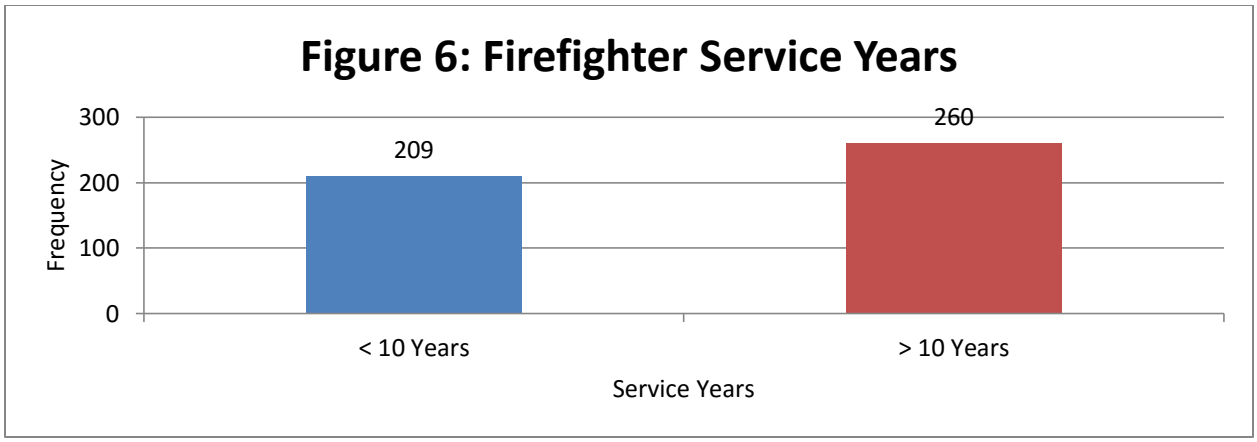

Figure 6: displays the distribution of firefighter service years of respondent firefighters

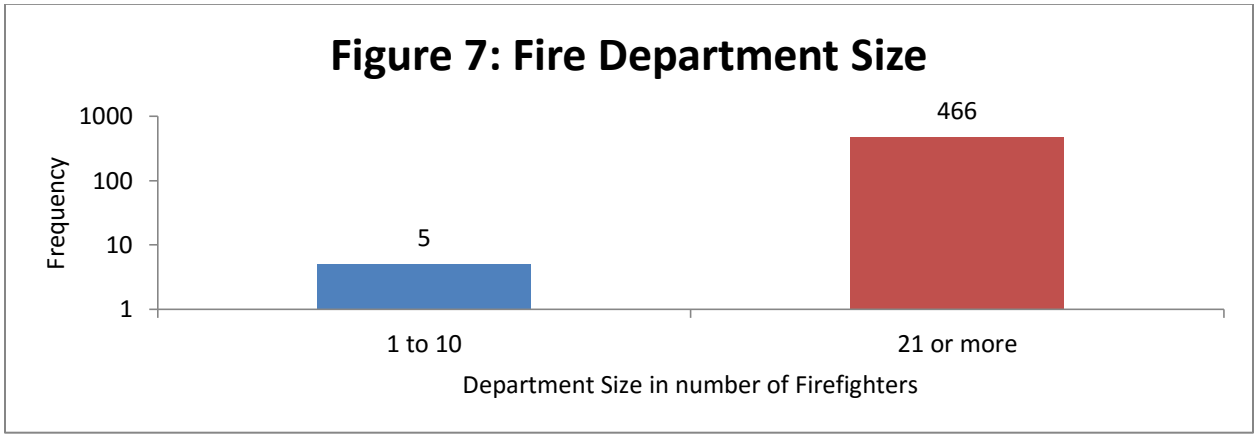

Figure 7: displays the distribution of department sizes of respondent firefighters

