Comprehensive Mitigation Strategies to Reduce the Prevalence of Cancer in the Fire Service

Harris R. Bouchillon

University of Florida

Honors Research Paper

Dr. Jeffrey Lindsey & Dr. Christopher Reynolds

Abstract

Firefighting has always been and continues to be an inherently dangerous profession. The risks firefighters face from acute and potentially life-threatening injuries are well known. From the advent of the organized fire service in colonial America, many of these risks that firefighters have faced have ultimately served as the catalysts for advancements in firefighter safety. The evolution of protective clothing from wool jackets and pants, to the multiple layered thermal and moisture barriers worn today has allowed firefighters to conduct interior firefighting operations in a safer manner than ever before, reducing the overall risk of thermal injury. The implementation of the self-contained breathing apparatus has drastically decreased the risks firefighters face from inhalation injuries and exposure to toxic gases and asbestos. While many of the risks firefighters have historically faced have been mitigated or reduced by the evolution of firefighting technologies, firefighters still continue to face significant and potentially lethal risks. Despite advancements in thermal and respiratory protection, the most prevalent risk firefighters now face throughout the fire service industry is cancer. Utilizing an applied, quantitative research methodology, this paper provides an analysis of cancer prevalence within the modern fire service. This paper also examines the components of a comprehensive mitigation strategy fire departments can implement to reduce or eliminate the industry-related development of cancer among firefighters.

Keywords: firefighting, firefighter cancer, cancer prevalence

Comprehensive Mitigation Strategies to Reduce the Prevalence of Cancer in the Fire Service

Firefighting is an inherently dangerous job. Technological advancements over the past several decades have resulted in vast improvements in firefighter personal protective gear, allowing firefighters the highest degree of thermal protection to date. Advancements in fire apparatus have increased the availability of sufficient water, and self-contained breathing apparatus allow firefighters to enter and remain in environments that are immediately dangerous to life and health, so that victim rescues can be performed effectively and efficiently. Despite these advancements, the risks firefighters face are still present; these risks, however, have changed.

In 2014, the National Fire Protection Association reported that approximately 56% of firefighter line-of-duty deaths were the result of sudden cardiac death; 14% died of asphyxiation or smoke inhalation, and only 3% died of thermal injuries (Firefighter Cancer Support Network, 2018). Over the course of the past decade, various scientific research efforts began identifying a relationship between cancer and firefighting; firefighters were experiencing an alarming increase in cancer diagnoses when compared to the general population. This growing risk was validated again in 2017 when the International Association of Fire Fighters reported that cancer had surpassed sudden cardiac death as the leading cause of death among firefighters. (Costello, 2017).

The body of evidence available that has bridged the assoication between cancer and firefighting warrants not only thorough examination, but action. Through an analysis of data representative of the cancer prevalence within the fire service, the variety of carcinogenic risks firefighters regularly encounter can be identified. Once these risks are identified, a comprehensive mitigation strategy can be implemented to reduce the risks of cancer firefighters now face.

Cancer Prevalence Within the Fire Service

In May, 2013, a report for the President's Cancer Panel (a three member panel that reports to the United States President on the National Cancer Program) stated that approximately 41% of Americans will be diagnosed with some form of cancer during their lifetime (Firefighter Cancer Support Network, 2013). Several decades ago, the survival rate for cancer was only 43% and cancer treatments themselves caused significant illness (Firefighter Cancer Support Network, 2013). At present, the five-year survival rate for all cancers has increased to 67% and more precise treatments have lessened the impacts resulting from cancer treatments. While the cancer prevalence among the general population is statistically significant, research has shown that firefighters face an even higher relative rate of cancer.

2006 Meta-Analysis Study

In 2006, researchers at the University of Cincinnati published a meta-analysis of 32 different studies that focused on a variety of cancers among firefighters (Firefighter Cancer Support Network, 2013). This analysis indicated that firefighters experience a significantly increased risk for developing a variety of cancers. This study, in part, prompted the World Health Organization's International Agency for Research on Cancer Working Group to classify firefighting as "possibly carcinogenic to humans", and called for additional research efforts to more clearly identify the cancer risks experienced by firefighters (Firefighter Cancer Support Network, 2013).

2013 NIOSH Study

In October, 2010, the National Institute for Occupational Safety and Health (NIOSH) embarked on a major retrospective study of cancer among firefighters. This study involved the collection of data from approximately 30,000 firefighters in three metropolitan fire departments: Chicago, Philadelphia and San Francisco (National Institute for Occupational Safety and Health, 2013). The results of this study were released on October 14, 2003, and the findings, representative of a larger population, for a longer duration, than many previous studies, strengthened the scientific credibility of the evidence indicating elevated cancer rates among firefighters (National Institute for Occupational Safety and Health, 2013). The NIOSH study (2013) found that respiratory, digestive and urinary cancers accounted mostly for the higher rates of cancer found within the firefighter study population; these higher rates suggest that firefighters are more prone to developing these types of cancers. The NIOSH study (2013) also found that the firefighter study population experienced a rate of mesothelioma two times greater than the general population; this elevated rate is likely due to exposures to asbestos.

