Fire Fighter/Paramedic Suffers Heart Attack After Performing Physical Fitness Training and Dies— Minnesota

Executive Summary

In August 2015, a 38-year old fire fighter/paramedic (FF/P) was working a 24-hour shift. During the shift he responded to five calls. He then exercised for about 1 hour in his fire station's gym. After showering, he developed chest tightness. He analyzed his own heart rhythm on a cardiac monitor, entered a restroom, and collapsed. Crew members found the FF/P. They began cardiopulmonary resuscitation (CPR) and advanced life support. They defibrillated the FF/P five times. Then they transported him to the hospital's emergency department (ED). ED staff continued CPR and advanced life support. The FF/P was taken emergently to the cardiac catheterization lab. Coronary angiography and balloon angioplasty revealed a totally occluded left anterior descending coronary artery. A stent was placed and the artery opened. However, the FF/P's heart rhythm remained in pulseless electrical activity/asystole and he was pronounced dead.

The death certificate and the autopsy report listed "coronary artery thrombosis due to atherosclerotic heart disease" as the cause of death. They also listed "coronary vessel disease – coronary sclerosis" as a contributing factor. The FF/P's biventricular hypertrophy and coronary heart disease were undiagnosed before this incident. These underlying conditions and the exertion of physical fitness training contributed to the FF/P's heart attack. The heart attack resulted in his death.

Key Recommendations

The following recommendations address general safety and health issues and would not have prevented the FF/P's death:

- *Ensure that fire fighters are cleared for return to duty by a physician knowledgeable about the physical demands of fire fighting, the personal protective equipment used by fire fighters, and the components of National Fire Protection Association (NFPA) 1582*
- *Perform an annual physical ability evaluation*
- *Phase in a mandatory comprehensive wellness and fitness program for fire fighters*

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The National Institute for Occupational Safety and Health (NIOSH), an institute within the Centers for Disease Control and Prevention (CDC), is the federal agency responsible for conducting research and making recommendations for the prevention of work-related injury and illness. In 1998, Congress appropriated funds to NIOSH to conduct a fire fighter initiative that resulted in the NIOSH Fire Fighter Fatality Investigation and Prevention Program, which examines line-of-duty deaths or on-duty deaths of fire fighters to assist fire departments, fire fighters, the fire service, and others to prevent similar fire fighter deaths in the future. The agency does not enforce compliance with state or federal occupational safety and health standards and does not determine fault or assign blame. Participation of fire departments and individuals in NIOSH investigations is voluntary. Under its program, NIOSH investigators interview persons with knowledge of the incident who agree to be interviewed and review available records to develop a description of the conditions and circumstances leading to the death(s). Interviewees are not asked to sign sworn statements and interviews are not recorded. The agency's reports do not name the victim, the fire department or those interviewed. The NIOSH report's summary of the conditions and circumstances surrounding the fatality is intended to provide context to the agency's recommendations and is not intended to be definitive for purposes of determining any claim or benefit.

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 August 31, 2015, a 38-year old FF/P suffered a heart attack after exercising in his fire station's gym and died after cardiac catheterization. NIOSH was notified of this fatality on September 1, 2015, by the U.S. Fire Administration. NIOSH contacted the affected fire department on September 1, 2015, to gather additional information and on January 11, 2016, to initiate the investigation. On January 19, 2016, a safety and occupational health specialist from 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
- Assistant Chief of Operations
- Assistant Chief of Emergency Medical Services
- Deputy Chief of Training
- Senior Human Resources Consultant
- International Association of Fire Fighters local President
- Crew members
- FF/P's family

NIOSH personnel reviewed the following documents:
- Fire Department standard operating guidelines
- Fire Department annual report for 2015
- Emergency medical service (ambulance) report
- Hospital ED records
- Hospital cardiac catheterization records
- Death certificate
- Autopsy report
- Fire Department medical evaluation records

Investigation

On August 31, 2015, the FF/P arrived at his fire station at about 0700 hours for his 24-hour shift. The FF/P was assigned to Engine 14/Medic 14. During the shift, he responded on Engine 14 to an alarm call and one natural gas odor call. He also responded in Medic 14 to three medical calls. Between responses, the FF/P performed station duties and equipment checks.

