2018
05

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 February 12, 2019

44-Year-Old Female Firefighter Suffers Sudden Cardiac Arrest at Station—Georgia

Executive Summary

On March 12, 2018, at approximately 0700 hours a 44-year-old female career firefighter (FF) completed a physical ability test (PAT) at the beginning of her 24-hour shift and then reported to the station and was assigned as the driver of the rescue unit. The FF and her crew responded to a full cardiac arrest late in the morning and then to a motor vehicle accident (MVA) shortly thereafter. Around 1200 hours, the crew returned to the station. Within 5 minutes of returning to the station, the FF complained of burning in her throat and grasped her shirt. As fellow fire department members were assessing the FF, she went into cardiac arrest. Paramedics in the station initiated cardiopulmonary resuscitation (CPR) and delivered two manual shocks. The transport ambulance arrived on scene at 1215 hours and participated in advanced cardiac life support (ACLS). The FF was loaded into the ambulance and resuscitation efforts were continued en route to the hospital emergency department (ED). Hospital ED personnel continued resuscitation efforts unsuccessfully for approximately 20 minutes. The FF was pronounced dead at 1306 hours.

The death certificate and the Medical Examiner's report listed the FF's cause of death as "occlusive coronary artery disease" due to "atherosclerotic cardiovascular disease". The autopsy found complete occlusion of the proximal left anterior descending (LAD) coronary artery. National Institute for Occupational Safety and Health (NIOSH) investigators concluded that the physical exertion of the PAT and emergency responses triggered a myocardial infarction in an individual with underlying cardiovascular disease.

The FF was a non-smoker and was very physically active. She had hypercholesterolemia (high cholesterol) and had begun medication for this within the past 3 months.

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*
- *Ensure firefighters are cleared for duty by a physician knowledgeable about the physical demands of firefighting, the personal protective equipment used by firefighters, and the various components of NFPA 1582*
- *Phase in a mandatory comprehensive wellness and fitness program for firefighters*
- *Continue to perform annual physical performance (physical ability) evaluations.*

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For further information, visit the program website at www.cdc.gov/niosh/fire or call toll free 1-800-CDC-INFO (1-800-232-4636).

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Introduction

On March 12, 2018, at approximately 1200 hours a 44-year-old female career FF suffered a cardiac arrest at the station after performing a PAT and responding to two calls (medical and MVA) earlier in the morning. Paramedics in the station initiated CPR and ACLS. The FF was transported to a nearby ED where she was pronounced dead at 1306 hours. The U.S. Fire Administration notified NIOSH of this fatality on March 12, 2018. The fire department (FD) contacted NIOSH on March 21, 2018 to discuss the possibility of inviting NIOSH to perform an investigation. On April 12–13, 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:

- Fire Chief
- Deputy Fire Chief
- District Fire Chiefs
- Firefighter/paramedic assigned to the rescue with the FF
- Firefighters who were working at the station with the FF
- Training center personnel who helped administer the PAT
- A firefighter who had worked with the FF for many years and was a close friend
- Father of the FF
- Medical Examiner

The NIOSH investigator reviewed the following documents:

- FD incident reports for calls during the day
- Emergency medical service (ambulance) report
- Transporting ambulance prehospital care report
- Hospital emergency department (ED) records
- Training records
- FD medical records
- Personal physician records
- Death certificate
- Autopsy report

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Investigation

On March 12, 2018, at about 0630 hours, a 44-year-old female FF reported to the training academy to perform her annual PAT. The FF arrived at the training facility early and interacted with several firefighters and instructors in the classroom, who all reported that she was in good spirits prior to the start of her PAT. At approximately 0730, baseline vital signs were taken (HR = 58 beats per minute; BP = 130/90 millimeters of mercury [mmHg]), and the FF performed her PAT. It was a clear, cool day (45°F). The timed test consisted of 11 tasks (see **Appendix A**) and was administered by training center staff. Test administrators reported that the FF performed the test at a steady pace and did not seem to be exhausted at the completion of the test. The FF passed the PAT, completing the test in 10 minutes and 56 seconds (passing time = 11:30 or less), but her time was longer than the previous year. The FF expressed disappointment in her time but did not show any signs of distress. After cooling down, she had several short conversations with other firefighters, including a conversation with the fitness coordinator in which she reported that her knees bothered her throughout the test. The FF left the training academy and reported to her fire station at approximately 0830 hours.