These, and other, studies have repeatedly resulted in credible, scientific evidence that demonstrates a relationship between cancer and firefighters that exists in a greater degree than among the general population. These elevated cancer rates include: a 2.02 times greater risk of testicular cancer; a 1.53 times greater risk of developing multiple myeloma; a 1.51 times greater risk of developing non-Hodgkin's lymphoma; a 1.39 times greater risk of developing skin cancer; a 1.28 times greater risk of developing prostate cancer; a 1.31 times greater risk of developing malignant melanoma; a 1.31 times greater risk of developing brain cancer; a 1.21 times greater risk of developing colon cancer; and a 1.14 times greater risk of developing leukemia (Firefighter Cancer Support Network, 2013). A recent study of women in the San Francisco Fire Department has shown a rate of breast cancer among female firefighters that is six times the national average within the general population (Costello, San Francisco Fire Department Sees Spike in Breast Cancer Rate, 2018).

Exposure Potential of Contaminated Firefighter Hoods

Firefighter hoods are utilized as a personal protective equipment (PPE) component to prevent dermal exposure to flames and heat (Solle, 2017). The underlying skin of the jaw angle, neck, forehead and scalp is highly permeable (Solle, 2017). This permeability increases with temperature and for every 5 degree increase in skin temperature, the skin's absorption potential increases 400% (Firefighter Cancer Support Network, 2013). While hoods are designed to provide dermal protection from flames and heat, these items are not generally designed to prevent particulate intrusion and subsequent skin absorption (Firefighter Cancer Support Network, 2013). Firefighter hoods frequently become contaminated during fire events and, if not cleaned in a timely manner subsequent to exposure to contaminants, can continue to serve as an exposure source for firefighters whenever they are worn, donned, or doffed (whether during live fire events or training) (Solle, 2017).

Broward County Firefighter Hood Study

In 2016, the Broward County Sheriff's Office Department of Fire Rescue and Emergency Services provided a number of used, soiled firefighter hoods to several different laboratories for the evaluation of potential contaminants. At the time of this study, there were no standardized methods of analysis of these items. Based upon the absence of such standards, procedures were adapted from the United States Environmental Protection Agency's (EPA) methods utilized to analyze environmental contaminants in soil and other solids; these methods were applied to this evaluation of firefighter hoods (International Personal Protection, 2016). The results of these analyses identified a number of chemicals and compounds found in the firefighter hoods and included a variety of heavy metals, hydrocarbons, and different persistent organic compounds that are known carcinogens or skin-toxic chemicals including phenol, bis (ethylhexyl) phthalate, and phenanthrene (International Personal Protection, 2016).

Study Methodology. The Broward Sheriff's Office Department of Fire Rescue and Emergency Services provided several, used/soiled firefighter protective hoods to International Personnel Protection, Inc. New firefighter protective hoods were also provided to serve as the control samples for comparing substances found within the soiled hoods (International Personal Protection, 2016). A variety of conventional and other sampling methods were utilized to identify the presence of metals, volatile organic compounds (VOCs), semi-volatile organic compounds (SVOCs) and total petrochemical hydrocarbons (TPH) (International Personal Protection, 2016).

Study Findings. There were several metals found in abundance within the soiled hoods that were not significantly present in the control samples; these include: aluminum, barium, copper, iron, lead and zinc (International Personal Protection, 2016). Few volatile organic compounds were found in both the control and soiled hoods; however, it is believed that most of the VOCs would evaporate from the hoods over time (International Personal Protection, 2016). Analyses for semi-volatile organic chemicals revealed the presence of phthalates, phenol and phenanthrene (a polycyclic aromatic hydrocarbon) (International Personal Protection, 2016). Additionally, DEHP (Bis (2-ethylhexl) phthalate), a confirmed human carcinogen, was present on the soiled hood samples, which is one of the more commonly identified environmental phthalate contaminants found in turnout clothing (International Personal Protection, 2016).Total Petrochemical Hydrocarbon (TPH) is a method of identifying the presence of hydrocarbons in the C6 to C35 range and is intended for quantifying levels of hydrocarbon mixtures (such as oils, greases, lubricants and other petrochemical products) that can be common contaminants of personal protective equipment (International Personal Protection, 2016). This study found elevated TPH levels in the soiled firefighter hoods when compared to the control hoods (International Personal Protection, 2016).

Studies from all of the involved laboratories revealed that these chemicals were found at low levels; however, their presence suggests that firefighters who wear unclean, fire-exposed hoods may face continuing exposure to hazardous substances. The contaminants that were present in the soiled firefighter hood samples include known skin-toxic and carcinogenic compounds. Such chronic exposure to known and potentially carcinogenic compounds may serve as a contributing factor to the elevated incidence of certain cancers among firefighters as compared to the general population (International Personal Protection, 2016).