After returning to the fire station from the last call at about 1600 hours, the FF/P went to the gym to exercise. He and his Captain did pushups and lunges. They also did a low weight circuit involving 4-5 exercises at each station for about 45 seconds each. Then they did abdominal strength exercises for about 10 minutes. The entire fitness period lasted about 1 hour. The FF/P then showered and went downstairs. He mentioned to a crew member that his chest felt tight. He connected himself to a cardiac monitor utilizing three of the twelve leads. The crew member suggested the FF/P go to the hospital for evaluation. The FF/P walked inside the radio room and into the restroom. Shortly, crew members heard a sound and checked on the FF/P. They found him collapsed and unresponsive.

Crewmembers began CPR and advanced life support. Dispatch was notified and a transport ambulance was requested (1713 hours). A cardiac monitor revealed ventricular fibrillation and one shock was administered. The FF/P was intubated; an intravenous (IV) line was placed, and cardiac resuscitation medications were administered. Oxygen was administered via bag-valve-mask. After three additional defibrillations were given, the FF/P regained consciousness. He fought resuscitation efforts and removed the endotracheal tube. His heart rhythm transitioned between sinus bradycardia (slow heart beat), pulseless electrical activity, and asystole (no heart beat). CPR resumed as the transport ambulance arrived at 1718 hours. A King Airway® was placed and one additional defibrillation attempt was made. The FF/P was put into the ambulance which left the scene at 1720 hours en route to the ED. Proper intubation tube placement was confirmed by capnography [Neumar et al. 2010]. CPR continued en route to the ED with no positive change in the FF/P's clinical status. The ambulance arrived at the ED at 1725 hours.

Inside the ED, CPR and advanced life support continued. A cardiac monitor revealed pulseless electrical activity as additional cardiac resuscitation medications were administered. Spontaneous circulation returned briefly but shortly the initial heart rhythm was lost. The FF/P remained in cardiac standstill. He was intubated with proper intubation tube placement confirmed by capnography [Neumar et al. 2010].

At 1750 hours, the FF/P was taken to the cardiac catheterization lab. Catheterization revealed an occluded left anterior descending coronary artery, a 60% occluded obtuse marginal coronary artery, and a 60% occluded distal right coronary artery. An aspiration thrombectomy was successful in removing the thrombus (blood clot). Balloon angioplasty was performed and a drug-eluting stent was placed in the proximal left anterior descending coronary artery. An echocardiogram revealed a left ventricular ejection fraction of 60%, trace mitral valve regurgitation, and trace tricuspid regurgitation. Cardiac pacing was attempted but was not successful. The FF/P's heart rhythm remained in asystole. After medical consultation, resuscitation efforts were stopped. The FF/P was pronounced dead at 1850 hours.

Medical Findings

The death certificate and the autopsy report were completed by the Medical Examiner. They listed "coronary artery thrombosis due to atherosclerotic heart disease" as the cause of death with "coronary vessel disease – coronary sclerosis" as a contributing factor. The FF/P had the following medical conditions:

Hypertension (Stage I, defined as 140-159 millimeters of mercury [mmHg] systolic or 90-99 mmHg diastolic) (Stage II, defined as >160 mmHg systolic or > 100 mmHg diastolic) - first diagnosed in 2009 and began prescription anti-hypertensive medication in 2012. Despite treatment, his blood pressure fluctuated between normal, Stage I, and Stage II. A blood pressure reading during a hospital visit on January 29, 2015 for an ankle sprain was 172/97 mmHg (normal is 120/80), classified as Stage II. His last reading, during his fire department medical evaluation, was normal (122/80 mmHg).

Hyperlipidemia – first diagnosed in 2012 but was not prescribed a lipid-lowering medication.

