2018
14

Death in the line of duty...

National Institute for Occupational Safety and Health NIOSH

A report from the NIOSH Fire Fighter Fatality Investigation and Prevention Program April 3, 2019

50-Year-Old Firefighter Suffers Fatal Heart Attack After Fighting Two Commercial Fires—Michigan

Executive Summary

On July 29, 2017, at approximately 1456 hours a 50-year-old career firefighter (FF) returned to the station after working a second commercial fire that day. The FF had reported to the first fire in an occupied apartment building in the late morning and performed fire suppression activities (searching for fire and looking for fire extension) and overhaul for one hour and twenty minutes. The second fire was dispatched at 1347 hours and involved a fully involved garage that extended to a vacant apartment building. The FF performed fire suppression activity (opening walls and ceiling) on the first and second floors. The FF and his squad were released from the scene at 1458 hours. Upon returning to the station, the Sergeant noticed that the FF was pale and sweating and was rubbing his upper abdomen/chest area. Upon questioning, the FF admitted that he was nauseous, had a tingling sensation in his arm, and had chest pain. The Sergeant, who is an emergency medical technician (EMT), and fellow firefighters initiated care and called for an ambulance. The paramedics arrived at 1509 hours and while they were assessing the FF, he suffered a cardiac arrest. A shock was administered and cardiopulmonary resuscitation (CPR) was initiated. The FF was loaded into the ambulance for transport to the hospital emergency department (ED). En route to the ED, additional shocks were administered, CPR was maintained, and advanced cardiac life support (ACLS) was provided. Hospital ED personnel, along with fire department (FD) personnel, continued resuscitation efforts unsuccessfully for approximately 30 minutes. The FF was pronounced dead at 1600 hours.

The death certificate and the Medical Examiner's report listed the cause of death as myocardial infarction due to hypertensive and arteriosclerotic cardiovascular disease. The autopsy found moderate atherosclerosis of the right coronary artery and an enlarged heart with thickened ventricles and microscopic changes indicative of hypertensive cardiovascular disease. NIOSH investigators concluded that the physical exertion associated with firefighting activity triggered a myocardial infarction in an individual with underlying cardiovascular disease.

Key Recommendations

NIOSH offers the following recommendations to reduce the risk of heart attacks and sudden cardiac arrest among firefighters at this and other fire departments across the country.

- *Ensure that all firefighters receive an annual medical evaluation consistent with National Fire Protection Association (NFPA) 1582, Standard on Comprehensive Occupational Medical Program for Fire Departments*

50-Year-Old Firefighter Suffers Fatal Heart Attack After Fighting Two Commercial Fires–Michigan

- *Ensure firefighters are cleared for duty by a physician knowledgeable about the physical demands of firefighting, the personal protective equipment (PPE) used by firefighters, and the various components of NFPA 1582*
- *Phase in a mandatory comprehensive wellness and fitness program for firefighters*
- *Wear self-contained breathing apparatus (SCBA) throughout fire suppression activities, including overhaul*
- *Implement formal incident scene rehabilitation with fire suppression activities.*

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Introduction

On July 29, 2017, at approximately 1502 hours a 50-year-old career FF suffered a sudden cardiac arrest at the station following work at a second commercial fire of the day. Fellow firefighters in the station initiated care with the use of oxygen. Paramedics took over care and transported the FF to a nearby ED where he was pronounced dead at 1600 hours. The U.S. Fire Administration notified NIOSH of this fatality on July 29, 2017. The fire department (FD) contacted NIOSH on October 27, 2017, to discuss the possibility of inviting NIOSH to perform an investigation. On July 30, 2018, a contractor for the NIOSH Fire Fighter Fatality Investigation and Prevention Program (the NIOSH investigator) conducted an on-site investigation of the incident.