Exposure Potential of Firefighter Thermal Protection

During the course of fire suppression activities, firefighters are exposed to the products of combustion present within the incident environment. These chemicals and compounds can include hydrogen cyanide, hydrogen chloride, asbestos, benzene, hydrogen sulfide, styrene, chlorine, formaldehyde, phosgene, chloroform, arcrolein, hydrochloric acid, hydrogen fluoride and others (Firefighter Cancer Support Network, 2018). Many of these chemicals have been classified as known carcinogens and have specifically been linked to a variety of cancers. Exposure to benzene has been scientifically linked to bladder cancer (Firefighter Cancer Support Network, 2018). Formaldehyde, benzene, vinyl chloride and acrylonitrile exposures have been linked to brain cancer (Firefighter Cancer Support Network, 2018). Asbestos has been linked to lung, colon and larynx cancer (Firefighter Cancer Support Network, 2018). Benzene, soot, formaldehyde, and polycyclic aromatic hydrocarbons (PAH) have been linked to leukemia (Firefighter Cancer Support Network, 2018). And other chemicals found within the fire environment have been linked with other forms of cancer, including lymphatic and hematopoietic cancers, lung cancers, soft tissue sarcomas, skin cancers, and pharynx cancers (Firefighter Cancer Support Network, 2018). These chemicals can be found contained within and carried by smoke particles produced through the combustion process.

For many years, the personal protective equipment firefighters utilized were primarily designed to protect the firefighter from thermal exposure and injury. Recent studies have shown that while these garments provided thermal protection to firefighters, the minute particles contained within smoke easily penetrated into the protective ensembles (Stull & Stull, 2015). The unburned carbon that largely comprises these particles also carries with them the toxic gases from the combustion process (Stull & Stull, 2015).

In January, 2015, the International Association of Fire Fighters commissioned a study regarding the exposure potential of firefighting protective ensembles. This testing was conducted at the Research Triangle Institute and utilized test subjects wearing firefighting personal protective equipment in a particle-laden chamber (Stull & Stull, 2015). The results of this study were significant. The subjects were found to have a large amount of exposure to the face and neck area (the area not protected by the self-contained breathing apparatus face piece), to the calves and thighs of both legs, to the chest (behind the coat front closure), to the coat and pant interface, and to the coat and glove interface (Stull & Stull, 2015). This study confirmed that despite the utilization of firefighting personal protective equipment, firefighters are still vulnerable to exposure from smoke and the carcinogenic components contained within smoke particulate.

Carcinogenic Exposure Potential at Fire Station Facilities

Much of the research regarding cancer prevalence within the fire service has been focused on the exposures firefighters encounter while fighting fires; however, potential carcinogenic exposures at the fire station are also cause for concern. In 2016, a pilot study was conducted at several fire stations within and around Boston, Massachusetts, to examine the air quality and to investigate what factors may influence the levels of contaminants found within these fire stations (Sparer, et al., 2017). Firefighters can spend a majority of their shift within their fire stations performing indoor and outdoor training and maintenance activities, administrative duties, sleeping, eating and performing other activities. During these activities firefighters may be exposed to diesel exhaust from idling apparatus, a known carcinogen (Sparer, et al., 2017). Additionally, gear and equipment utilized during fireground operations may off-gas contaminants that contain known and/or suspected carcinogens (Sparer, et al., 2017).

Previous studies regarding this potential source of exposure have been conducted in the past; however, these studies were limited and only utilized qualitative methods, dust samples, or fire apparatus run data and building design characteristics to assess the exposure risks (Sparer, et al., 2017). Additionally, several recent studies that examined the levels of polycyclic aromatic hydrocarbons within and around fire stations involved air quality sampling lasting 4 to 8 hours (Sparer, et al., 2017). These sampling periods do not accurately capture the prolonged potential exposure period many firefighters who serve 24 hour shift assignments may be subject to.

Study Methodologies

The 2016 study compared the levels of certain contaminants with known associations to diesel exhaust both within the fire apparatus bay and the outside. This study also measured the levels of these contaminants within the kitchens of older and newer fire station facilities to determine what, if any, impact newer construction had on exposure levels. Additionally, this study examined organizational policies and practices among fire stations to determine what, if any, impact such policies and practices had on the levels of contaminants within the air.

Fire Station Selection Methodology. Four fire stations were selected that provided diversity in the dates of construction, the neighborhoods which surrounded them, and the average number of emergency responses per shift. The dates of construction included fire stations build in 1948, 1959, 1974 and 2007 (Sparer, et al., 2017). Three of the fire stations were located within urban areas of Boston; one fire station was located in a residential neighborhood, one was located near a bus terminal, and one was located near a commercial area (Sparer, et al., 2017). The remaining fire station was located in a suburban residential area (Sparer, et al., 2017). Three of the fire stations studied house one ladder company and one engine company; the fourth fire station housed only an engine company. The call volumes for these selected fire stations ranged from 5-7 calls per shift, 12-14 calls per shift for each company, 8-10 calls per shift for each company and 40 calls per shift for each company (Sparer, et al., 2017).