Obesity – The FF/P was 73 inches tall and weighed 238 pounds at autopsy, giving him a body mass index of 31.4 kilograms per meters squared [CDC 2015].

Fire Department

At the time of the NIOSH investigation, the fire department consisted of 15 fire stations with 434 career uniformed personnel. It served 285,000 residents in a geographic area of 56 square miles. In 2015, the fire department responded to 42,868 incidents: 10,234 fire calls and 32,634 emergency medical calls.

Employment and Training

The fire department requires new career fire fighter/emergency medical technician (EMT) applicants to be 18 years of age; have a high school diploma or a general education development diploma; have a valid state driver's license; have a current state EMT certification; pass a written aptitude exam; pass a physical agility test (see Appendix B); pass a background check; and have an oral interview prior to being offered conditional employment. The conditional hire must then pass a preplacement medical evaluation (described below), a drug screen, a driver's license check, a credit check, and a psychological screening prior to being offered full employment. The new member is on probation for 1 year. The member then attends the 16-week Fire Fighter Academy to be trained to the NFPA 1001 Fire Fighter I and II, Hazardous Material Operations, state certification board, and International Fire Service Accreditation Congress Fire Fighter I and II levels. The State requires career fire fighter candidates to meet the State Minimum Standards and Certification Board guideline, which is the NFPA 1001, *Standard for Fire Fighter Professional Qualifications* [NFPA 2013a]. New members are placed on a 24-hour shift and work 24-hours on duty, 24-hours off-duty for four tours, then are off six days; 24-hours on duty, 24-hours off-duty for four tours, then are off four days (averaging 10-11 days per month and 56 hours per week). The new hire must complete a 3-year journey level apprenticeship, maintain EMT or paramedic certification, maintain a fire fighter license, and pass other annual certifications as required by the Occupational Safety and Health Administration. The FF/P was certified as a fire fighter II, driver/operator, emergency medical technician-paramedic, in hazardous materials operations, and in technical rescue. He had 8 years of fire fighting experience**.**

Preplacement Medical Evaluation

The fire department requires preplacement medical evaluations for all applicants conducted by a fire department contract physician. Components of this evaluation include the following:

- Complete medical history
- Physical examination (including vital signs – height, weight, blood pressure, pulse, and respirations)
- Urine drug screen
- Audiogram
- Respirator use questionnaire
- Spirometry
- Vision test
- TB Mantoux test

- Urinalysis
- Resting electrocardiogram
- Chest x-ray (baseline)
- Complete blood count with lipid panel

Once this evaluation is complete, the contracted physician makes a determination regarding medical clearance for fire fighting duties and forwards this decision to the fire department human resources office. The FF/P passed his preplacement medical evaluation in 2007.

Periodic Medical Evaluations/Return to Work Medical Evaluations

Annual medical evaluations are required by the fire department and are conducted by a different fire department contract physician than the one doing the preplacement evaluation. Components of this evaluation include the following:

- Complete medical history
- Physical examination (including vital signs – height, weight, blood pressure, pulse, and respirations)
- Audiogram
- Spirometry
- Urinalysis
- Resting 12-lead electrocardiogram
- Chem 23 blood test

Medical clearance to wear self-contained breathing apparatus is required. The FF/P passed his periodic medical evaluation in April 2015. Members injured on duty may be evaluated by the fire department contracted physician or the member's primary care physician (in consultation with the fire department physician). Results are provided to the fire department human resources office, which makes the final determination regarding return to work. Members who are ill and miss three shifts must be evaluated by their primary care physician who makes the final determination regarding return to work.

Wellness/Fitness Programs

The fire department does not have a comprehensive wellness/fitness program as recommended by the IAFF/IAFC Wellness Fitness Initiative [IAFF, IAFC 2008]. Fitness equipment (strength and aerobic) is available in the fire stations and members are encouraged to exercise while on duty. The FF/P exercised every shift by walking and by doing low impact aerobic and functional fitness exercises.