During the investigation, the NIOSH investigator interviewed the following people:

- Chief of Fire Operations
- Chief of Fire Investigations
- Fire Investigator
- Director of Special Projects
- Sergeant
- Wife of FF

The NIOSH investigator reviewed the following documents:

- FD incident reports for fire calls
- Investigative report
- Witness statements
- Emergency medical service (ambulance) report
- Hospital ED records
- Personal physician records
- Death certificate
- Autopsy report

50-Year-Old Firefighter Suffers Fatal Heart Attack After Fighting Two Commercial Fires–Michigan

Investigation

On July 29, 2017, at about 0730 hours a 50-year-old FF reported to the station to begin his shift, which began at 0800 hours. As usual, he was assigned to a Tactical Mobile Squad (Squad 3). From 0800 hours to 0950 hours, the FF and other members of the squad (4 in total) performed typical daily housework (apparatus and equipment review, mopping, etc.) and outside chores (yard work, trash disposal). The firefighters were then free to attend to personal activities.

At 1003 hours, Squad 3 was dispatched to a commercial box alarm fire. The FF and Squad 3 arrived on the scene as the second squad at 1013 hours to find a working fire in a 3-story apartment complex building. At this point, other fire suppression crews had hose lines stretched and were operating on the roof to ventilate the building. Members of Squad 3 were assigned to gain access to the attic space above the third-floor porch to find fire that had extended into the attic space. The FF and his crew attempted to break through ¾-inch plywood but found it difficult and time-consuming, so they returned to the first floor and then ascended the fully extended (> 100 foot) aerial ladder to gain access to the attic from the roof. Once the fire was extinguished, Squad 3 performed overhaul activities to ensure there was no hidden, smoldering fire. The squad members then assisted three engines to reload their hose lines. It was a warm day (74°F) [Weather Underground no date]. Squad 3 was cleared from the fire scene at approximately 1130 hours and told to stay out of service for one hour to take care of the apparatus and to allow personnel to shower, rest, and recover from the firefighting activities. Firefighters from the squad returned to the station, showered and cleaned up, and then went to the grocery store to shop for groceries for lunch. They returned to the station, prepared lunch, and at approximately 1335 hours, they began their lunch.

At 1339 hours, lunch was interrupted and Squad 3 was dispatched to another box alarm. While en route, they were canceled because the first arriving engine had the fire contained. While returning to the station, the squad noticed a smoke column off the highway. They heard radio traffic indicating that a citizen was reporting a structure fire. Squad 3 was assigned to respond to the fire and was on scene at 1352 hours. Initial suppression crews arrived on scene several minutes before the squad and found a fully engaged two-story structure that was later determined to be a garage. Fire extended to an adjacent vacant apartment building. When the squad arrived, the Sergeant went to assist suppression crews with the garage fire and the FF and the rest of the Squad 3 went into the first floor of the apartment building and used their pike poles to look for fire in the ceiling of an apartment close to the burning garage. First floor conditions were relatively smoke-free and the firefighters operated without wearing their SCBA face mask. Once this assignment was completed, the members of Squad 3 exited the building and were rejoined by their Sergeant. The entire crew ascended the stairs to pull ceiling and expose fire in an upstairs apartment that was involved in fire. The squad worked alongside engine crews to suppress the fire and were wearing full respiratory protection. After the fire was suppressed, the squad did additional overhaul work, including on the garage structure that had burned to the ground. The squad then assisted the engine crews in reloading their hose. The temperature that afternoon was now over 80°F and the crews were hot, tired, and sweaty. Squad 3 was released at 1456 hours and Command told them to stay out of service for 30 minutes to allow the firefighters to rest and recover.

On the way back to the station, the FF was unusually quiet but, at the time, it was assumed that he was just tired.

At the fire station, at approximately 1500 hours, the Sergeant stepped off the rig, put his boots down, and looked up to see the FF behind the Squad rubbing his upper abdomen/chest area. The Sergeant asked if the FF needed some water. The FF replied that he was sick to his stomach, turned around, and went to the bathroom to vomit. When the FF returned a minute or two later, the Sergeant asked if he had any chest pain or tingling in the arm and the FF admitted that he did. The Sergeant summoned other firefighters, requested an ACLS ambulance, notified command, and began patient care. The firefighter was an ashen color and was sweating profusely. He was now complaining of chest pain. Fellow firefighters administered oxygen via a non-rebreather mask and took his vitals. His blood pressure was 170/120 millimeters of mercury (mmHg). The firefighters retrieved the automated external defibrillator (AED) from the station and placed the pads on the FF's chest.

