Fire Fighter Dies of Heart Attack After Skills Training the Previous Night - New Hampshire

Executive Summary

On June 13, 2016, a 43-year-old male paid-on-call fire fighter (FF) took part in a weekly training drill involving rescue equipment. The FF had a history of cardiac events including prior heart attack and stenting. Medical records indicate that he had complained of chest pains to his fiancée in the previous 2 weeks. However, interviews revealed that he had not reported symptoms at work in the preceding 2 weeks or during the drill. Upon awakening at home the next morning, the FF reported having chest pain. He asked that an ambulance be called. Shortly after the 911 call was made he collapsed and lost consciousness. When EMS (emergency medical services) staff arrived, the FF was receiving CPR (cardiopulmonary resuscitation). He was unresponsive, pulseless, and not breathing. Cardiac monitoring showed ventricular fibrillation, and a shock was delivered. EMS provided CPR and ACLS (advanced cardiac life support) measures on scene and en route to the hospital for almost an hour. The FF arrived at the hospital ED (emergency department) in asystole. ED staff treated the FF without success for another 15 minutes and pronounced him dead.

The autopsy report listed the cause of death as myocardial infarction (heart attack), due to coronary artery thrombosis, due to coronary artery atherosclerosis. The report documented evidence of hypertensive and atherosclerotic cardiovascular disease, including previous myocardial infarction with multiple stent procedures, left ventricular hypertrophy, and a severely enlarged heart (cardiomegaly). Severe coronary atherosclerosis was noted, and an occlusive thrombus was evident in the right coronary artery. NIOSH investigators concluded that the physical stress of participating in training might have exacerbated the cardiac symptoms that the FF had reported in the preceding weeks.

The FF had multiple risk factors for heart disease to include smoking, dyslipidemia, high blood pressure, diabetes mellitus, obesity, lack of physical activity, and family history. He suffered his first heart attack at age 39, after which he entered a cardiac rehabilitation program but did not achieve aerobic capacity beyond 4.9 METs (metabolic equivalents).

Key Recommendations

- *Ensure that all fire fighters receive an annual medical evaluation consistent with National Fire Protection Association (NFPA) 1582,* Standard on Comprehensive Occupational Medical Program for Fire Departments.
- *Ensure fire fighters are cleared for duty by a physician knowledgeable about the physical demands of fire fighting, the personal protective equipment used by fire fighters, and the various components of NFPA 1582.*
- *Phase in a mandatory comprehensive wellness and fitness program for fire fighters.*

- *Perform an annual physical performance (physical ability) evaluation.*

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Introduction

On June 14, 2016, a 43-year-old paid-on-call FF suffered a cardiac arrest at his home shortly after waking. He had led departmental hands-on rescue training the night before. The U.S. Fire Administration notified NIOSH of this fatality on June 15, 2016. NIOSH contacted the affected FD (fire department) on June 15, 2016, and again on January 31, 2017, to gather additional information and to initiate the investigation. On February 15, 2017, a contractor for the NIOSH Fire Fighter Fatality Prevention and Investigation Program conducted an on-site investigation of the incident.

During the investigation, NIOSH personnel interviewed the following people:

- Fire Chief
- Deputy Chief
- FF's fiancée

NIOSH personnel reviewed the following documents:

- FD incident report
- FD injury/illness investigation report
- FD medical evaluation records
- Previous hospital records
- Emergency medical services (ambulance) report
- Hospital emergency department records
- Death certificate
- Autopsy report

Investigation

On June 13, 2016, a 43-year-old male paid-on-call FF was an instructor in a weekly training exercise. The regularly scheduled, outdoor training began at 1900 hours. The FF and a fellow member oversaw a portion of the training that involved the use of extrication tools and airbags and setting up landing zones. Students took out and set up all the tools, operated the tools, and then set up a landing zone with lights. Three groups of students rotated through this station during the approximately 90 minutes of training. The class involved regular FD members and cadets. The FF worked closely with the cadets to get the tools and set them up for use. At approximately 2030 hours the extrication tools training was completed, and the Fire Chief asked the FF to help a group that was training on packaging a patient and using the stair chair for transport down a flight of stairs. At 2100 hours the training drill ended with a short debriefing. Throughout the evening the FF spoke with several individuals, including the Fire Chief and Deputy Chief, made no complaints of symptoms, and seemed to be in no pain or discomfort.