Discussion

Sudden Cardiac Events

In the United States, atherosclerotic coronary heart disease (CHD) is the most common risk factor for cardiac arrest and sudden cardiac death [Meyerburg and Castellanos 2008]. Risk factors for its development are grouped into non-modifiable and modifiable. Non-modifiable risk factors include age older than 45, male gender, and family history of coronary heart disease. Modifiable risk factors include diabetes mellitus, smoking, high blood pressure, high blood cholesterol, and obesity/physical

inactivity [AHA 2016; NHLBI 2016]. The FF/P had two non-modifiable risk factors (male gender and family history of CHD) and three modifiable CHD risk factors (hypertension, high cholesterol, and obesity [as determined by body mass index]). Severe CHD was found during cardiac catheterization and at autopsy.

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. Heart attacks (myocardial infarctions) typically occur with the sudden development of complete blockage (occlusion) in one or more coronary arteries that have not developed a collateral blood supply. This sudden blockage is primarily due to blood clots (thromboses) forming on top of atherosclerotic plaques [Libby 2013]. Establishing a recent (acute) heart attack requires any of the following: characteristic electrocardiogram changes, elevated cardiac enzymes, or coronary artery thrombus. The FF/P had a coronary artery thrombus (blood clot) that occluded his left anterior descending coronary artery.

Physiological Stress of Firefighting

Heart attacks and sudden cardiac death are also triggered by heavy physical exertion [Mittleman 1993; Willich 1993; Albert et al. 2000]. Among fire fighters, sudden cardiac events have been associated with/triggered by alarm response, fire suppression, and heavy exertion during training (including physical fitness training) [Kales et al. 2003; Kales et al. 2007; NIOSH 2007]. The FF/P's activities during physical fitness training expended between 4.3 and 8.0 metabolic equivalents, which is considered moderate physical activity [Gledhill and Jamnik 1992; Ainsworth et al. 2011]. The heart attack that preceded the FF/P's cardiac death was probably triggered by this exertion.

Occupational Medical Standards for Structural Fire Fighters

To reduce the risk of sudden cardiac arrest or other incapacitating medical conditions among fire fighters, the National Fire Protection Association (NFPA) developed NFPA 1582, *Standard on Comprehensive Occupational Medical Program for Fire Departments* [NFPA 2013b]. This voluntary industry standard provides the components of a preplacement and annual medical evaluation and medical fitness for duty criteria. The FF/P had two conditions addressed by NFPA 1582: poorly controlled Stage II hypertension and beta blocker medication use.

Hypertension. The FF/P fluctuated between normal, Stage I and Stage II hypertension. NFPA 1582 suggests that members with stage I hypertension be referred to their primary care physician to ensure that their blood pressure is controlled and to determine whether screening for end organ damage is indicated [NFPA 2013b]. The FF/P's hypertension was diagnosed in 2009 and was poorly controlled with medication. However, his most recent blood pressure reading at his periodic fire department medical evaluation was normal (122/80 mmHg). He did not have a complete work-up for end organ damage. The autopsy revealed left ventricular hypertrophy (LVH), one complication of hypertension. LVH is associated with an increased risk of sudden incapacitation and sudden cardiac death [Koren et al. 1991].

NFPA considers that Stage II hypertension (systolic ≥160 mmHg or diastolic ≥ 100 mmHg) or end organ damage (retinopathy, nephropathy, neuropathy, or vascular/cardiac complications) compromises the member's ability to safely perform five of the thirteen essential job tasks [NFPA 2013b]. Therefore, according to NFPA 1582, the FF/P should have received further evaluation.

Beta-Blocker Medication. NFPA 1582 considers use of anti-hypertensive beta-blockers to compromise the member's ability to safely perform essential job tasks such as the following: 1) "wearing fire protective ensemble that is encapsulating and insulated, which will result in significant fluid loss that frequently progresses to clinical dehydration and can elevate core temperature to levels exceeding 102.2ºF;" and 2) "wearing personal protective ensemble and SCBA, climbing ladders, operating from heights, walking or crawling in the dark along narrow and uneven surfaces, and operating in proximity to electrical power lines and/or other hazards due to risk for dehydration, electrolyte disorders, lethargy, and disequilibrium, and the physician shall report applicable job limitations to the FD" [NFPA 2013b].