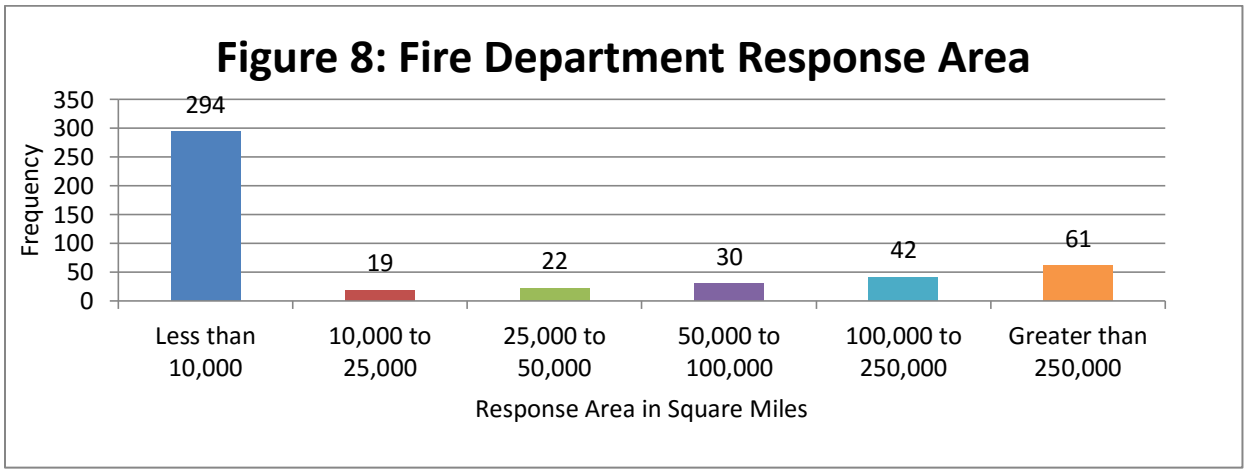

Figure 8: displays the distribution of fire department response areas among respondent firefighters

Description of Firefighter Activities

Table 1: Firefighter Respiratory Protection Survey Results displays firefighter respiratory practices regarding several aspects of firefighter respiratory protection programs according to the NFPA guidelines. Of respondents 73% always use respirators when responding to a fire and 90% maintain respirator use during firefighting activities. Half of respondent firefighters, 50%, performed fireground monitoring prior to doffing respirators. The majority of respondent firefighters, 89%, performed first responder/ emergency medical technician/ paramedic activities as compared to 8% hazardous materials operations, 8% search and rescue operations, and 4% water rescue and diving operations. Half of respondent firefighters, 50%, only use respirators during fire extinguishing activities and 97% use the self-contained breathing apparatus type respirator.

Table 1: Firefighter Respiratory Protection Survey Results

	n	%
When responding to a fire, I use a respirator		
Never	40	9
Sometime	41	9
Often	46	10
Always	338	73
Required to maintain respirator use during firefighting		
Yes	423	90
No	45	10
Fireground monitoring before doffing respirator		
Yes	232	50
No	234	50
Duties beyond fire response I participate in		
First Responder/ EMT/ Paramedic	414	89
HAZMAT	38	8
Search and Rescue Operations	35	8
Water Rescue/ Diving	18	4
Respirator use in non-fire related incidents		
Never	233	50
Sometimes	210	45
Often	9	2
Always	15	3
Type of respirator used		
Air Purifying Respirator	16	3
SCBA	449	97
Unknown	4	1
My department has a written respiratory program		
Yes	382	83
No	16	3
Unknown	63	14
Dress code (beard/sideburns) for proper respirator fit		
Yes	455	99
No	2	0
Unknown	3	1
Department compliance with NFPA 1500		
Yes	386	84
No	10	2
Unknown	65	14
Department compliance with OSHA 1910.134		
Yes	412	90
No	29	6
Unknown	18	4
Department compliance with NFPA 1404		
Yes	400	88
No	11	2
Unknown	46	10
I am familiar with department written respiratory program		
Yes	377	83
No	79	17
Reason for no respiratory program		
Financial Resources	0	0
Lack of Knowledge	5	1
It is not required	2	1
Other	21	5
Not applicable	370	93
I received training for respirator use		
Yes	451	99
No	4	1
Have you undergone fit testing		
Yes	452	99
No	3	1
Fit testing frequency		
Annually	355	78
Every six months	62	14
As required	38	8
Type of fit testing		
Quantitative method	326	72
Qualitative method	45	10
Unknown	89	20
Medical assessment prior to respirator use		
Yes	354	77
No	84	18
Unknown	19	4
Who determines medical fitness		
Occupational Health Nurse	165	36
Occupational Medicine Physician	99	22
Primary Care Physician	21	5
No one	74	16
Other	24	5
Unknown	81	18
Frequency of medical fitness		
Annually	196	43
Every six months	7	2
Never	154	34
Other	32	7
Unknown	67	15
Medical fitness methods		
Questionnaire only	15	3
Questionnaire with physical	40	9
Physical examination only	42	10
Spirometry	24	5
All of the above	125	28
Other	30	7
Unknown	172	39