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On the morning of June 14, 2016, the FF awoke at approximately 0520 hours and asked his fiancée to call 911 because he thought he was having a heart attack. He complained of shortness of breath, chest pain, and chills and sweats. Shortly after 911 was called, the FF collapsed on the bed and his fiancée initiated CPR. The ambulance was dispatched at 0524 hours and arrived on scene at 0537 hours, just as the Fire Chief and another fire fighter were responding to the residence. EMS found the FF unresponsive, not breathing and pulseless. EMS took over CPR and attached a cardiac monitor. The monitor revealed ventricular fibrillation, and a shock was delivered. Intraosseous access was gained and cardiac medications were administered. An oral airway was placed and supplemental oxygen was delivered. The FF was placed on a MegaMover® (a tarp with handles used to rescue patients from areas inaccessible to stretchers), slid down a hallway, and placed on a cot. EMS continued CPR throughout the transfer. The FF's cardiac rhythm was reanalyzed and no shock was advised. Additional cardiac medications were given. En route to the hospital, a King™ Airway was inserted (an emergency airway used in the field) with placement confirmed by lung sounds, no sounds over the epigastrium, and good compliance with bag-valve. The ambulance arrived at the hospital at 0622 hours, and care was transferred to ED staff.

When the FF arrived at the hospital ED the cardiac monitor revealed that he was in asystole. Additional cardiac medications were administered but he never regained a rhythm. After proceeding with ACLS for approximately 10 to 15 minutes without an organized rhythm, CPR was discontinued, and the FF was pronounced dead at 0637 hours.

Medical Findings

The Deputy Chief Medical Examiner for the state performed the autopsy. The autopsy identified the cause of death as a recent myocardial infarction, due to coronary artery thrombosis, due to coronary atherosclerosis. The autopsy revealed a history of myocardial infarction with multiple stents, severe coronary artery atherosclerosis, an occlusive thrombus in the right coronary artery, severe cardiac enlargement (heart weight of 822 grams) with concentric left ventricular hypertrophy, obesity, and generalized organomegaly. See Appendix A for a more detailed description of autopsy findings.

The FF had his last occupational medical examination for the FD in 2006. At that time, he had elevated total cholesterol, triglycerides, and bad cholesterol (low-density lipoproteins or LDL), and a low level of good cholesterol (high-density lipoproteins or HDL). The FF had low pulmonary function scores on a spirometry exam indicating early chronic obstructive pulmonary disease. His EKG (electrocardiogram) showed nonspecific ST-T wave alterations. A chest x-ray found the heart size within normal limits.

In May 2012, the FF underwent a sleep evaluation. It revealed severe sleep apnea with loud snoring and oxygen desaturation to approximately 80% (normal oxygen saturation is approximately 89%–98%) [Gries and Brooks 1996].

The FF had an extensive history of coronary artery disease (coronary heart disease). In June 2012, he had a heart attack and had multiple stents placed in his coronary arteries. Once the FF had stabilized from the heart attack and stent placement, he was enrolled in a cardiac rehabilitation program.

Documentation obtained upon entry to cardiac rehabilitation indicated that the FF had multiple risk factors for cardiovascular disease including smoking, diabetes mellitus, dyslipidemia, hypertension (high blood pressure), obesity, sedentary lifestyle, stress, and family history. He was taking multiple medications for his cardiovascular disease. He was 72 inches tall and weighed 323 pounds, giving him a BMI (body mass index) of 43.8 kilograms per meter squared (BMI ≥30 is considered obese) [NHLBI no date]. His blood pressure was 120/70 mm Hg (millimeters of mercury); normal at rest is 90 to 119 mmHg (systolic) and 60 to 79 mmHg (diastolic) [NHLBI 2010; NHLBI 2015]. Blood work performed at the time indicated he had normal levels of total cholesterol and LDL (total cholesterol 189 mg/dL [milligrams per deciliter], desirable <200; LDL 85 mg/dL, optimal <100). His triglycerides were elevated (405 mg/dL, desirable <150), and his level of HDL cholesterol was low (23 mg/dL, desirable >40) [NHLBI 2005; Quest Diagnostics 2017]. He had a slightly elevated fasting blood glucose of 103 mg/dL (normal <100) [ADA 2014]. When the FF began cardiac rehabilitation his exercise tolerance (aerobic capacity) was 2.7 METs. He attended five sessions and was then discharged because of lack of attendance. His exercise tolerance at his last session had improved to 4.9 METs.

The FF had three more coronary stents placed in 2013. In May 2013, he was hospitalized for a viral infection. At that time his blood glucose levels were elevated (125 mg/dL). An echocardiogram showed that the FF had a left ventricular ejection fraction of 55% to 60%, indicating good systolic function at rest (normal is in the range of 50% to 70%) [AHA 2015]. The echocardiogram also revealed a mildly dilated left atrium and mild concentric left ventricular hypertrophy of 1.4 cm (centimeters); normal by echocardiographic measurement is 0.6 cm to 1.0 cm [Connolly and Oh 2012].