At the fire station, the FF was assigned as driver of the rescue unit. Station members were assigned to complete CPR training during the day. After brief conversations, members set up equipment to review a CPR training video and began watching the video. At 1022 hours, the rescue unit was dispatched to a cardiac arrest in a neighboring area. The FF assisted with carrying equipment for the call. A fellow firefighter on scene noticed that the FF was diaphoretic. When questioned, the FF indicated that she had done the PAT and was tired. The rescue unit returned to the station and restocked the vehicle. A few minutes after their return, at 1125 hours, the rescue unit was dispatched to assist with an MVA with an individual who was displaying an altered level of consciousness. The rescue crew was on scene with the engine crew from their station for about 13 minutes. Some members reported that the FF performed in a typical fashion on scene, while others remembered that she might have been more subdued than normal and eager to return to the station. On the way back to the station, the FF complained that she had a burning sensation in her throat, which she attributed to breathing cold air during the PAT.

The rescue unit returned to the station a few minutes before noon. Within approximately five minutes of returning to the station, the FF began complaining of the burning in her throat and indicated that it had gotten much worse. She stated that it was 10 out of 10 on the pain scale and became increasingly agitated. Her primary complaint was the burning in her throat but she also said she was having difficulty breathing and one firefighter heard her complain of chest pain. She also grabbed her shirt indicating that she had chest pain. She was given 325 mg of aspirin. Fellow firefighters, three of whom were paramedics, tried to calm the FF and help her find a comfortable position but she was in obvious distress and could not find a comfortable position. After repeated sitting and standing, the FF went to her knees and the crew helped her to the floor where she assumed the left lateral recumbent position. A set of vitals were taken (HR = 132 beats per minute; BP = 132/83 mmHg; respirations = 24 breaths per minute) and it was noted that she was diaphoretic. Although the FF was alert and oriented and following instructions, she was clearly in pain, and one of the firefighters contacted Command Staff via phone that there was a firefighter who was having a serious health issue. Electrodes were placed on the FF but an error screen obscured the view of the monitor. As the paramedics were attempting to get

an electrocardiogram (EKG), the FF went into seizure-like activity and had a cardiac arrest. The FF was cyanotic from the chest up. CPR was initiated immediately. An oral airway could not be secured because the FF had a clenched jaw. Oxygen was administered via bag-valve mask and skin color began to improve. An intravenous (IV) access was gained in the antecubital space. A nasal airway was secured. Automated external device (AED) pads were placed on the FF and a shock was delivered. Epinephrine was administered.

While paramedics were rendering care to the FF, another firefighter called dispatch and requested a transport ambulance, and alerted the Acting Battalion Chief of the serious nature of the call. The transporting ambulance arrived at approximately 1215 hours and found the FF unresponsive, pulseless, cyanotic, and apneic. CPR was in progress and a LUCAS™ device (automated chest compressions) was applied. The FF was attached to a cardiac monitor, which indicated that the FF's heart rhythm was ventricular fibrillation (VFIB). A shock was delivered. The FF released the clenching of her jaw and was successfully intubated at approximately 1226 hours. Additional cardiac medications were administered and the FF received two more shocks. At approximately 1234 hours, the FF's heart rhythm went into pulseless electrical activity (PEA).

The ambulance arrived at the ED at 1243 hours. The FF was in asystole. CPR and ACLS were continued. The ED physician's diagnosis was acute non-ST elevation myocardial infarction (NSTEMI). The FF received additional epinephrine, as well as magnesium sulfate, and calcium chloride. Bedside ultrasound results revealed no cardiac activity. At 1306 hours, the FF was pronounced dead.