EMT = Emergency Medical Technician; HAZMAT = Hazardous Materials; SCBA = Self-Contained Breathing Apparatus
NFPA = National Fire Protection Association; OSHA = Occupational Safety and Health Administration

Multinomial Logistic Regression

Table 2 displays which demographic factors were associated with recorded firefighter knowledge and practices regarding the respiratory protection program. The associations measured in the multinomial logistic regression are displayed as odds ratios (OR) and confidence intervals (CI). In regards to respirator use activities, the multinomial logistic regression shows that a larger fire department with at least 20 members had a 0.186 OR (0.035-0.974 CI) of using a respirator as compared to a smaller fire department with 1-10 members and less than 10 years of service experience had a 1.939 OR (1.240-3.034 CI) of not using a respirator in non-fire situations as compared to greater than 10 years of service experience. Additionally respondents from fire departments with a 100,000-250,000 versus less than 10,000 square miles response area had a 4.964 OR (1.243-19.827 CI) of using a SCBA type respirator. Fireground quality sampling and monitoring prior to doffing respirator was associated with both being a former smoker, 1.719 OR (1.050-2.813 CI) versus never smokers, and less than 10 years of service experience, 1.690 OR (1.012-2.558 CI) versus greater than 10 years of service experience.

Table 2: Statistically Significant Results from the Multinomial Logistic Regression

	Odds Ratio	Confidence Interval
Respirator use comparing fire department size >20 with 1-10	0.186	0.035-0.974
Fireground monitoring prior to respirator doffing comparing former versus never smokers	1.719	1.050-2.813
Fireground monitoring prior to respirator doffing comparing <10 versus >10 years of service	1.690	1.012-2.558
First Responder/ EMT/ Paramedic duty comparing African-American versus Caucasian ethnicity	3.824	1.127-12.981
First Responder/ EMT/ Paramedic duty comparing <10 versus >10 years of service	0.435	0.196-0.967
HAZMAT job duties comparing African-American versus Caucasian ethnicity	0.283	0.090-0.890
Non-fire respirator use comparing <10 versus >10 years of service	1.939	1.240-3.034
SCBA type respirator comparing 100-250K versus <10K square miles response area	4.964	1.243-19.827
Written respiratory protection program comparing >250K versus <10K square miles response area	0.444	0.219-0.901
OSHA 1910.134 compliance comparing Other versus Caucasian ethnicity	0.169	0.058-0.497
Annual fit testing comparing Other versus Caucasian ethnicity	0.372	0.144-0.960
Annual fit testing comparing 25-50K versus <10K square miles response area	0.336	0.119-0.950
Qualitative fit testing comparing <10 versus >10 service years	0.540	0.321-0.907
Quantitative fit testing comparing <10 versus >10 service years	2.160	1.296-3.600
Occupational medicine physician assessment comparing 50-100K versus <10K response area	2.847	1.022-7.933
Annual medical fitness testing comparing former versus never smoker	0.600	0.385-0.933
Annual medical fitness testing comparing African-American versus Caucasian ethnicity	3.222	1.025-10.128
Annual medical fitness testing comparing >250K versus <10K square miles response area	0.528	0.312-0.894
Medical fitness with questionnaire only comparing >250K versus <10K square miles area	0.483	0.249-0.937
Medical fitness with questionnaire and physical comparing volunteer versus career firefighter type	0.122	0.020-0.760
Medical fitness with questionnaire and physical comparing department size >20 versus 1-10	0.090	0.011-0.722
Medical fitness with physical only comparing department size >20 versus 1-10	9.232	1.511-56.394
Medical fitness with physical only comparing 50-100K versus <10K square miles response area	0.348	0.145-0.833
Medical fitness with spirometry comparing volunteer/ career versus career firefighter type	0.081	0.016-0.405
Medical fitness with spirometry comparing >250K versus <10K response area	0.363	0.185-0.712
Medical fitness with all modalities comparing fire department size >20 with 1-10	0.114	0.014-0.943