Air Sampling Methods. Diesel exhaust is comprised of two primary components: gases and soot (American Cancer Society, 2015). The gas portion of diesel exhaust is comprised of carbon dioxide, carbon monoxide, nitric oxide, nitrogen dioxide, sulfur oxides, and hydrocarbons (including polycyclic aromatic hydrocarbons) (American Cancer Society, 2015). The particulate portion of diesel exhaust is comprised of carbon, organic materials (including polycyclic aromatic hydrocarbons) and traces of metallic compounds (American Cancer Society, 2015). The International Agency for Research on Cancer has classified many of these chemicals into categories that correspond to their carcinogenic properties. Many polycyclic aromatic hydrocarbons have been classified as *carcinogenic to humans (Group 1)*, while others have been classified as *probably carcinogenic to humans (Group 2A)* and others have been designated as *possibly carcinogenic to humans (Group 2B)* (Sparer, et al., 2017). Particulate matter from outdoor air pollution (including $PM_{2.5}$) has been classified as *carcinogenic to humans (Group 1)* (Sparer, et al., 2017).

Air sampling included integrated and continuous measurements of particulate matter ($PM_{2.5}$) and continuous measurements of particle-bound polycyclic aromatic hydrocarbons (PAHs) in three primary areas in and around the fire station; these included the fire apparatus bay area, the fire station kitchen area, and the outside (Sparer, et al., 2017). Particulate matter and particle-bound polycyclic hydrocarbons were selected as potential exposures of interest as these served as viable proxies for diesel exhaust and other potential exposures from off-gassing of equipment, cooking, etc.

Qualitative Methods. In addition to the quantitative analysis of airborne contaminants, interviews were conducted with officers at each of the four fire stations. These interviews focused on the daily activities of the firefighters, and the policies and practices regarding apparatus engine idle-time, washing of contaminated clothing post-fire incident, and any other fire station related health and safety activities (Sparer, et al., 2017). A total of seven interviews were conducted, and all involved the fire station Lieutenant.

Study Findings

Measured levels of PAH and $PM_{2.5}$ were observed at each location and varied throughout the day. Levels of PAH and $PM_{2.5}$ varied from minute to minute inside of the fire stations; this may be related to station activities, including the idling of fire apparatus, entering/leaving the fire station, cooking, etc. (Sparer, et al., 2017). Exterior PAH and $PM_{2.5}$ levels also varied throughout the day which may be related to changes in weather or local neighborhood activities (Sparer, et al., 2017). Levels of $PM_{2.5}$ and PAH concentrations were higher in the fire apparatus bays than the outside, suggesting that the fire apparatus may be significant sources of indoor and outdoor air contaminants (Sparer, et al., 2017). There were noticeably lower levels of PAHs in the interior of the newest fire station (20% less than the two older fire stations) (Sparer, et al., 2017). This reduction is credited to the absence of pole holes which the other fire stations possessed. It is difficult to fully assess the observed levels of PAHs and $PM_{2.5}$ given that many occupational exposure limitation guidelines are designed around an 8 hour work day / exposure period. Further research regarding prolonged exposure timeframes, as exist with a firefighter's 24 hour shift, are needed.

Two primary areas of practice emerged from the qualitative interviews: the washing of bunker gear subsequent to firefighting, and the use of systems designed to ventilate vehicle exhaust at the fire stations (Sparer, et al., 2017). The fire stations involved in this study each had direct-capture vehicle exhaust extractor systems in place. Existing policies required the firefighters to connect the exhaust extractor duct to the vehicles as the vehicles were backing into the apparatus bay; however, the actual practice of this policy differed among the studied fire stations and their personnel (Sparer, et al., 2017). The timely washing of bunker gear following firefighting was also inconsistently applied among the studied fire stations and their personnel. Those fire stations with commercial grade washers were generally more compliant with the immediate washing of contaminated bunker gear. The fire stations that did not have commercial grade washers were required to send contaminated bunker gear to headquarters, which was reported to be a slow process (Sparer, et al., 2017). This delay can be credited for the lack of compliance with the policy directing the timely washing of contaminated bunker gear.

Comprehensive Cancer Mitigation Considerations

The data collected over the past decade suggests that firefighters face increased exposure potential to a variety of carcinogens when compared to the general population. These carcinogens can be found within the fire stations, within the fire apparatus, on the fireground, and contained within contaminated clothing and equipment subsequent to fireground exposure. Given the variety of potential carcinogenic sources firefighters can be exposed to, a comprehensive cancer mitigation effort must consider these sources and reduce or eliminate the exposure potentials that currently exist. Some mitigation efforts may be cost-restrictive or cost-prohibitive for some fire departments; however, fire departments should implement the immediate changes that are feasible, and conduct the necessary planning to implement the remaining strategies over a defined timeframe. Every potential source of carcinogenic exposure that is eliminated through mitigation efforts can reduce the cancer prevalence within the fire service. Through an analysis of potential mitigation components, fire departments can identify those that are currently feasible, and begin to improve the firefighters' resilience to the risk of cancer.