Fire Department

At the time of the NIOSH investigation, the FD had 21 uniformed personnel working out of a single fire station. It served a population of approximately 2,200 in a geographic area of 37 square miles. In 2016, the FD responded to approximately 450 calls.

Employment and Training

Applicants must be at least 18 years of age, possess a valid state driver's license, and pass a background check. Potential members fill out an application, meet with the Fire Chief, and are invited to attend a monthly meeting to get to know the members. The Chief interviews the potential member and then presents him or her to the Board of Selectmen for review and approval. Once a conditional offer of employment is made, the candidate must pass a Department of Motor Vehicles background check and a medical evaluation. The new member is on probation for 1 year and must become a certified Fire Fighter I or EMT (Emergency Medical Technician) basic within 1 year. The FF was certified as a Fire Fighter II and EMT. He had been with the FD for 19 years**.** The FF also worked as an EMT for a local ambulance company and regularly worked multiple overnight shifts during the week.

Medical Evaluations

The FD requires preplacement medical evaluations for all applicants. Evaluations are conducted by a contract occupational medical group. Components of this 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 EKG
- Chest x-ray

Within the year before this fatality, the FD had adopted a policy of providing a periodic medical evaluation to members every 3 years. The periodic evaluation includes the same components as the pre-employment medical evaluation except that drug screening is not performed. Once the medical evaluation is complete, the contracted healthcare provider makes a determination regarding medical clearance for fire fighting duties and forwards this decision to the FD office. The FF had his last occupational medical evaluation in 2006. On the basis of the new departmental policy of providing medical evaluations to members every 3 years, the FF was due to have his next medical evaluation in 2017. Members who experience a significant illness are required to have a medical clearance for return to duty.

Wellness/Fitness Programs

The FD does not have exercise equipment for members. It does not offer a comprehensive wellness/fitness program as recommended by the IAFF/IAFC Wellness Fitness Initiative [IAFF, IAFC 2008].

Discussion

Coronary Artery Disease

In the United States, atherosclerotic coronary heart disease is the most common risk factor for cardiac

arrest and sudden cardiac death [Meyerburg and Castellanos 2008]. Risk for its development is grouped into nonmodifiable and modifiable risk factors. Nonmodifiable risk factors include age older than 45, male gender, and family history of coronary artery disease. Modifiable risk factors include diabetes mellitus, smoking, high blood pressure, unhealthy blood cholesterol levels, and obesity/physical inactivity [AHA 2016; NHLBI 2016]. The FF had all five of these modifiable risk factors. Working on rotating shifts or for long hours has also been linked to increased risk of heart disease [Steenland 2000; Steenland et al. 2000]. In addition to his work at the FD, the FF was employed as an EMT, so he worked long hours and often overnight.

Sudden Cardiac Events

The narrowing of the coronary arteries by atherosclerotic plaques occurs over many years, usually decades [Libby 2013]. However, the growth of these plaques probably occurs in a nonlinear, often abrupt fashion. 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], including snow shoveling [Franklin et al. 2001] and fire fighting activity [Kales et al. 2003; Kales et al. 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 had evidence of a thrombus and heart damage at autopsy, confirming a recent heart attack.

Regarding fire fighters, NFPA 1582 considers a history of heart attack, coronary artery stenting or bypass, or similar procedures to compromise the ability to safely perform a number of critical duties [2013a]. For example, history of a heart attack could impair the ability to rescue and carry victims in full protective gear or to respond as an integral team member where sudden incapacitation could jeopardize the mission. The standard recommends that physicians report duty limitations to the department if a member has any of the following:

- Current angina pectoris (chest pain) even if relieved by medication
- Persistent significant stenosis in any coronary artery (>70%) following treatment
- Lower than normal left ventricular ejection fraction
- Maximal exercise tolerance below 12 METs
- Exercise-induced ischemia or ventricular arrhythmias observed during a radionuclide stress test that reaches at least 12 METs
- Persistent modifiable risk factor(s) for acute coronary plaque rupture, e.g., smoking, hypertension despite treatment, total cholesterol >180 or LDL >100 despite treatment, or hemoglobin A1C >7% despite exercise or weight loss [NFPA 2013a]

The FF had a heart attack in 2012 after which he had stents placed. He was at risk for future plaque rupture, and did not have aerobic capacity of 12 METs. Therefore, NFPA 1582 guidance would have recommended duty limitations.