EMT = Emergency Medical Technician; HAZMAT = Hazardous Materials

SCBA = Self-Contained Breathing Apparatus; OSHA = Occupational Safety and Health Administration

Written Respiratory Protection Program

Regarding the written respiratory program, 83% of respondents confirmed their department had a written respiratory protection program while, 14% did not know, and 3% responded that their department did not have a written respiratory protection program. This corresponds to the 83% of respondents who confirm that they are familiar with their department's respiratory program. Essentially all fire departments, 99%, had policies in place regarding facial hair, sideburns, and/ or glasses that would prevent proper respirator fit according to respondents. Additionally most fire departments followed specific OSHA and NFPA guidelines, 90% OSHA 1910.134 "Two-in & Two-out" rule, 88% NFPA 1404, and 84% NFPA 1500. Logistic regression shows that a greater than 250,000 square miles response area had a

0.444 OR (0.219-0.901 CI) of having written respiratory program as compared to a less than 10,000 square miles response area. In regards to OSHA 1910.134 “Two-in & Two-out” rule, responding Other for ethnicity had a 0.169 OR (0.058-0.497 CI) when compared to responding Caucasian for ethnicity.

Barriers to Written Respiratory Protection Program

None of the firefighters surveyed listed lack of financial resources as a reason for not having a written respiratory protection program. The most cited reasons for not having a written respiratory protection program include lack of knowledge (1%), it is not required (1%), and other reason (5%). Even with the opportunity for free text responses during survey completion, there were no free text responses associated with the Other response for not having a written respiratory protection program.

Respiratory Training and Fit Testing

Nearly all of respondents, 99%, confirmed that they had received both training for respirator use and respirator fit testing. Specific to fit testing 78% received annually fit testing, 14% received fit testing every six months, and 8% as needed. Logistic regression shows that annual fit testing was associated with both ethnicity and fire department response area. Responding Other for ethnicity had a 0.372 OR (0.144-0.960 CI) when compared with responding Caucasian for ethnicity in regards to having annual fit testing. A fire department with

a 25,000-50,000 square miles response area had a 0.336 OR (0.119-0.950 CI) for having annual fit testing as compared to a less than 10,000 square miles response area.

Quantitative testing was most commonly performed according to 72% respondents. This is contrasted with 10% of respondents undergoing qualitative testing and 20% of respondents not knowing which type of fit testing they received. Having less than 10 service years experience had a 2.160 OR (1.296-3.600 CI) of having quantitative testing as compared to greater than 10 service years experience. Conversely less than 10 service years experience had a 0.540 OR (0.321-0.907 CI) of having qualitative testing as compared to greater than 10 service years experience.

Respirator Medical Fitness Assessment

The majority of respondents, 77%, reported having a medical assessment prior to being approved to use a respirator. Those with medical assessments most often reported being evaluated by an occupational health nurse (36%), followed by occupational medicine physician (22%), unknown (18%), primary care physician (5%), and other (5%). Logistic regression demonstrates that a response area of 50,000-100,000 square miles had a 2.847 OR (1.022-7.933 CI) of having a medical assessment from an occupational medicine physician as compared to having a less than 10,000 square miles response area. 18% percent of respondents reported not having a medical assessment which corresponds with 16% of respondents indicating that no one performed the medical assessment. Only 45% of respondents reported having at least annual medical fitness testing (annual 43%, every six months 2%).