Overhaul Protection Measures

The dangers of suppression efforts involving the initial fire are well known to firefighters; however, after the main body of fire is extinguished a variety of dangers still exist. Firefighters are trained to utilize their self-contained breathing apparatus (SCBSA) when engaged in firefighting activities to protect themselves from thermal inhalation injuries and to afford themselves with improved visibility. Once the threat of thermal exposure is mitigated and visibility has improved, firefighters may disregard the ongoing safety their self-contained breathing apparatus can afford them. During overhaul operations, incomplete products of combustion (including poisonous gasses) remain within the environment. It is in this environment which many firefighters remove their self-contained breathing apparatus, unaware of or minimizing the exposure dangers that are still present. For some firefighters, overhaul may not be considered within the "operational" phase of the incident, thereby negating the need for the respiratory protection of a SCBA.

In 2000, the Phoenix Fire Department and the University of Arizona conducted a study regarding the chemical hazards present during firefighting overhaul (Herbert, 2008). This study, *Characterization of Firefighter Exposures During Overhaul*, by Dawn Bolstad-Johnson, et al, involved air monitoring in 25 separate post-fire structures during overhaul operations by firefighters (Herbert, 2008). This study "demonstrated that maximum concentrations of contaminants in the overhaul atmosphere exceeded occupational exposure limits and could therefore result in adverse health effects in firefighters without respiratory protection. In a variable number of fires, concentrations of acrolein, carbon monoxide, formaldehyde, and glutaraldehyde exceeded their respective ceiling values; concentrations of sulfur dioxide exceeded the STEL value; and concentrations of coal tar pitch volatiles (PNAs) exceeded the OSHA PEL, ACGIH TLV, and NIOSH REL" (Herbert, 2008). One limitation of this study involved the delay in researchers obtaining air monitoring samples when overhaul operations began, so actual values and concentrations are assumed to be higher than recorded (Herbert, 2008).

In 2001, toxicologist Jeffery Burgess, et al, published a study entitled *Adverse Respiratory Effects Following Overhaul in Firefighters* that utilized a different methodology than the Bolstad-Johnson, et al, study (Herbert, 2008). As opposed to measuring levels of toxic and carcinogenic gases present within the overhaul environment, the Burgess, et al, study involved researchers obtaining spirometric measurements and measured serum pneumoproteins in the blood of firefighters after they performed overhaul operations (Herbert, 2008). Two groups of firefighters were utilized in this study: Tucson, Arizona, firefighters (who did not utilize any respiratory protection), and Phoenix firefighters (who utilized cartridge respirators) (Herbert, 2008). This study indicated that cartridge respirators did not sufficiently protect firefighters from the inhalation hazards found within the overhaul environment. The serum pneumoproteins in both groups of firefighters indicated that they were exposed to carboxyhemoglobin, acetaldehyde, formaldehyde, sulfur dioxide, sulfuric acid and respiratory dust (Herbert, 2008). The study noted that, "these findings provide strong evidence that the current practice of removing SCBA prior to overhaul may result in exposure to respiratory toxicants and subsequent adverse health effects" (Herbert, 2008).

In addition to the carcinogenic and toxic gases that are present in the overhaul environment, other toxic materials also exist. The inhalation of asbestos fibers, exposure to lead from paint and respirable dust also serve as potential sources of toxic exposure to firefighters who lack the use of SCBA (Herbert, 2008). Based upon the potential health consequences exposure to these chemicals and gasses pose, it is essential for fire departments to codify their requirements for firefighters to fully utilize their self-contained breathing apparatus during overhaul operations.

Personal Protective Equipment Cleaning and Personal Hygiene

Within the current generation of firefighters, there are those that recall when “dirty” personal protective equipment was symbolic of experience, and considered a “badge of honor”. Studies have shown that the carcinogenic chemicals firefighters are exposed to within the fireground can become entrapped within the firefighters’ protective ensembles (Stull & Stull, 2014). While many of these toxic chemicals are volatile and dissipate over time, those that are carried on the carbon particles contained within soot can be held in place on the firefighter’s personal protective equipment and skin. These chemicals then serve as potential sources of acute and chronic exposure, making firefighters more vulnerable to the hazards initially thought present only on the fireground (Stull & Stull, 2014).

