2018
01

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 11, 2019

47-Year-Old Firefighter Suffers Cardiac Arrest at Gym After Shift—Massachusetts

Executive Summary

On March 30, 2017, at approximately 1100 hours a 47-year-old male career firefighter (FF) went to a cross training gym for a workout a few hours after completing a 24-hour shift. It was a light-recovery day workout, and after one set of three exercises, he suddenly collapsed. Bystanders on scene initiated cardiopulmonary resuscitation (CPR) and delivered one shock as advised by an automated external defibrillator (AED). An ambulance was dispatched at 1136 hours and arrived on scene at 1141 hours. Emergency medical services (EMS) staff initiated advanced cardiac life support, which was continued en route to the hospital emergency department (ED). Hospital ED personnel continued resuscitation efforts unsuccessfully for approximately 15 minutes. The FF was pronounced dead at 1220 hours.

The Medical Examiner's report listed the FF's cause of death as hypertensive cardiovascular disease. The autopsy report found an enlarged heart (weight of 470 grams) and no significant atherosclerosis. National Institute for Occupational Safety and Health (NIOSH) investigators concluded that given the evidence of an enlarged heart, the physical exertion of his workout may have triggered a cardiac arrest.

Regarding cardiovascular risk factors, the FF was male and older than 45 (two non-modifiable risks), but was a nonsmoker and very physically fit. The fire department does not require annual medical evaluations and NIOSH investigators did not have access to private physician records, so it is unknown if the FF had been diagnosed with hypertension or had other cardiovascular disease risk factors.

Key Recommendations

NIOSH offers the following recommendations to help reduce the risk of sudden cardiac events 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*
- *Perform an annual physical performance evaluation (physical ability test)*
- *Provide annual medical clearance for self-contained breathing apparatus (SCBA) use.*

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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 30, 2017, a 47-year-old male career FF suffered sudden cardiac arrest while working out at a gym a few hours after completing a 24-hour shift. The U.S. Fire Administration notified NIOSH of this fatality on April 3, 2017. NIOSH contacted the affected fire department (FD) on April 7, 2017, and again on February 16, 2018, to gather additional information and to initiate the investigation. On February 20, 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:

- Deputy Fire Chief
- Firefighters who worked with the FF
- Union President
- Trainer (and Owner) at the gym where FF was exercising
- Medical Examiner

The NIOSH investigator reviewed the following documents:

- FD incident reports for medical calls on preceding shift day
- EMS (ambulance) report
- Hospital ED records
- Death certificate
- Autopsy report

Investigation

On March 30, 2017, at approximately 1100 hours, a 47-year-old male career FF went to a cross training gym for a workout after completing a 24-hour shift at approximately 0730 hours. During his shift, the FF responded to two medical calls. The first call was dispatched at 0948 hours. The Engine (with the FF, Driver, and Officer) arrived on scene to assist an obese patient who had fallen. Because the patient had labored breathing, weakness, and pain, the Officer requested an ambulance. The engine crew lifted the patient to a chair and then assisted the patient to the ambulance. According to coworkers, the FF mentioned later in the day that he had “torqued his back” during the call.

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His coworkers asked if he wanted to get it looked at, but he said "no," and that he would do so later if it was still bothering him. The FF also responded to a medical call at 2048 hours for a patient with difficulty breathing. EMS arrived on the scene within one minute of the FD, took over care, and transported the patient without assistance from the FD.

Throughout the shift, the FF had no signs or symptoms, other than the mention of his back pain noted above. Rather, most of the conversations were about his next workout. The FF was a fitness enthusiast who exercised regularly. He had completed several marathons and participated in "tough mudders," which are runs on an obstacle course. He had been going to a gym for over 6 months.