Logistic regression demonstrates multiple associations with having annual medical fitness testing: former smoker 0.600 OR (0.385-0.933 CI) as compared to never smoker, African-American ethnicity 3.222 OR (1.025-10.128 CI) as compared to Caucasian ethnicity, and greater than 250,000 square miles response area 0.528 OR (0.312-0.894 CI) as compared to less than 10,000 square miles response area. The reported experience regarding how the medical fitness testing was performed was varied with 28% reporting use of all modalities (questionnaire, physical examination, and spirometry), 39% reporting that the modality was unknown, and 27% reporting a specific combination of the modalities. Logistic regression shows multiple associations with modality of medical fitness testing. Having questionnaire as the only modality had a 0.483 OR (0.249-0.937 CI) of being associated with a greater than 250,000 as compared to a less than 10,000 square miles response area while using all modalities had a 0.114 OR (0.014-0.943 CI) of being associated with a fire department size of greater than 20 as compared to 1-10. Having a medical questionnaire with follow up physical examination as needed for medical fitness testing demonstrated a 0.122 OR (0.020-0.760 CI) when comparing volunteer with career type firefighter and a 0.090 OR (0.011-0.722 CI) when comparing a fire department size of greater than 20 with 1-10. Medical fitness evaluation with physical examination only demonstrated a 9.232 OR (1.511-56.394 CI) when comparing a fire department size of greater than 20 with 1-10 and a 0.348 OR (0.145-0.833 CI) when comparing a 50,000-100,000 square miles response area with a less than 10,000 square miles response area. Medical fitness testing with spirometry demonstrated a 0.081 OR (0.016-0.405 CI) when comparing combination volunteer/ career with career type firefighter and a 0.363 OR (0.185-0.712 CI) when comparing greater than 250,000 square miles response area with less than 10,000 square miles response area.

DISCUSSION

The demographic data on both firefighters and fire departments suggests that there was not a large amount of diversity among the firefighters who completed the survey. The majority of those surveyed were Caucasian male career firefighters who never smoked from fire departments with 21 or more members responsible for a service area that is less than 10,000 square miles. Other than Caucasian ethnicity (77%), status of never smoker (76%), and a less than 10,000 square miles service area (63%), these characteristics describe greater than 90% of the survey respondents. This lack of diversity limits our ability to understand the differences within this group and suggests that the respondent firefighters belong to a small group of fire departments.

Even so multinomial logistic regression found differences among the firefighters and fire departments. Smaller fire department size, 1-10 members, and less than 10 years of service experience were associated with not using a respirator during non-fire activities. These associations provide little insight into compliance with the respiratory protection program. This association likely shows that smaller fire departments and firefighters with less experience are less likely to perform advanced techniques that require respirators in non-fire situations. The finding that the relatively large fire department service area of 100,000-250,000 as compared to less than 10,000 square miles was associated with SCBA type respirator use is less meaningful given neither a statistically significant association nor a directional trend was found when other response area sizes including the largest response area group, greater than 250,000 square miles, were assessed. The finding that being a former smoker and having less than 10 years of service

experience was associated with fireground monitoring prior to respirator doffing suggests perceived respirator risk plays an important role in this activity. Former smokers are likely to have more baseline lung damage than never smokers and thus be more sensitive to poor air quality and respiratory occupational exposure.[13,19] Additionally less experienced firefighters are more likely to perceive higher risk during fire extinguishing activities and be more cautious about the potential for poor air quality and respiratory occupational exposure.

Specific to the written respiratory protection program, logistic regression analysis found fire departments with a greater than 250,000 square miles response area were negatively associated with having a written respiratory protection program as compared to fire departments with a less than 10,000 square miles response area. Even though the survey did not collect specific information to determine whether a fire department had an urban or rural location, service area can be used as a surrogate as those fire departments covering a greater response area are more likely to be rural. This would suggest that urban fire departments were more likely to have a written respiratory protection program as compared to rural fire departments. These findings are consistent with previous data which suggested that urban fire departments with more funding, more resources, and less volunteer fire departments were associated with compliance with the requirement for a written respiratory protection program.[3] There were no statistically significant findings regarding barriers to compliance with the requirement for a written respiratory protection program. This is most likely due to insufficient power to find differences regarding barriers as 93% of respondents recorded not applicable in the survey question on barriers to compliance.

There were firefighter demographic level differences among specific aspects of the respiratory protection program. Caucasian ethnicity was associated with compliance with the OSHA 1910.134 "Two-in & Two-out" rule and having an annual respirator fit test as compared to Other ethnicity. It is difficult to draw conclusions from this as 4% of respondents classified themselves as Other and within the Other ethnicity there were eight unique responses for ethnicity. African-American ethnicity was associated with annual medical fitness testing recommended by respiratory protection program guidelines as compared to Caucasian ethnicity. Similarly it is difficult to draw meaningful inferences regarding respiratory protection program compliance from this association given that this response is compared against four unique responses, "at least every six months", "never", "other", and "unknown" only one of which (never) can be equated to non-compliance. Logistic regression also found that annual respirator medical fitness testing was negatively associated with former as compared to never smoker status. Unfortunately one is not able to interpret this to suggest that former smoker status is associated with noncompliance as only one of the other four unique responses is consistent with non-compliance, "never". Additional firefighter level demographics showing statistically significant differences were found in quantitative fit testing which was associated with less experience. As both quantitative and qualitative fit testing is recognized as valid by OSHA, this difference represents little importance in regards to compliance with the respiratory protection program.[14]