Medical Findings

The FF suffered a witnessed cardiac arrest and received immediate treatment from fellow firefighters/paramedics at her fire station, was transported by an ACLS ambulance, and underwent continued resuscitation efforts for approximately 20 minutes in the ED. The Medical Examiner's report identified the cause of death as occlusive coronary artery disease due to atherosclerotic heart disease. See **Appendix B** for a more detailed description of autopsy findings.

The FF was active in recreational sporting activity and exercised regularly although her frequency of exercise had decreased since she entered paramedic school. She was a competitive athlete in high school and college, and played semi-professional basketball after college. She continued to compete competitively in tennis, play basketball and softball, and do horseback riding, ballroom dancing, and martial arts. The FF had knee surgery in 2016 and had been struggling with knee pain for the past several months. The FF had medical evaluations as part of the Hazardous Materials (HAZ MAT) Response Team in prior years but her last medical evaluation for HAZ MAT was in 2015. In March of 2017, the FF received a medical evaluation following her service as a member of the HAZ MAT team; no medical concerns were noted. As a requirement for paramedic school, the FF received a FD medical evaluation in October of 2017; a follow-up examination in February of 2018 included a resting EKG at which time vital signs were also recorded. The EKG was normal, no major concerns were noted, and a medical clearance letter was given. At that time, the FF had a blood pressure of 120/81 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. 2018]). Blood work performed in May 2015 indicated the FF had a high level of total cholesterol (257 milligrams per deciliter [mg/dL]; desirable < 200 mg/dL), a borderline high level of "bad" cholesterol or low density lipoprotein (LDL = 146 mg/dL; optimal < 100 mg/dL), a high level of triglycerides (TG = 233 mg/dL; normal < 160 mg/dL), a normal level of "good" cholesterol or high density lipoprotein (HDL = 64 mg/dL; desirable ≥ 60 mg/dL), and a normal level of blood glucose (88 mg/dL; fasting normal < 100 mg/dL) [Kratz et al. 2004; NHLBI 2013]. Although the FF had a history of elevated cholesterol levels and high triglycerides noted in her HAZ MAT physicals dating back to July of 2012, she had only begun taking cholesterol lowering statin medication (Crestor®) in the past 3 months. In January 2018, she called her physician to complain of heartburn after starting the medication. Although the physician did not believe the heartburn was due to the medication, it was advised that she try switching to a lower dose. The FF had a family history of high cholesterol but no other history of cardiovascular disease in the family. She was never a smoker. She was 65 inches tall and weighed 207 pounds, giving her a BMI of 34.4 kilograms per meter squared (kg/m^2) (a BMI of 30.0 or greater is considered obese) [NHLBI no date]. The Medical Examiner noted her BMI but reported in a phone conversation that she was extremely muscular.

Fire Department

At the time of the NIOSH investigation, the FD consisted of approximately 700 uniformed personnel operating out of 29 fire stations. The FD serves a population of approximately 750,000 in a geographic area of 305 square miles.

Employment and Training

Applicants must be at least 18 years of age, possess a valid state driver's license, and have a high school diploma or equivalent. Applicants complete an online application, take a written examination, and complete a PAT. A background check is performed and applicants have an initial interview. Successful applicants are then offered conditional employment but must pass a polygraph, a psychological evaluation, and a medical evaluation. Applicants then meet with the Chief for an interview. New members attend the Fire Academy for approximately one year and are certified in firefighting and as AEMTs (advanced emergency medical technicians). New hires are on probation for 18 months after they are offered conditional employment. The FF had been with the FD for almost 19 years.

Medical Evaluations

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

- Complete medical history
- EKG
- Complete blood count

- Urinalysis
- Urine drug screen
- Audiogram
- Vision test
- Respirator use questionnaire
- Spirometry (lung function testing)
- Chest X-ray

The FD does not require annual medical evaluations for all members or annual medical clearance for self-contained breathing apparatus (SCBA) respirator use. Members of the HAZ MAT Response Team receive a medical clearance yearly through the County Medical Clinic. Firefighters are required to provide medical clearance following a serious injury or illness that has the member off duty for 30 days or more.