Left Ventricular Hypertrophy/Cardiomegaly

Hypertrophy of the heart's left ventricle is a common finding among individuals with long-standing high blood pressure, a heart valve problem, obesity, or cardiac ischemia (reduced blood supply to the heart muscle) [Cramariuc and Gerdts 2016; Cuspidi et al. 2014; Korre et al. 2016; Siegel 1997; Tavora et al. 2012]. Left ventricular hypertrophy (LVH) and cardiomegaly are structural changes of the heart that increase the risk for arrhythmias and sudden cardiac death [Chatterjee et al. 2014; Kahan and Bergfeldt 2007; Spirito et al. 2009; Tavora et al. 2012]. The FF had concentric LVH and cardiomegaly, with his heart weighing more than twice the normal weight.

Obstructive Sleep Apnea

Obstructive sleep apnea syndrome is characterized by pauses or decreases in breathing during sleep, and symptoms of excessive daytime sleepiness [Patil et al. 2007]. If untreated, sleep apnea is associated with fatigue and cognitive defects as well as arrhythmias, cardiovascular disease, and heart attack [Mansukhani et al. 2015; Destors et al. 2014]. Because problems with alertness and fatigue could compromise a fire fighter's ability to safely carry out a number of essential job tasks, NPFA 1582 recommends duty restriction until the fire fighter is under treatment [Somers et al. 2008; NFPA 2013a]. The FF had been diagnosed with severe obstructive sleep apnea, but no treatment was recorded in his medical records.

Diabetes Mellitus

Having elevated blood glucose increases the risk of developing cardiovascular disease, including heart disease and stroke [NIDDKD no date]. NFPA 1582 considers diabetes to be a condition that could impair the ability to safely perform emergency operations requiring prolonged periods of strenuous exertion without access to meals, hydration, rest periods, or medications. Duty limitations are recommended unless the fire fighter meets a number of specific medical criteria. Apart from the acute events in 2012 and 2013, the FF did not see a physician regularly, and there is no documentation of controlled blood glucose levels as recommended by 1582 [NFPA 2013A].

Occupational Medical Standards for Structural Fire Fighters

NFPA 1582 provides guidance on the components of preplacement and annual medical evaluations and medical criteria for determining fitness for duty [NFPA 2013a]. The FF was scheduled to have a medical evaluation the year after his death. The information available to the NIOSH investigator indicates that the FF should not have been cleared for unrestricted fire fighting duty because of the severity of his heart disease and low aerobic capacity.

Recommendations

Recommendation #1: Ensure that all fire fighters 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 2013a]. These evaluations are completed to determine the medical ability of fire fighters to perform duties without presenting a significant risk to the safety and health of themselves or others.

Recommendation #2: Ensure that fire fighters are cleared for duty by a physician knowledgeable about the physical demands of fire fighting, the personal protective equipment used by fire fighters, and the various components of NFPA 1582.

Discussion: According to NFPA 1582, the FD should require that physicians be familiar with the physical demands of fire fighting and the hazards fire fighters encounter and should guide, direct, and advise members with regard to their health, fitness, and suitability for duty [NFPA 2013a]. The physician should review job descriptions and essential job tasks required for all FD positions to understand the physiological and psychological demands of fire fighting and the environmental conditions under which fire fighters perform, as well as the personal protective equipment they must wear during various types of emergency operations. This information is utilized to evaluate members and identify conditions that could affect their ability to safely respond to and engage in emergency operations. When medical conditions or lab abnormalities are found, the physician should provide a copy of the abnormal results and instruct the fire fighter to follow up with his or her primary care physician.

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

Discussion: Workplace health promotion and wellness programs have been demonstrated to be cost effective by increasing productivity, decreasing absenteeism, and reducing work-related injuries and lost work days [Aldana 2001; Stein et al. 2000]. Health promotion programs for fire fighters have been shown to reduce coronary heart disease risk factors and improve fitness levels, with mandatory programs producing the greatest benefit [Blevins et al. 2006; Dempsey et al. 2002; Womack et al. 2005]. Guidance for fire department wellness/fitness programs to reduce cardiovascular risk factors and improve aerobic capacity is found in NFPA 1583 *Standard on Health-Related Fitness Programs for Fire Fighters* [NFPA 2015], the *Fire Service Joint Labor Management Wellness/Fitness Initiative* [IAFF, IAFC 2008], the *Health and Wellness Guide for the Volunteer Fire and Emergency Services* [USFA 2009], and in *Firefighter Fitness: A Health and Wellness Guide* [Schneider 2010].