Medic 8 was dispatched at 1503 hours and arrived at the station at 1510 hours to find the FF sitting in the bay of the fire station in the care of his fellow firefighters. The FF was alert and oriented but pale and clammy. His airway was patent and breath sounds were clear bilaterally. His heart rate was 100 beats per minute (bpm), respiratory rate was 20 breaths per minute, and blood pressure was 174/118 mmHg. At 1513 hours, a 3-lead electrocardiogram (ECG) was obtained with difficulty due to an abundance of chest hair and profuse sweating. The ECG revealed runs of ventricular tachycardia. At 1521 hours, the FF became unresponsive. The ECG indicated an ST-elevation myocardial infarction (STEMI). The AED was activated with a command to shock. A shock was administered. The FF was now in asystole. CPR was initiated by members of his squad with oxygen provided by bag-valve mask. The FF was placed on a stretcher and loaded into the ambulance. The FF was not breathing, had no pulse, and remained unresponsive. A King™ Airway was placed, with placement verified by auscultation, and intravenous access was obtained. The ECG revealed ventricular fibrillation. The FF was defibrillated a second time. The cardiac rhythm returned to asystole. The ambulance departed the fire station at 1527 hours and cardiac medications were administered en route to the ED. The ambulance arrived at the ED at 1532 hours.

The FF arrived at the ED unresponsive, with pupils fixed and dilated. He was in asystole and cardiac ultrasound showed no movement compatible with life. The FF was intubated using a GlideScope® and received additional cardiac medications, including amiodarone, and was given thrombolytics. The FF was defibrillated three times in the ED and CPR was maintained throughout care. Despite these efforts, the FF never regained an organized cardiac rhythm or spontaneous circulation. The FF was pronounced dead at 1600 hours.

Medical Findings

The FF suffered a witnessed cardiac arrest and received immediate treatment from fellow firefighters/EMTs at his fire station, was transported by an ACLS ambulance, and underwent continued resuscitation efforts for approximately 30 minutes in the ED. The Medical Examiner's report identified the cause of death as myocardial infarction due to hypertensive and arteriosclerotic

cardiovascular disease. A complete autopsy report was not completed because of organ retrieval for donation.

The FD does not require periodic medical evaluations for members. However, the FF began seeing a primary care physician in March of 2016. At that time the FF had a blood pressure of 130/82 mmHg (normal is < 120/80, elevated systolic blood pressure/prehypertension is 120–129/ < 80, and hypertension is considered ≥ 130 systolic and/or ≥ 80 diastolic) [Whelton et al. 2017]. Blood work ordered at that visit indicated the FF had a high level of total cholesterol (total cholesterol = 282 milligrams per deciliter [mg/dL]; desirable < 200 mg/dL), a high level of "bad" cholesterol (LDL = 159 mg/dL; optimal < 100 mg/dL), a low level of "good" cholesterol (HDL = 30 mg/dL; normal > 40 mg/dL), and blood glucose within the normal range (91 mg/dL; normal fasting < 100 mg/dL) [Kratz et al. 2004; NHLBI 2013].

The FF saw his primary care physician in November of 2016 with a complaint of intermittent respiratory wheezing and the physician ordered several tests. A chest x-ray revealed no acute cardiopulmonary disease. A pulmonary function test with a methacholine challenge was performed. The methacholine test was positive (Forced Expiratory Volume in 1 second [FEV1] decreased by more than 20% following administration of methacholine), indicating respiratory airway disease (asthma). Although the physician indicated a low suspicion for cardiac etiology, he ordered an exercise stress test because of the FF's age and family history of myocardial infarction (his father died of a heart attack at 54 years of age). The FF exercised for 7:25 min using a standard Bruce exercise protocol and achieved 9 METs with a maximum heart rate of 150 beats per minute. The FF had no ischemic ST changes noted during the test. The FF was 70 inches tall and weighed 309 pounds giving him a BMI of 44 (a BMI of 30.0 kilograms per meter squared or greater is considered obese; a BMI of 40 or greater is considered severe obesity) [NHLBI no date]. The FF did not exercise regularly. He was not a smoker. The American Cardiology Association (ACC) Heart Risk calculator indicated that the FF had a 9.7% 10-year risk of heart attack or stroke.