Wellness/Fitness Programs

The FD has aerobic and strength-training equipment in the fire stations and firefighters are permitted and encouraged to work out on duty. The FD requires members to complete the PAT every year and employs a fitness coordinator who is available to assist members. However, the FD does not offer a comprehensive wellness/fitness program as recommended by the IAFF/IAFC Wellness Fitness Initiative [IAFF and IAFC 2018]. Members do have access to health maintenance programs through the County Medical Clinic. Additionally, for many years the FD has recommended an annual physical as part of its yearly performance appraisal.

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 plaque develops over many years, typically decades [Libby 2013]. However, the growth of these plaques probably occurs in a nonlinear, often abrupt fashion. Plaque buildup can restrict blood flow and result in insufficient delivery of oxygen to heart muscle (myocardial ischemia), particularly with exertion, which may produce chest pain (angina). Heart attack or myocardial infarction typically occurs with the sudden occurrence 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].

Major risk factors for coronary artery disease and heart attacks are categorized as modifiable or non-modifiable risk factors. Non-modifiable risk factors include male sex, age > 45 years for men and > 55 years for women, and heredity/family history. Modifiable risk factors are those that can be controlled or eliminated by lifestyle changes or medications. Major modifiable risk factors include smoking, hypertension, diabetes, hyperlipidemia/dyslipidemia, obesity, and lack of physical inactivity [Mayo clinic no date]. The FF had no known non-modifiable risk factors and two modifiable risk factors (dyslipidemia and obesity). Beyond the major modifiable risk factors, it is also known that the risk of cardiovascular disease in women increases after menopause [AHA 2015; Manson and Woodruff 2016]. The FF had a hysterectomy approximately one year earlier and had begun estrogen replacement therapy approximately 3 months before her death.

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 acute NSTEMI. The autopsy found complete occlusion of the LAD coronary artery confirming that the FF died of a heart attack.

Heart Attack Symptoms

An individual who is experiencing a heart attack may experience a range of signs and symptoms, including [AHA 2016]:

- Uncomfortable pressure, squeezing, fullness or pain in the chest
- Pain or discomfort in one or both arms, the back, neck, jaw, or stomach
- Shortness of breath
- Sweating (diaphoresis)
- Nausea or vomiting
- Dizziness or lightheadedness

The signs and symptoms of a heart attack vary greatly in how they present and in their severity. Some experience the sensation of “an elephant on their chest,” while others may experience shortness of breath or fatigue; in some individuals, sudden cardiac death is the first sign of myocardial infarction. Some of the variability in the signs and symptoms occurs because of the location of the blockage. There is also evidence that the symptoms of a heart attack vary by age and gender [AHA 2016]. Although the most common symptom in women is some type of chest pain, pressure, or discomfort in the chest, it is not always severe or even the most prominent symptom. Women are more likely than men to have heart attack symptoms that are unrelated to chest pain, such as neck, jaw, shoulder, upper back or abdominal discomfort; shortness of breath; pain in one or both arms; nausea or vomiting; sweating; lightheadedness or dizziness [Mayo Clinic no date]. When considering only the chief complaint at admission, which often guides triage and treatment, men have been found to have chest pain as the chief complaint more often (69%) than women (54%) [Milner et al. 2004]. Although it is

not fully known why men and women have different signs and symptoms of a heart attack, it may be related to differences in comorbidities [Arslanian-Engoren et al. 2006] or in the type of vessels occluded (major epicardial arteries versus microvascular arteries) [Mayo Clinic no date].

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 and/or cardiomegaly/left ventricular hypertrophy [Geibe et al. 2008; Kales et al. 2003; 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].