The FD does not have a wellness/fitness program. Given the FD's structure and budget limitations, resources that may be helpful for starting a program include the National Volunteer Fire Council's *Heart-Healthy Firefighter Program* [NVFC, no date], and the *Health and Wellness Guide for the Volunteer Fire and Emergency Services* [USFA 2009].

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

Discussion: NFPA 1500, *Standard on Fire Department Occupational Safety and Health Program,* recommends that members who engage in emergency operations be evaluated annually and certified

by the FD as having met the physical performance requirements identified in paragraph 10.2.3 of the standard [NFPA 2013b]. The purpose is to ensure fire fighters are physically capable of performing the essential job tasks of structural fire fighting. The physical ability test could be performed as part of the FD's annual training program.

References

ADA [2014]. Diagnosing diabetes and learning about prediabetes. Arlington, VA: American Diabetes Association, http://www.diabetes.org/are-you-at-risk/prediabetes/.

AHA [2015]. Ejection fraction heart failure measurement. Dallas, TX: American Heart Association, http://www.heart.org/HEARTORG/Conditions/HeartFailure/DiagnosingHeartFailure/Ejection-Fraction-Heart-Failure-Measurement_UCM_306339_Article.jsp#.WOQUfcJU270.

AHA [2016]. Understand your risks to prevent a heart attack. Dallas, TX: American Heart Association, http://www.heart.org/HEARTORG/Conditions/HeartAttack/UnderstandYourRiskofHeartAttack/Understand-Your-Risk-of-Heart-Attack_UCM_002040_Article.jsp.

Albert CM, Mittleman MA, Chae CU, Lee IM, Hennekens CH, Manson JE [2000]. Triggering of sudden death from cardiac causes by vigorous exertion. N Engl J Med *343*(19):1355–1361, http://dx.doi.org/10.1056/NEJM200011093431902.

Aldana SG [2001]. Financial impact of health promotion programs: a comprehensive review of the literature. Am J Health Promot *15*(5):296–320, http://dx.doi.org/10.4278/0890-1171-15.5.296.

Bauml MA, Underwood DA [2010]. Left ventricular hypertrophy: an overlooked cardiovascular risk factor. Cleve Clin J Med *77*(6):381–387, http://dx.doi.org/10.3949/ccjm.77a.09158.

Blevins JS, Bounds R, Armstrong E, Coast JR [2006]. Health and fitness programming for fire fighters: does it produce results? Med Sci Sports Exerc *38*(5):S454.

Blumenthal RS, Epstein AE, Kerber RE [2007]. Expert panel recommendations. Cardiovascular disease and commercial motor vehicle driver safety. Washington, DC: Federal Motor Carrier Safety Administration, https://www.fmcsa.dot.gov/regulations/medical/expert-panel-recommendations-cardiovascular-disease-and-commercial-motor-vehicle.

Chatterjee S, Bavishi C, Sardar P, Agarwal V, Krishnamoorthy P, Grodzicki T, Messerli FH [2014]. Meta-analysis of left ventricular hypertrophy and sustained arrhythmias. Am J Cardiol *114*(7):1049–1052, http://dx.doi.org/10.1016/j.amjcard.2014.07.015.

Connolly HM, Oh JK [2012]. Echocardiography. In: Bonow RO, Mann DL, Zipes DP, Libby P, Braunwald E, eds. Heart disease: a text of cardiovascular medicine. 9th ed. Vol. 1. Philadelphia, PA: Elsevier Saunders.

Cramariuc D, Gerdts E [2016]. Epidemiology of left ventricular hypertrophy in hypertension: implications for the clinic. Expert Rev Cardiovasc Ther *14*(8):915–926, http://dx.doi.org/10.1080/14779072.2016.1186542.

Cuspidi C, Rescaldani M, Sala C, Grassi G [2014]. Left-ventricular hypertrophy and obesity: a systematic review and meta-analysis of echocardiographic studies. J Hypertens *32*(1):16–25, http://dx.doi.org/10.1097/HJH.0b013e328364fb58.

Davies MJ [1992]. Anatomic features in victims of sudden coronary death. Coronary artery pathology. Circulation *85*[Suppl I]:I-19–24, PMID: 1728500.

Dempsey WL, Stevens SR, Snell CR [2002]. Changes in physical performance and medical measures following a mandatory firefighter wellness program. Med Sci Sports Exerc *34*(5):S258.

Destors M, Tamisier R, Baguet JP, Levy P, Pepin JL [2014]. Cardiovascular morbidity associated with obstructive sleep apnea syndrome. Abstract. Rev Mal Respir *31*(4):375–385, http://dx.doi.org/10.1016/j.rmr.2013.12.003.