Fire Department

At the time of the NIOSH investigation, the FD consisted of approximately 830 uniformed personnel operating out of 34 fire stations. It serves a population of approximately 714,000 in a geographic area of 143 square miles. The FD responds to approximately 165,000 emergency calls annually. Approximately 80% of the calls are medical and approximately 9,000 are working structure fires.

Employment and Training

Applicants must be at least 18 years of age, possess a valid state driver's license, have a high school diploma or equivalent, and be in good general health. Applicants complete an online application, take a written examination (civil service exam), and must pass a candidate physical ability test (CPAT). The highest ranked candidates then undergo an initial interview. A criminal background check is performed after successful completion of the interview. Successful applicants are then offered conditional employment and must pass a medical evaluation before they are hired. New members attend training

and are probationary firefighters for one year. New firefighters are initially assigned to an engine company, then rotate to a ladder company, and then are assigned as needed throughout the department. The FF had been with the FD for 20 years.

Preplacement, Annual, and Return to Work Medical Evaluations

The FD requires preplacement medical evaluations for applicants. Components of the medical evaluation include the following:

- Complete medical history
- ECG
- Complete blood count
- Urinalysis
- Urine drug screen
- Audiogram
- Vision test
- Respirator use questionnaire
- Spirometry (lung function test)
- Chest x-ray.

The FD does not require annual medical evaluations for all members. However, the FD does require medical evaluation when members are promoted and members of the Hazardous Materials Response Teams (HAZMAT) receive annual medical evaluations. Firefighters complete a respiratory questionnaire that is reviewed by a contract health care provider for annual medical clearance for SCBA use. Firefighters are required to provide medical clearance following a serious injury or illness only if the member is off duty for more than one year.

Wellness/Fitness Programs

The FD does not offer a comprehensive wellness/fitness program or provide exercise equipment in the fire stations.

Discussion

Sudden Cardiac Events

Sudden cardiac events are most often caused by myocardial infarction (heart attack) or cardiac arrest (fatal arrhythmias). In the United States, atherosclerotic coronary heart disease (coronary artery disease) is the most common risk factor for cardiac arrest and sudden cardiac death [Myerburg and Castellanos 2008].

Coronary Artery Disease

Coronary artery disease refers to atherosclerotic plaque in the coronary arteries and the complications of the plaque. The narrowing of the coronary arteries by atherosclerotic plaques occurs over many years, typically decades [Libby 2013]. However, the growth of these plaques probably occurs in a nonlinear, often abrupt fashion. Plaque buildup that restricts blood flow and prevents sufficient oxygen delivery to the myocardium is called ischemia and can cause chest pain (angina), particularly with exertion. Heart attacks or myocardial infarctions typically occur with the sudden development of complete blockage (occlusion) in one or more coronary arteries that have not developed a collateral blood supply. This sudden blockage is primarily due to blood clots (thromboses) forming on top of a ruptured atherosclerotic plaque [Libby 2013]. Heart attacks and sudden cardiac death can be triggered by heavy physical exertion [Albert et al. 2000; Mittleman et al. 1993; Willich et al. 1993], including snow shoveling [Franklin et al. 2001] and firefighting activity, to include alarm response and training [Kales et al. 2003, 2007; NIOSH 2007].

Establishing the occurrence of an acute heart attack requires any of the following: characteristic EKG changes, elevated cardiac enzymes, or coronary artery thrombus/plaque rupture. In this case, the FF was diagnosed with a STEMI based on EKG changes. A complete autopsy was not performed due to organ harvesting but the organ retrieval team reported that the heart had moderate atherosclerosis of the right coronary artery and the heart was enlarged, with thickened ventricles and microscopic changes indicative of hypertensive cardiovascular disease.