The replacement cycle for firefighting personal protective equipment (jacket and pants) is long, and the average firefighting protective ensemble can be exposed to repeated and regular contamination during its lifecycle (Magnusson & Hultman, 2014). Other personal protective equipment components, such as the helmet and gloves, also have surface layers that are prone to contamination to the same extent as the firefighting jacket and pants (Magnusson & Hultman, 2014). Despite this similarity, helmets and gloves are even less likely to undergo timely or regular decontamination (Magnusson & Hultman, 2014). Firefighting boots are often designed with a deep tread to increase traction on different surfaces. This design enhances the potential for dirt and contaminated waste from the fireground to be spread onto different surfaces, including the firefighter’s fire apparatus and fire station. Finally, the firefighter’s self-contained breathing apparatus (SCBA) can serve as a source of latent contamination and subsequent exposure. SCBA straps and harnesses can contain materials that absorb the contaminated carbon particles found within the fireground environment. Thorough cleaning of the self-contained breathing apparatus subsequent to fireground use can be laborious and time consuming, thereby making the SCBA less likely to undergo timely and regular decontamination (Magnusson & Hultman, 2014).

Firefighters who are potentially exposed during fireground operations should undergo a gross decontamination process prior to departing the fireground (Stull & Stull, 2014). This decontamination process can involve the use of soap and a light application of water to scrub off the exterior of a firefighter's personal protective equipment while still being worn by the firefighter. In addition to decontamination of this equipment, firefighters should also perform a gross decontamination of their skin by utilizing wet wipes to remove soot (and other contaminants) from the head, neck, jaw, throat, underarms and hands (Stull & Stull, 2014). If possible, firefighter personal protective equipment should be stored in an exterior apparatus compartment.

Once firefighters return to the fire station, it is imperative that all potentially contaminated firefighting personal protective equipment undergo complete decontamination. Utilization of secondary sets of personal protective equipment can allow for this process to occur. Other equipment utilized on the fireground, including SCBA assemblies, should also undergo a complete cleaning to remove any latent contaminants. In addition, the underlayer of clothing and uniform items worn by firefighters should be thoroughly washed and firefighters should change into a clean set of uniforms (Stull & Stull, 2014). It is imperative for firefighters to shower immediately after returning to the fire station, and to keep all potentially contaminated equipment, clothing and other items out of the fire station's living and sleeping areas (Stull & Stull, 2014). Contaminated clothing or other contaminated items should not be taken home or stored in a vehicle (Stull & Stull, 2014).

Fire Apparatus Contamination and Exhaust Control Measures

Fire apparatus can serve as potential sources of contamination, both internally and externally. Firefighters returning from the fireground can contaminate fire apparatus through placement of contaminated equipment, clothing and other items into the interior of the apparatus. Firefighters can then come into repeated contact with these interior surfaces during subsequent responses, training, and routine utilization of the apparatus (Magnusson & Hultman, 2014). In order to prevent the contamination of the fire apparatus interior, there are several actions fire departments and firefighters can take.

Keeping a spare set of clothes/uniforms on the apparatus for each firefighter can ensure that following gross decontamination, firefighters can remove their potentially contaminated uniforms and undergarments, store these items in an airtight container on the fire apparatus, and don a clean set of clothes for return to the fire station (Magnusson & Hultman, 2014). Contaminated personal protective equipment (including SCBAs) should also be housed in an airtight container after undergoing gross decontamination to minimize off-gassing and secondary contamination of the fire apparatus interior. The goal of this and the aforementioned decontamination efforts is to ensure that firefighters' return transportation is conducted in a clean environment (Magnusson & Hultman, 2014).

Externally, fire apparatus can serve as potential sources of contamination through exposure to diesel exhaust. In August, 1988, the Centers for Disease Control and Prevention released a document, *Carcinogenic Effects of Exposure to Diesel Exhaust*, which asserted that animal research had confirmed the carcinogenicity of whole diesel exhaust and that diesel exhaust should be regarded as a potential occupational carcinogen (Avsec, 2012). In the following decades, research has proven the link between diesel exhaust and cancer, as well as other respiratory illnesses, such as asthma (Avsec, 2012).

Fire stations should be equipped with an apparatus exhaust removal system to minimize the potential exposure to diesel exhaust. There are a variety of exhaust removal systems; these include: a hose-based, direct source capture system; a vehicle mounted, direct source capture system; and buildings space filtration systems (Avsec, 2012). Each type of system varies in cost and suitability depending on the design of the fire station and the type and age of the fire apparatus being utilized. Regardless of type, a vehicle exhaust removal system is a critical component in maintaining a fire station environment (including apparatus bays and interior living quarters) that is free from the particulates and gasses present within apparatus diesel exhaust (Avsec, 2012).

Annual Employee Physicals

A survey conducted by the International Association of Fire Chiefs (IAFC) found that 80% of career firefighters and 45% of volunteer firefighters receive annual physicals (International Association of Fire Chiefs, 2016). Studies have identified a relationship between firefighters and certain illness and diseases, including elevated risks of cardiovascular disease, certain forms of cancer, musculoskeletal injuries, behavioral health disorders, sleep disorders and infectious disases (International Association of Fire Chiefs, 2016). As such, yearly physical examinations are beneficial in allowing for early detection and treatment of these medical conditions and provide firefighters the highest degree of value if they are tailored to assess and identify those illnesses and diseases more prevalent among firefighters.