Franklin BA, George P, Henry R, Gordon S, Timmis GC, O'Neill WW [2001]. Acute myocardial infarction after manual or automated snow removal. Am J Cardiol *87*(11):1282–1283, PMID: 11377355.

Gries RE, Brooks LJ [1996]. Normal oxyhemoglobin saturation during sleep. How low does it go? Chest *10*(6):1489–1492, PMID: 8989066.

IAFF, IAFC [2008]. The fire service joint labor management wellness/fitness initiative. 3rd ed. Washington, DC: International Association of Fire Fighters, International Association of Fire Chiefs.

Kahan T, Bergfeldt L [2005]. Left ventricular hypertrophy in hypertension: its arrhythmogenic potential. Heart *91*(2):250–256, http://dx.doi.org/10.1136/hrt.2004.042473.

Kales SN, Soteriades ES, Christoudias SG, Christiani DC [2003]. Firefighters and on-duty deaths from coronary heart disease: a case control study. Environ health: a global access science source *2*(1):14, PMID: 14613487.

Kales SN, Soteriades ES, Christophi CA, Christiani DC [2007]. Emergency duties and deaths from heart disease among fire fighters in the United States. N Engl J Med *356*(12):1207–1215, http://dx.doi.org/10.1056/NEJMoa060357.

Korre M, Porto LGG, Farioli A, Yang J, Christiani DC, Christophi CA, Lombardi DA, Kovacs RJ, Mastouri R, Abbasi S, Steigner M, Moffatt S, Smith D, Kales SN [2016]. Effect of body mass index on left ventricular mass in career male firefighters. Am J Cardiol *118*(11):1769–1773, http://dx.doi.org/10.1016/j.amjcard.2016.08.058.

Kuehl KS, Elliot DL, Goldberg L, Moe EL, Perrier E, Smith J [2013]. Economic benefit of the PHLAME wellness programme on firefighter injury. Occup Med *63*(3):203–209, http://dx.doi.org/10.1093/occmed/kqs232.

Libby P [2013]. Mechanisms of acute coronary syndromes and their implications for therapy. N Engl J Med *368*(21):2004–2013, http://dx.doi.org/10.1056/NEJMra1216063.

Mansukhani MP, Wang S, Somers VK. Sleep, death, and the heart [2015]. Am J Physiol Heart Circ Physiol *309*(5):H739-749, http://dx.doi.org/10.1152/ajpheart.00285.2015.

Meyerburg RJ, Castellanos A [2008]. Cardiovascular collapse, cardiac arrest, and sudden cardiac death. In: Fauci AS, Braunwald E, Kasper DL, Hauser SL, Longo DL, Jameson JL, Loscalzo J, eds. Harrison's principles of internal medicine. 17th ed. New York: McGraw-Hill.

Mittleman MA, Maclure M, Tofler GH, Sherwood JB, Goldberg RJ, Muller JE [1993]. Triggering of acute myocardial infarction by heavy physical exertion. N Engl J Med *329*(23):1677–1683, http://dx.doi.org/10.1056/NEJM199312023292301.

NFPA [2015]. Standard on health-related fitness programs for fire fighters. Quincy, MA: National Fire Protection Association. NFPA 1583.

NFPA [2013a]. Standard on comprehensive occupational medical program for fire departments. Quincy, MA: National Fire Protection Association. NFPA 1582.

NFPA [2013b]. Standard on fire department occupational safety and health program. Quincy, MA: National Fire Protection Association. NFPA 1500.

NHLBI [no date]. Calculate your Body Mass Index. Bethesda, MD: U.S. Department of Health and Human Services, National Institutes of Health, National Heart, Lung, and Blood Institute, https://www.nhlbi.nih.gov/health/educational/lose_wt/BMI/bmi-m.htm. Date accessed: August 2016.

NHLBI [2005]. High blood cholesterol: what you need to know. Bethesda, MD: U.S. Department of Health and Human Services, National Institutes of Health, National Heart, Lung, and Blood Institute, https://www.nhlbi.nih.gov/health/resources/heart/heart-cholesterol-hbc-what-html.

NHLBI [2010]. What is hypotension? Bethesda, MD: U.S. Department of Health and Human Services, National Institutes of Health, National Heart, Lung, and Blood Institute, https://www.nhlbi.nih.gov/health/health-topics/topics/hyp.

NHLBI [2015]. Description of high blood pressure. Bethesda, MD: U.S. Department of Health and Human Services, National Institutes of Health, National Heart, Lung, and Blood Institute, https://www.nhlbi.nih.gov/health/health-topics/topics/hbp.