Occupational Medical Standards for Structural Firefighters

Nearly half of all firefighter duty-related deaths are caused by sudden cardiac death. Firefighting results in multiple cardiovascular changes that could lead to plaque rupture or arrhythmogenic changes in individuals with underlying cardiovascular disease [Smith et al. 2016]. Research relying on autopsy data suggests that the majority of firefighter duty-related sudden cardiac deaths have atherosclerosis, cardiomegaly/left ventricular hypertrophy, or both [Geibe et al. 2008; Kales et al. 2003; Smith et al. 2018; Yang et al. 2013]. To reduce the risk of sudden cardiac events or other incapacitating conditions among firefighters, the NFPA developed 1582, *Standard on Comprehensive Occupational Medical Program for Fire Departments* [NFPA 2018a]. Regarding cardiovascular disease (CVD) screening for asymptomatic firefighters, NFPA 1582 recommends basing the decision for exercise stress testing on the firefighter's 10-year Heart Risk score (which is based on age, lipids/cholesterol, and other cardiovascular risk factors) [ACC/AHA 2018; NFPA 2018a]. Heart Risk should be calculated each year beginning at age 40, and firefighters whose risk is 10% to < 20% should receive a symptom-limiting EST (with or without imaging) to at least 12 metabolic equivalents (METs) [NFPA 2018a].

The FD did not require medical evaluations for members. The FF had a medical evaluation with his primary care physician in November of 2016 that indicated that he had asthma and low cardiopulmonary fitness (9 METs). NFPA 1582 indicates that asthma interferes with the ability to perform multiple job tasks and that the physician should report these limitations to the fire department unless the member can meet several criteria, including a negative methacholine challenge test [NFPA

2013, 2018]. Asthma can lead to sudden incapacitation from status asthmaticus and/or cardiac ischemia [NFPA 2013, 2018].

NIOSH offers the following recommendations to reduce the risk of heart attacks and sudden cardiac arrest among firefighters at this and other fire departments across the country.

Recommendations

***Recommendation #1: Ensure that all firefighters receive an annual medical evaluation consistent with NFPA 1582,* Standard on Comprehensive Occupational Medical Program for Fire Departments.**

Discussion: Guidance regarding the content and frequency of these medical evaluations can be found in NFPA 1582 [NFPA 2018a]. These evaluations are performed to determine a firefighter's medical ability to perform duties without presenting a significant risk to the safety and health of themselves or others. This medical evaluation should be consistent with the requirements of NFPA 1582.

Recommendation #2: Ensure firefighters are cleared for duty by a physician knowledgeable about the physical demands of firefighting, the PPE used by firefighters, and the various components of NFPA 1582.

Discussion: According to NFPA 1582, the FD should require that physicians are familiar with the physical demands of firefighting and the risks that firefighters encounter and should guide, direct, and advise members with regard to their health, fitness, and suitability for duty [NFPA 2018a]. The physician should review job descriptions and essential job tasks required for all FD positions to understand the physiological and psychological demands of firefighting and the environmental conditions under which firefighters perform, as well as the personal protective equipment they must wear during various types of emergency operations.

Fire service and medical experts developed a tool to assist primary care physicians and other community providers who take care of firefighters away from the FD. The *Healthcare Provider's Guide to Firefighter Physicals* provides information on the physical, environmental, and mental stress of firefighting and the unique occupational health risks firefighters face due to the demands of their job. The guide is a helpful first step to orient primary care providers to firefighter health issues and can be downloaded free from the Firefighter Safety Through Advanced Research (FSTAR) website [IAFC 2017].

Recommendation #3: Phase in a mandatory comprehensive wellness and fitness program for firefighters.