The FF arrived at the gym where he regularly worked out at approximately 1100 hours. He had seen his trainer earlier in the morning at a coffee shop and indicated that he was looking forward to the training session. The FF was doing the workout with several other members of the gym and they all gathered to do stretching and discuss the workout. During this time, the FF was talking about the races he was signing up for in the coming months. The scheduled exercise routine was for a light workout/active recovery day. The scheduled routine involved three sets of three different exercises: 20 pushups, ring rows (pulling rings toward the body to work the arm and chest muscles), and 200-meter run. The FF completed the first set of exercises and came back into the gym after finishing the run. He completed the second round of 20 pushups and prepared to do the second round of ring rows. As he was reaching for the rings, he collapsed and fell forward. A police officer who was also doing the exercise routine assessed the FF, asked that 911 be called, and began chest compressions. Responders in the gym inserted an oropharyngeal tube and other bystanders retrieved an AED. One shock was administered (as advised by the AED) prior to the arrival of EMS.

EMS was dispatched at 1136 hours and arrived on scene at 1141 hours. Paramedics found the FF unresponsive on the floor with blood around his nose and mouth (presumably from the fall) and CPR in progress. The FF was pulseless and not breathing. The cardiac monitor showed that he was in ventricular fibrillation (VFIB), and a shock was advised and delivered. Paramedics took over CPR and transported the FF to the ambulance. In the ambulance, the LUCAS™ device (automated chest compressions) was applied to the FF. Intraosseous access was gained in the right tibia. The FF was intubated with an endotracheal tube with correct placement confirmed by capnography (exhaled carbon dioxide [CO_2]). Multiple rounds of epinephrine and amiodarone were administered. En route to the hospital ED, the FF had multiple rhythm changes (asystole, VFIB, pulseless electrical activity [PEA]) and was shocked three times. There was a brief return of circulation during transport but the FF remained unresponsive throughout.

The ambulance arrived at the ED at 1203 hours. Physical exam upon arrival noted no cardiac activity (PEA) or pulse and no spontaneous respirations. The pupils were fixed and dilated and there was lividity noted on the back. The endotracheal tube was confirmed with a GlideScope® showing visualization through the vocal cords. ACLS was continued. The FF received three more rounds of epinephrine, bicarbonate, and intravenous (IV) fluids. Bedside ultrasound results revealed no evidence of right ventricular strain, normal lung sliding bilaterally, and no cardiac activity. At 1220 hours, approximately 45 minutes after his collapse, the FF was pronounced dead.

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Medical Findings

The Medical Examiner's report identified the cause of death as hypertensive cardiovascular disease. The autopsy reported cardiac enlargement (heart weight 470 grams) with no significant atherosclerosis. See **Appendix A** for a more detailed description of autopsy findings.

The FF was a nonsmoker and exercised regularly. He enjoyed competition and participated in dozens of races, including marathons, tough mudders, and Spartan races. NIOSH did not have the opportunity to discuss his medical history with the family, but those who worked out with the FF reported that he had a family history of early death from a cardiovascular event (mother) and that his exercise was, in part, motivated by this fact. It is unknown if he regularly saw a physician or if he had known cardiovascular disease risk factors. (Records from 2009 and 2010 indicate that the FF did not have hypertension at that time.) At autopsy, he measured 70 inches tall and 204 pounds, for a body mass index (BMI) of 29.3 kilograms per meter squared (kg/m^2); a BMI under 30 kg/m^2 is not considered obese [NHLBI no date].

Fire Department

At the time of the NIOSH investigation, the career fire department consisted of 6 fire stations with approximately 150 uniformed personnel. The FD served a population of over 56,000 in a 25-square-mile area.

Employment and Training

Applicants must be at least 21 years of age, possess a valid state driver's license, have a high school diploma or equivalent, and be a state resident. Applicants take a civil service examination and a physical ability test (PAT). The applicant must complete an application, provide a resume and references, and undergo a background check. The FD then interviews top ranked applicants. Successful applicants are offered conditional employment subject to successfully completing a second PAT, a psychological evaluation, and a medical evaluation. Once hired, a firefighter must complete Firefighter I and II training at the State Academy. After the Academy training is completed, the newly hired member completes 2–3 weeks of in-house training and receives his/her shift assignment based on vacancies in the FD. The new member is on probation for 1 year. The FF had been with the FD for 14 years.