In 2016, the International Association of Fire Chiefs released *A Healthcare Provider's Guide to Firefighter Physicals*. The purpose of this guide is to assist healthcare providers in their evaluation and treatment of firefighters. This guideline was created to align with the National Fire Protection Association's *Standard on Comprehensive Occupational Medicine Program for Fire Departments (NFPA 1582)* (International Association of Fire Chiefs, 2016).

Broward Sheriff's Office Fire Rescue Annual Physical Implementation. Despite the data reflective of the prevalence of certain illnesses and diseases among firefighters, many fire departments still do not provide or require an annual physical evaluation for firefighter personnel. Several factors may contribute to the absence of such wellness programs; these can include the costs associated with implementing annual firefighter physicals, as well as labor union reluctance to potentially exposing members to the financial impacts of mandated disability consequences. Prior to 2014, the Broward Sheriff's Office Department of Fire Rescue and Emergency Services lacked a mandatory annual physical examination for firefighters.

In partnership with the International Association of Fire Fighters Local 4321, the Broward Sheriff's Office implemented mandatory annual physical examinations for all firefighters. Funding for this effort was obtained through financial grants and was eventually included within the annual operating budget. Physical examinations were tailored to the health and wellness risks faced by firefighters, and the results of each firefighter's examination remained confidential between the healthcare provider (LifeScan) and the employee. In the event that an employee learned of a signficant healthcare issue, it was incumbent upon the employee to initiate the workers compensation process and notify the Department.

During the first year of implementation, 634 firefighters from the Broward Sheriff's Office participated in the physical examination process administered by LifeScan (Broward Sheriff's Office, 2015). Of those evaluated, a variety of significant early detection findings were identified. These findings were later nde-identified and provided to the Broward Sheriff's Office for review. Findings specific to heart and arterial diseases included: 37 firefighters with left ventricular hypertrophy; 2 firefighters with cardiac valve insufficiency; 5 firefighters with severe carotid artery blockages; 60 firefighters with undiagnosed or uncontrolled hypertension; 8 firefighters with abnormal stress test findings; and 7 firefighters with abnormal EKGs (Broward

Sheriff's Office, 2015). With regards to pulmonary and respiratory findings, 1 firefighter was found with significantly decreased results on his/her pulmonary function test (less than 70%).

In addition to cardio-respiratory abnormalities, a variety of organ disease and potentially cancerous findings were also identified; these included: 18 firefighters with undiagnosed or uncontrolled diabetes; 22 firefighters with kidney abnormalities; 55 firefighters with liver abnormalities; 1 firefighter with a pancreatic abnormality; 8 firefighters with enlarged spleens; 2 firefighters with splenic masses; 20 firefighters with gallbladder polyps; 1 firefighter with an ovarian cyst; 3 firefighters with uterine abnormalities; 26 firefighters with enlarged prostates; 9 firefighters with prostate masses; 44 firefighters with hypogonadism; 55 firefighters with thyroid nodules (6 confirmed with thyroid cancer); 83 firefighters with currently benign thyroid nodules; and 1 firefighter with a testicular mass (confirmed as cancerous) (Broward Sheriff's Office, 2015). Other significant findings included: 79 firefighters with obesity; 42 firefighters with high cholesterol/triglycerides; 13 firefighters with elevated PSA blood levels; 19 firefighters with abnormal TSH; 11 firefighters with complete blood count (CBC) abnormality; 4 firefighters with significant thrombocytopenia; and 2 firefighters with decreased renal function (Broward Sheriff's Office, 2015).

As evident within the Broward Sheriff’s Office findings, funding and implementing mandatory firefighter wellness physical examinations can identify a variety of potentially significant illnesses and diseases. Early identification of these illnesses and diseases can allow affected firefighters with the opportunity to engage in early and aggressive corrective treatments, reduce firefighter morbidity and reduce firefighter mortality. Annual physical examinations compliant with the IAFC *A Healthcare Provider’s Guide to Firefighter Physicals* guideline are an integral component of any comprehensive cancer mitigation strategy.

Conclusion

Scientific studies continue to provide a growing body of evidence that suggests a causal relationship between firefighting and various forms of cancer. Although fire departments are largely responding to fewer fires than in the past, today's firefighters may experience an increased amount of exposure to carcinogens found within the fire environment due to the limited number of available firefighters that may be found due to budget cuts or staffing reductions (Firefighter Cancer Support Network, 2013). Additionally, modern fires evolve at a more rapid rate and the common products of combustion (increasingly made of synthetic materials) that firefighters encounter produce a host of carcinogenic chemicals. Many states currently lack presumptive illness laws that recognize the relationship between firefighting and cancer; however, this lack of validation should not prohibit or delay fire departments from implementing mitigation strategies that reduce or eliminate the firefighters' exposure to carcinogens. While many mitigation efforts can be cost-restrictive or cost-prohibitive for some fire departments, it is incumbent upon fire department leaders to identify and implement a comprehensive mitigation plan that can systematically reduce or eliminate the sources of potential carcinogenic exposure identified within this report. As with other identified risks firefighters have faced throughout the course of history, the growing risk of cancer now warrants an evolution of personal protective gear and equipment, and progressive policies and practices from fire department and community leaders that incorporate cancer reduction strategies.