NHLBI [2016]. Who is at risk for coronary heart disease? Bethesda, MD: U.S. Department of Health and Human Services, National Institutes of Health, National Heart, Lung, and Blood Institute, http://www.nhlbi.nih.gov/health/health-topics/topics/cad/atrisk.html.

NIDDKD [no date]. Diabetes, heart disease, and stroke. Bethesda, MD: U.S. Department of Health and Human Services, National Institutes of Health, National Institute of Diabetes and Digestive and Kidney Diseases, https://www.niddk.nih.gov/health-information/diabetes/overview/preventing-problems/heart-disease-stroke. Date accessed: June 2017.

NIOSH [2007]. NIOSH alert: preventing fire fighter fatalities due to heart attacks and other sudden cardiovascular events. Cincinnati, OH: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 2007-133, http://www.cdc.gov/niosh/docs/2007-133.

NVFC [no date]. Heart-Healthy Firefighter Program. Greenbelt, MD: National Volunteer Fire Council, http://www.healthy-firefighter.org/about-the-heart-healthy-firefighter-program. Date accessed: April 2017.

Patil SP, Schneider H, Schwartz AR, Smith PL [2007]. Adult obstructive sleep apnea: pathophysiology and diagnosis. Chest *132*(1):325–337, PMID: 17625094.

Quest Diagnostics [2017]. LDL cholesterol calculations. Madison, NJ: Quest Diagnostics, http://education.questdiagnostics.com/faq/FAQ164.

Schneider EL [2010]. Firefighter fitness: a health and wellness guide. New York: Nova Science Publishers.

Siegel RJ [1997]. Myocardial hypertrophy. In: Bloom S, ed. Diagnostic criteria for cardiovascular pathology acquired diseases. Philadelphia, PA: Lippencott-Raven.

Somers VK, White DP, Amin R, Abraham WT, Costa F, Culebras A, Daniels S, Floras JS, Hunt CE, Olson LJ, Pickering TG, Russell R, Woo M, Young T; American Heart Association Council for High Blood Pressure Research Professional Education Committee, Council on Clinical Cardiology; American Heart Association Stroke Council; American Heart Association Council on Cardiovascular Nursing; American College of Cardiology Foundation [2008]. Sleep apnea and cardiovascular disease: an American Heart Association/American College of Cardiology Foundation Scientific Statement from the American Heart Association Council for High Blood Pressure Research Professional Education Committee, Council on Clinical Cardiology, Stroke Council, and Council on Cardiovascular Nursing. In collaboration with the National Heart, Lung, and Blood Institute National Center on Sleep Disorders Research (National Institutes of Health). Circulation *118*(10):1080–1111, http://dx.doi.org/10.1161/CIRCULATIONAHA.107.189375.

Spirito P, Autore C, Rapezzi C, Bernabò P, Badagliacca R, Maron MS, Bongioanni S, Coccolo F, Estes NA, Barillà CS, Biagini E, Quarta G, Conte MR, Bruzzi P, Maron BJ [2009]. Syncope and risk of sudden death in hypertrophic cardiomyopathy. Circulation *119*(13):1703–1710, http://dx.doi.org/10.1161/CIRCULATIONAHA.108.798314.

Steenland K [2000]. Shift work, long hours, and cardiovascular disease: a review. In: Schnall PL, Belkic K, Landsbergis P, Baker D, eds. The workplace and cardiovascular disease. Occupational Medicine: State of the Art Reviews *15*(1):7–17. Philadelphia, PA: Hanley and Belfus, Inc.

Steenland K, Fine L, Belkić K, Landsbergis P, Schnall P, Baker D, Theorell T, Siegrist J, Peter R, Karasek R, Marmot M, Brisson C, Tüchsen F [2000]. Research findings linking workplace factors to CVD outcomes. Occup Med *15*(1):7–68, PMID: 10620786.

Stein AD, Shakour SK, Zuidema RA [2000]. Financial incentives, participation in employer sponsored health promotion, and changes in employee health and productivity: HealthPlus health quotient program. J Occup Environ Med *42*(12):1148–1155, PMID: 11125677.

Tavora F, Zhang Y, Zhang M, Li L, Ripple M, Fowler D, Burke A [2012]. Cardiomegaly is a common arrhythmogenic substrate in adult sudden cardiac deaths, and is associated with obesity. Pathology *44*(3):187–191, http://dx.doi.org/10.1097/PAT.0b013e3283513f54.