Medical Evaluations

The FD requires preplacement medical evaluations for applicants. These are performed by a clinic that provides the medical evaluations on a contractual basis. Components of the preplacement medical evaluation include the following:

- Complete medical history
- Physical examination (height, weight, blood pressure, pulse, and respiratory rate)

- Complete blood count
- Urinalysis
- Urine drug screen
- Audiogram
- Vision test
- Respirator use questionnaire
- Spirometry
- Resting electrocardiogram (EKG)
- Chest X-ray.

The FD does not require annual medical evaluations for members or annual medical clearance for SCBA respirator use. Members are required to provide medical clearance from a personal physician following a serious injury or illness.

Wellness/Fitness Programs

The FD does not offer a comprehensive wellness/fitness program as recommended by the International Association of Fire Fighters/International Association of Fire Chiefs Wellness Fitness Initiative [IAFF and IAFC 2008]. Members do have access to health maintenance programs through the City Employee Assistance Program (EAP). The FD has aerobic and strength-training equipment in the fire stations and firefighters are permitted to work out on duty.

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]. Risk for its development is grouped into non-modifiable and modifiable risk factors. Non-modifiable cardiovascular risk factors include male sex, age over 45, and family history of coronary artery disease. Modifiable risk factors include smoking, high blood pressure (hypertension), unhealthy blood cholesterol levels, diabetes mellitus, and obesity/physical inactivity [AHA 2016; NHLBI 2016]. The FF had two non-modifiable risk factors (male sex, age > 45 years); however, it is unknown whether he had any modifiable cardiovascular disease risk factors. A structurally enlarged heart (cardiomegaly or left ventricular hypertrophy) is also common among many individuals who die of sudden cardiac events [Tavora et al. 2012]. Among hypertensive individuals, modification/regression is possible with blood pressure control, but may not be the only “driving force” behind these structural changes [Diamond and Phillips 2005].

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 can prevent delivery of sufficient oxygen to the heart muscle (myocardial ischemia), which may produce chest pain (angina), particularly with exertion. Heart attacks 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], to include snow shoveling [Franklin et al. 2001] and firefighting activity [Kales et al. 2003, 2007; NIOSH 2007], including an alarm response.

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 had very little atherosclerosis, suggesting that his death was not due to coronary artery disease.

Hypertensive Heart Disease

Interactions between genetic factors and hemodynamic factors cause hypertensive heart disease in individuals with arterial hypertension [Diamond and Phillips 2005]. Hypertensive heart disease includes anatomical and functional changes to the heart and vessels as a consequence of long-standing hypertension. Left ventricular hypertrophy (LVH), due to myocyte enlargement with or without fibrosis, is a reflection of hypertensive end-organ damage, which can lead to increased ventricular mass, abnormal perfusion, congestive heart failure, and arrhythmias [Prisant 2005]. Recent medical records are not available for the FF, so it is unknown if he had hypertension. Records from his primary care physician in 2009 and 2010 indicate that he did not have hypertension at that time.

The Medical Examiner listed the cause of death as hypertensive heart disease. In discussions with the Medical Examiner, he indicated that he made this determination primarily because he had ruled out other underlying causes of death and the heart was enlarged, which is often the result of hypertension. Increased heart mass predisposes to the risk for fatal arrhythmia, which was presumed to be the mechanism for the sudden cardiac death [Kahan and Bergfeldt 2007; Tavora et al. 2012].

Left Ventricular Hypertrophy (LVH)/Cardiomegaly

In addition to chronic hypertension, LVH can also be caused by a heart valve problem (the FF had no evidence of this at autopsy), obesity, or myocardial ischemia [Siegel 1997; Tavora et al. 2012].

Athlete's Heart

LVH can develop in ultra-endurance athletes [Shave et al. 2017]. This type of hypertrophy, sometimes called "Athlete's Heart," is considered physiologic and is not pathologic. It is generally thought to result from increased myocyte mass without an increase in the extracellular space [McDiarmid et al. 2016]. Most research suggests that Athlete's Heart does not involve fibrosis, reduced blood flow, impaired function, etc. and does not increase the risk of ventricular ectopy/PVCs [Hegde and Solomon

2015]. However, there is some controversy as to whether the ventricular remodeling that accompanies Athlete's Heart may be arrhythmogenic [Rowland 2011].