References

American Cancer Society. (2015, July 27). *Diesel Exhaust and Cancer*. Retrieved from American Cancer Society Web site: https://www.cancer.org/cancer/cancer-causes/diesel-exhaust-and-cancer.html

Avsec, R. (2012, November 15). *The Choice: 3 Systems to Remove Engine Exhaust*. Retrieved from Fire Rescue 1 Web site: https://www.firerescue1.com/fire-products/vehicle-equipment/exhaust-removal-systems/articles/1368873-The-choice-3-systems-to-remove-engine-exhaust/

Broward Sheriff's Office. (2015). *Broward Sheriff Fire Rescue 2014-2015 Significant Early Detection Findings.* Fort Lauderdale: Broward Sheriff's Offce.

Costello, T. (2017, October 13). *Cancer is the Biggest Killer of America's Firefighters*. Retrieved from NBC News Web site: https://www.nbcnews.com/health/cancer/cancer-biggest-killer-america-s-firefighters-n813411

Costello, T. (2018, February 26). *San Francisco Fire Department Sees Spike in Breast Cancer Rate*. Retrieved from NBC News Web site: https://www.nbcnews.com/health/cancer/san-francisco-fire-department-sees-spike-breast-cancer-rate-n847276

Firefighter Cancer Support Network. (2013, August). *Taking Action Against Cancer in the Fire Service.* Retrieved from Pennsylvania Office of the State Fire Commissioner: http://www.osfc.pa.gov/SiteCollectionDocuments/Cancer%20in%20the%20Fire%20Service%20(Taking%20Action).pdf

Firefighter Cancer Support Network. (2018, March 8). *Chief, What's the Cancer Rate in Your Fire Department?* Retrieved from Firefighter Cancer Support Network Web site: https://firefightercancersupport.org/

Herbert, J. L. (2008, March 1). *Structure Fire Overhaul: Respiratory Hazards and Personal Protective Equipment*. Retrieved from Fire Engineering Web site: http://www.fireengineering.com/articles/print/volume-161/issue-3/features/structure-fire-overhaul-respiratory-hazards-and-personal-protective-equipment.html

International Association of Fire Chiefs. (2016, November 7). *IAFC Releases Guide to Address Gap in Firefighter Physicals*. Retrieved from International Association of Fire Chiefs Web site: http://www.fstaresearch.org/iafc-releases-guide-to-address-gap-in-firefighter-physicals/

International Personal Protection. (2016). *Report on Evaluation of Used, Soiled Sample Firefighter Hoods Provided by Broward Sheriff Fire Rescue & Emegency Services Department.* Austin: International Personal Protection, Inc. .

Magnusson, S., & Hultman, D. (2014). *Healthy Firefighters - the Skelleftea Model Improves the Work Environment.* Karstad: Swedish Civil Contingencies Agency.

National Institute for Occupational Safety and Health. (2013, October 17). *NIOSH Study of Firefighters Finds Increased Rates of Cancer*. Retrieved from Centers for Disease Control and Prevention Web site: https://www.cdc.gov/niosh/updates/upd-10-17-13.html

Solle, N. S. (2017). *South Florida Firefighters and Cancer Prevention.* Miami: University of Miami Miller School of Medicine.

Sparer, E. H., Prendergast, D. P., Apell, J. N., Bartzak, M. R., Wagner, G. R., Adamkiewicz, G., . . . Sorensen, G. (2017). Assessment of Ambient Exposures Firefighters Encounter While at the Fire Station. *Journal of Occupational and Environmental Medicine*, 1017-1023. Retrieved from Journal of Occupational and Environmental Medicine Web site: https://journals.lww.com/joem/Citation/2017/10000/Assessment_of_Ambient_Exposures_Firefighters.14.aspx

Stull, G. G., & Stull, J. O. (2015, April 13). *Firefighter Research Shows PPE Exposure Risk*. Retrieved from Fire Rescue 1 Web site: https://www.firerescue1.com/firefighter-safety/articles/2154096-Firefighter-research-shows-PPE-exposure-risk/

Stull, J. O., & Stull, G. G. (2014, January 18). *8 Ways to Protect Against Cancer with PPE*. Retrieved from Fire Rescue 1 Web site: https://www.firerescue1.com/fire-products/Personal-protective-equipment-ppe/articles/1658839-8-ways-to-protect-against-cancer-with-PPE/