There were fire department demographic level differences among both the frequency of fit testing and the frequency of medical fitness testing. Urban fire departments, as suggested by a less than 10,000 square miles response area, were associated with both annual fit and medical fitness testing. This finding is consistent with previous studies suggesting urban as compared to

rural fire departments have more resources to be in compliance with the respiratory protection guidelines. Annual fit testing only showed statistical significance comparing a less than 10,000 square miles response area with a response area of 25,000-50,000 square miles and not greater than 250,000 square miles. This suggests that more urban fire departments were more likely to have the mandated annual testing. Unfortunately, this association was not found when other response areas were compared nor was there a trend found regarding response area size. Of note similar to the firefighter level differences found regarding annual medical fitness testing, the unique responses other than annual medical fitness or fit testing were not necessarily associated with non-compliance thus reducing the strength of association these findings have with respiratory protection program compliance.

Being evaluated by an occupational medicine physician was associated with a 50,000-100,000 square miles response area as compared to that of less than 10,000 square miles. Similarly this is difficult to interpret as a response area of greater than 250,000 square miles is most clearly associated with rural fire departments. At the same time medical fitness testing by an individual other than an occupational medicine physician suggests but is not necessarily consistent with NFPA guideline non-compliance. The guidelines state that the fire department physician will make determination of medical certification with a medical evaluation which includes a medical examination. Medical examination is defined as an "examination performed or directed by the fire department physician." Being a fire department physician is not specific to occupational medicine physicians and a non-physicians clinician working under the direction of the fire department physicians would satisfy this definition of a medical examination.

There was a great amount of variability among the different modalities for annual fit testing. Small urban fire departments were associated with using all modalities as compared to large rural fire departments. When different specific modality combinations were evaluated, small urban fire departments were also associated with physical examination and spirometry testing. These findings are consistent with prior research suggesting that urban departments have more resources and thus can perform the full complement of modalities and have access to the more advanced equipment required for spirometry and medical assessment beyond medical questionnaire.[3] Career firefighters were associated with the modality of spirometry testing and the modality of questionnaire with follow up physical examination for medical fitness assessment. This is also consistent with prior research suggesting that career type fire department have more resources as compared to volunteer type fire departments.[3]

Limitations

There were some significant limitations of the study. The fact that all the survey data came from respondent firefighter self-reporting increased the potential for misclassification. This misclassification could result from lack of understanding related to the survey questions, fear of being perceived negatively for non-compliance, and lack of knowledge which respondents reported in the questions regarding the written respiratory program, specific program standards, and type of respirator used. It is also important to note that many questions had multiple responses regarding respiratory compliance which split the data. This made it more challenging to detect differences as compared to dichotomous responses with less nuanced answer choices.

Additionally the homogeneity of the data regarding firefighter and fire department demographics limited the ability to find significant differences between those groups.

CONCLUSIONS

Overall Florida fire departments are doing a good job of implementing their respiratory protection programs. Even so there are firefighters who are potentially inadequately protected against the occupational hazard of smoke inhalation. Additional attention needs to be given to Florida fire departments to ensure that all firefighters receive adequate respiratory protection in accordance with both Occupational Safety and Health Administration and National Fire Protection Association guidelines. The study finding that urban fire departments do a better job of being in compliance with the guidelines as compared to rural departments is consistent with prior research regarding fire department compliance. Additional research should focus on why these differences exist in the rural fire departments. The differences are likely not related to funding as no respondents cited this as a reason for not having a written respiratory protection program. More effective training and overall program robustness likely plays a key role in the differences found as many respondents stated or demonstrated a lack of knowledge regarding respiratory protection program requirements. Future research efforts should focus on fire department respiratory protection education and training.

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