Sudden Cardiac Death of Unknown Cause

In some cases, the cause of sudden cardiac death is unclear at autopsy. Most victims of sudden cardiac events have previously known or unrecognized cardiac abnormalities, with coronary artery disease, hypertrophic cardiomyopathy, and aortic valve stenosis being the most common findings [Wever and Robles de Medina 2004]. Sudden cardiac death in individuals without coronary artery disease or structural heart disease may be due to electrical conduction problems (such as inherited channelopathies) or coronary artery spasm [Katritsis et al. 2016].

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 [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 2013a, 2018].

Regarding screening asymptomatic firefighters, the edition (2013) of NFPA 1582 in effect at the time of this fatality recommended basing the decision to screen on the presence of risk factors for cardiovascular disease. For firefighters (such as the FF) with two non-modifiable risk factors (male sex and age > 45 years), the presence of just one additional risk factor (e.g., hypertension, high cholesterol, diabetes, or smoking) would have been sufficient to recommend screening with a symptom-limiting exercise stress test (EST) [NFPA 2013a]. Guidance in the new (2018) edition of NFPA 1582 recommends annual risk assessment of all firefighters $\geq$ 40 years old with a "Heart Risk Calculator" that takes into account age, sex, blood pressure, smoking status, etc., to estimate 10-year risk of sudden cardiac events or stroke [ACC/AHA 2019; NFPA 2018]. Firefighters with elevated 10-year Heart Risk (e.g., 10%–19%) are recommended to undergo futher evaluation with an EST [NFPA 2018].

The FD did not require medical evaluations for members. It is unknown if the FF had modifiable cardiovascular disease risk factors such as hypertension, and recent clinical data were not available to estimate his 10-year Heart Risk. It was reported that a first-degree family member died of a sudden cardiac event at an early age and this was part of the FF's motivation to engage in regular fitness training. It is unclear if it also motivated him to obtain period medical evaluations from a primary care physician.

Recommendations

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

***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 2018]. 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 himself/herself 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 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 2018]. 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 Fire Fighters* [NFPA 2015], the *IAFF/IAFC Fire Service Joint Labor Management Wellness/Fitness Initiative (WFI)* [IAFF and IAFC 2008], and *Firefighter Fitness: A Health and Wellness Guide* [Schneider 2010]. 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].

The FD has exercise equipment available to members but does not have a wellness/fitness program. The FF regularly exercised on his own, so this recommendation would not have affected the outcome of this case; however, NIOSH recommends that all firefighters have access to a well-structured health and wellness program such as the IAFF/IAFC WFI.

Recommendation #4: Perform an annual physical performance (physical ability) evaluation.

Discussion: NFPA 1500 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 2013b]. This is recommended to ensure firefighters are physically capable of performing the essential job tasks of structural firefighting. The physical ability test could be incorporated into the FD's training program.

Recommendation #5: Provide annual medical clearance for SCBA use.

Discussion: The Occupational Safety and Health Administration (OSHA) Revised Respiratory Protection Standard requires employers to provide medical evaluations and clearance for employees using respiratory protection [29 CFR 1910.134]. These clearance evaluations are required for private industry employees and only for public employees in states that operate OSHA-approved state plans [OSHA 2019]. Because Massachusetts does not operate a state OSHA plan, the fire department is not mandated to provide medical evaluations for employees using respirators. However, we recommend voluntary compliance with this recommendation to improve firefighter health and safety.

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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
Autopsy Findings

- Minimal coronary artery atherosclerosis
- Structural heart disease
    - Cardiomegaly (heart weighed 470 grams)
    - Left ventricular thickness–1.2 centimeters (cm)
- Microscopic
    - Scattered hypertrophic myocytes in left and right ventricles
- No evidence of a pulmonary embolus (blood clot in the lung arteries)
- Blood analysis
    - Ibuprofen detected
    - Negative for drugs of abuse

Author's Discussion:
Predicted normal heart weight is 376 grams (ranges between 285 and 496 grams as a function of sex and body weight), according to research in Silver and Silver [2001].

Left ventricular thickness of 1.2 cm is high normal on the basis of postmortem studies by Kitzman et al. [1988] (normal range 1.07 cm–1.39 cm).

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