Recommendations for conducting exercise stress tests (ESTs) on asymptomatic individuals without known heart disease are varied. NFPA 1582, a voluntary industry standard, recommends risk stratification beginning at age 40 using the "Heart Risk" score (estimated 10-year risk of heart attack, cardiac death, or stroke) [ACC/AHA 2019; NFPA 2018a]. Firefighters with intermediate risk (10-year risk 10% to < 20%) should receive a symptom-limiting EST to $\geq$ 12 metabolic equivalents (METs) to ensure the cardiac workload for strenuous firefighting will not precipitate a sudden cardiac event [NFPA 2018a]. (The FF's 10-year Heart Risk score was calculated using risk factor data from her most recent medical exam and laboratory testing. Her estimated 10-year Heart Risk was 0.8%, which is considered low risk.) The Heart Risk calculator does take into account premature menopause.

The FD did not require but recommended annual medical evaluations for all members. The FF had received a FD medical evaluation in prior years because she was as part of the HAZ MAT team and was recently evaluated as she began paramedic school. She had seen her personal physician approximately 3 months earlier and had begun medication for her high cholesterol/high triglycerides.

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. It is unclear if any of these recommendations could have prevented the sudden cardiac arrest and subsequent death of this FF.

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.

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Recommendation #2: 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.

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 PPE they must wear during various types of emergency operations.

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 Department Members* [NFPA 2015], 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, reducing absenteeism, and reducing the number of work-related injuries and lost workdays [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: Continue to perform annual physical performance (physical ability) evaluations.

Discussion: NFPA 1500, *Standard on Fire Department Occupational Safety and Health Program,* recommends fire department members who engage in emergency operations be annually evaluated and certified by the FD as having met the physical performance requirements identified in paragraph 10.2.3 of the standard [NFPA 2018b]. This is recommended to ensure firefighters are physically capable of performing the essential job tasks of structural firefighting. Although it is known that strenuous physical exercise or work can trigger a cardiovascular event in individuals with underlying risk, a variety of epidemiological, basic scientific, and clinical evidence suggests that regular physical activity decreases the risk of a cardiac event and that the benefits of regular activity outweigh the risks [Thompson et al. 2007].

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44-Year-Old Female Firefighter Suffers Sudden Cardiac Arrest at Station—Georgia

Investigator Information

This incident was investigated by the NIOSH Fire Fighter Fatality Investigation and Prevention Program, Cardiac and Medical LODD Component, within the Division of Surveillance, Hazard Evaluations, and Field Studies (DSHEFS), 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 New York. Dr. Smith is also a member of the NFPA Technical Committee on Fire Service Occupational Safety and Health. Dr. Smith was working as a contractor for NIOSH during this investigation. Wendi Dick, MD, MSPH, provided medical consultation and contributed to the report. Dr. Dick is Medical Officer for the Cardiac and Medical LODD Component.

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Appendix A
Physical Ability Test

This test consists of 11 tasks and is mandatory for all sworn members. The test is timed and must be completed in 11 minutes and 30 seconds or less to pass. The member being tested wears a helmet, gloves, and SCBA without face piece.

Task 1: Hose Advance – 3′ Uncharged Line

Task 2: Hose Couple

Task 3: Equipment Carry/Stair Climb/Forced Entry

Task 4: Line Crawl

Task 5: Victim Rescue

Task 6: Ladder Mount/Carry

Task 7: Hose Advance – 1¾ inch Charged Line

Task 8: Hydraulic Spreader Tool

Task 9: Pike Pole

Task 10: Hose Uncouple

Task 11: Hose Roll

Appendix B
Autopsy Findings

- Coronary Heart Disease
  - Acute coronary thrombosis
  - Complete occlusion of the proximal LAD coronary artery
  - Other coronary arteries without significant atherosclerotic changes
- Normal cardiac valves
- No evidence of a pulmonary embolus (blood clot in the lung arteries)
- Heart weight within normal limits (390 grams)

Author's Discussion:
Predicted normal heart weight is 318 grams (ranges between 217 and 465 grams as a function of sex and body weight), according to research in Silver and Silver [2001].

The LAD provides the majority of blood for the left ventricle (main pumping chamber of the heart) as well as the interventricular septum (contains the conducting system that makes the ventricles contract) [University of Minnesota 2017].

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