USFA [2009]. Health and Wellness Guide for the Volunteer Fire and Emergency Services. Emmitsburg, MD: Federal Emergency Management Agency; United States Fire Administration. Publication No. FA-321, https://www.usfa.fema.gov/downloads/pdf/publications/fa_321.pdf.

Weber JR [1991]. Left ventricular hypertrophy: Its prevalence, etiology, and significance. Clin Cardiol *14*:13–17, http://dx.doi.org/10.1002/clc.4960140704.

Willich SN, Lewis M, Lowel H, Arntz HR, Schubert F, Schroder R [1993]. Physical exertion as a trigger of acute myocardial infarction. N Engl J Med *329*(23):1684–1690, http://dx.doi.org/10.1056/NEJM199312023292302.

Womack JW, Humbarger CD, Green JS, Crouse SF [2005]. Coronary artery disease risk factors in firefighters: effectiveness of a one-year voluntary health and wellness program. Med Sci Sports Exerc *37*(5):S385.

Investigator Information

This incident was investigated by the NIOSH Fire Fighter Fatality Investigation and Prevention Program, Cardiac and Medical Line-of-Duty Deaths (LODD) Investigations Team, located in Cincinnati, Ohio. Denise L. Smith, Ph.D., led the investigation and authored the report. Dr. Smith is a Professor of Health and Exercise Sciences and Director of the First Responder Health and Safety Laboratory at Skidmore College, where she was awarded the Tisch Family Distinguished Professorship in 2017. She is also a member of the NFPA Technical Committee on Occupational Safety and Health. Dr. Smith was working as a contractor with the NIOSH Fire Fighter Fatality Investigation and Prevention Program, Cardiac and Medical LODD Investigations Team, during this investigation. Wendi Dick, MD, MSPH, provided medical consultation and contributed to the report. Dr. Dick is Lead for the Cardiac and Medical LODD Investigations Team in Cincinnati.

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Fire Fighter Dies of Heart Attack After Skills Training the Previous Night - New Hampshire

Appendix A

Autopsy Findings

- Hypertension (clinical history)
  - Cardiomegaly with concentric left ventricular hypertrophy (heart weighed 822 grams; predicted normal weight is 476 grams [ranges between 358 and 624 grams as a function of sex and body weight]) [Silver and Silver 2001]
  - Left ventricular wall – 2.0 cm
    - Normal at autopsy is 0.76–0.88 cm [Colucci and Braunwald 1997]
  - Right ventricular wall – 0.3 cm
    - Normal at autopsy is 0.2–0.7 cm with an average of 0.35–0.39 cm [Hutchins and Anaya 1973; Murphy et al. 1988]
- Coronary artery and aortic atherosclerosis
  - Stents through the majority of the left anterior descending artery and mid segment of the right coronary artery with superimposed severe atherosclerotic disease as evidenced by up to 90% narrowing of the vessel lumens
  - 90% stenosis of the left circumflex artery
- Occlusive tan-red thrombus in proximal right coronary artery
- Normal cardiac valves
- Aorta exhibits multifocal and confluent atheromatous plaques with calcification of the infrarenal aorta
- Microscopic examination
  - Sections of left ventricle and right ventricle show generalized myocyte hypertrophy and patchy interstitial and perivascular fibrosis
  - Section of left ventricle shows dense transmural replacement fibrosis and adjacent hypertrophied myocytes
  - Section of left ventricle shows atrophied and vacuolated subendocardial myocytes with surrounding interstitial congestion and coagulative necrosis
  - Sections of coronary arteries show high grade atheromatous plaques with calcification and perivascular chronic inflammation

- No evidence of a pulmonary embolus (blood clot in the lung arteries)
- Negative blood test for drugs of abuse

REFERENCES

Colucci WS, Braunwald E [1997]. Pathophysiology of heart failure. In: Braunwald, ed. Heart disease. 5th ed. Philadelphia, PA: W.B. Saunders Company.

Hutchins GM, Anaya OA [1973]. Measurements of cardiac size, chamber volumes and valve orifices at autopsy. Johns Hopkins Med J *133*(2):96–106, PMID: 4737243.

Murphy ML, White HJ, Meade J, Straub KD [1988]. The relationship between hypertrophy and dilatation in the postmortem heart. Clin Cardiol *11*(5):297–302, http://dx.doi.org/10.1002/clc.4960110505.

Silver MM, Silver MD [2001]. Examination of the heart and of cardiovascular specimens in surgical pathology. In: Silver MD, Gotlieb AI, Schoen FJ, eds. Cardiovascular pathology. 3rd ed. Philadelphia, PA: Churchill Livingstone.