Discussion: Guidance for fire department wellness/fitness programs to reduce risk factors for cardiovascular disease and improve cardiovascular capacity is found in NFPA 1583, *Standard on Health-Related Fitness Programs for Fire Fighters* [NFPA 2015a], and the IAFF/IAFC *Fire Service Joint Labor Management Wellness-Fitness Initiative* [IAFF and IAFC 2018]. Worksite health promotion programs have been shown to be cost effective by increasing productivity, decreasing

absenteeism, and reducing the number of work-related injuries and lost work days [Aldana 2001; Stein et al. 2000]. Health promotion programs for firefighters have been shown to reduce coronary heart disease risk factors and improve fitness levels, with mandatory programs showing the most benefit [Blevins et al. 2006; Dempsey et al. 2002; Womack et al. 2005].

Recommendation #4: Wear SCBA throughout fire suppression activities, including overhaul.

Discussion: NFPA 1500, *Standard on Fire Department Occupational Safety and Health Program,* contains general recommendations for firefighter protective clothing and PPE for structural firefighters [NFPA 2018b]. Chapter 7.10, Respiratory Protection Program, specifies that departments should require SCBA use wherever firefighters could encounter environments that are IDLH (immediately dangerous to life or health) or potentially IDLH, or "where the atmosphere is undefined or hazardous (including overhaul)" [NFPA 2018b].

Products of combustion such as VOCs (volatile organic compounds), PAHs (polycyclic aromatic hydrocarbons), and PM (particulate matter) are released into the air during all structural fires, and some VOCs/PAHs are known or suspected carcinogens (e.g., benzene increases the risk of leukemia) [Baan et al. 2009; IARC 2002]. These contaminants are not detected by 4-gas monitors or other common detection devices, and their levels may not show any relationship to measured gas levels such as carbon monoxide [Bolstad-Johnson et al. 2000]. Particulates are byproducts of fires found in air pollution. According to community studies, exposure to the fine particulate air pollution can trigger sudden cardiovascular events in people with underlying coronary artery disease, and long-term exposure may initiate or advance atherosclerosis [Brook 2008; Lewtas et al. 2007].

NIOSH scientists have studied controlled burns to measure airborne contaminants during knockdown/overhaul phases, as well as biological levels in firefighters' skin, exhaled breath, etc., pre- and post-burns. Results from these studies led NIOSH researchers to recommend the use of SCBA throughout knockdown *as well as throughout overhaul* to minimize the risk of breathing in harmful combustion contaminants [Fent et al. 2014, 2018; NIOSH 2013]. Given that positive-pressure SCBA has the highest protection factor (10,000) of any respirator available [29 CFR 1910.134], use of SCBA should essentially prevent inhalation of PAHs and other harmful combustion byproducts [Bolstad-Johnson et al. 2000].

Recommendation #5: Implement formal incident scene rehabilitation during fire operations.

Discussion: Guidance for fire department incident scene rehabilitation is found in NFPA 1584, *Standard on the Rehabilitation Process for Members During Emergency Operations and Training Exercises* [NFPA 2015b]. Incident scene rehabilitation is an integral component of an occupational safety and health program and is designed to mitigate against the physical, physiological, and emotional stress of firefighting in order to delay the onset of fatigue, improve performance, and decrease the likelihood of on-scene injury or death [NFPA 2015b; Smith et al. 2010]. Incident scene rehabilitation provides for relief from climatic conditions, rest and recovery, cooling (or heating as warranted), rehydration, calorie and electrolyte replacement, and medical monitoring.

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Investigator Information

This incident was investigated by the NIOSH Fire Fighter Fatality Investigation and Prevention Program, Cardiac/Medical Line-of-Duty Death (LODD) Component, within the Division of Surveillance, Hazard Evaluations, and Field Studies, located in Cincinnati, Ohio. Denise L. Smith, PhD, led the investigation and authored the report. Dr. Smith is Tisch Distinguished Professor of Health and Exercise Sciences and Director of the First Responder Health and Safety Laboratory at Skidmore College in Saratoga Springs, New York. She is also a member of the NFPA Technical Committee on Fire Service Occupational Safety and Health. Dr. Smith was working as a contractor with NIOSH during this investigation. Wendi Dick, MD, MSPH, provided medical consultation and contributed to the report. Dr. Dick is the Medical Officer for the Cardiac/Medical LODD Component at NIOSH.

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