Recommendations

The following recommendations address general safety and health issues and would not have prevented the FF/P's death:

Recommendation #1: Ensure that fire fighters are cleared for return to 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 fire department should have an officially designated physician who is responsible for guiding, directing, and advising the members with regard to their health, fitness, and suitability for duty [NFPA 2013b]. The physician should review job descriptions and essential job tasks required for all fire department positions. The physician must understand the physiological and psychological demands of fire fighters and the environmental conditions under which they must perform, as well as the personal protective equipment they must wear during various types of emergency operations. The fire department allows the member's personal physician to clear fire fighters who miss work due to illness or off-duty injury. Personal physicians may be unaware of the hazardous and physical demands of structural fire fighting and the guidance provided by NFPA 1582.

Recommendation #2: Perform an annual physical ability evaluation.

Discussion: NFPA 1500, Standard on Fire Department Occupational Safety and Health Program, requires a fire department to develop physical performance requirements for candidates and members who engage in emergency operations [NFPA 2013c]. Members who engage in emergency operations must be annually qualified (physical ability test) as meeting these physical performance standards for structural fire fighters [NFPA 2013c]. Once developed by the fire department, this evaluation could be performed as part of its annual training program.

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

Discussion: Guidance for fire department wellness/fitness programs to reduce risk factors for cardiovascular disease and improve cardiovascular capacity is found in the IAFF/IAFC Fire Service Joint Labor Management Wellness/Fitness Initiative, in Firefighter Fitness: A Health and Wellness Guide, and in NFPA 1583, Standard on Health-Related Fitness Programs for Fire Fighters [IAFF, IAFC 2008; Schneider 2010; NFPA 2015]. 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 work days [Pelletier 2009; Baicker et al. 2010]. Fire service health promotion programs have been shown to reduce coronary artery disease risk factors and improve fitness levels, with mandatory programs showing the most benefit [Dempsey et al. 2002; Womack et al. 2005; Blevins et al. 2006; Poston et al. 2013]. A study conducted by the Oregon Health and Science University reported a savings of more than $1 million for each of four large fire departments implementing the IAFF/IAFC wellness/fitness program compared to four large fire departments not implementing a program. These savings were primarily due to a reduction of occupational injury/illness claims with additional savings expected from reduced future nonoccupational healthcare costs [Kuehl et al. 2013].

The fire department does not offer a wellness/fitness program. However, exercise equipment is available in the fire stations. NIOSH recommends a formal, mandatory wellness/fitness program. The program should ensure all members can receive the benefits of a health promotion program.

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Investigator Information

This incident was investigated by the NIOSH Fire Fighter Fatality Investigation and Prevention Program, Cardio Disease Component in Cincinnati, Ohio. Mr. Tommy Baldwin (MS) led the investigation and authored the report. Mr. Baldwin is a Safety and Occupational Health Specialist, a National Association of Fire Investigators (NAFI) Certified Fire and Explosion Investigator, an International Fire Service Accreditation Congress (IFSAC) Certified Fire Officer I, and a former Fire Chief and Emergency Medical Technician.

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Appendix A
Autopsy Findings

- Coronary artery atherosclerosis
  - Coronary artery thrombosis in the left anterior descending coronary artery (at catheterization)
  - 90% focal narrowing in the left circumflex coronary artery
  - 75% focal narrowing in the right coronary artery
  - Stent placement in the proximal and distal portions of the left anterior descending coronary artery; both patent
- Hypertensive heart disease
  - Mild cardiomegaly (heart weighed 505 grams [g]; predicted normal weight is 406 g [ranges between 308 g and 536 g as a function of sex, age, and body weight]) [Silver and Silver 2001]
  - Biventricular hypertrophy
    - Left ventricle thickening (1.7-1.8 centimeters [cm]
      - Normal at autopsy is 0.76–0.88 cm [Colucci and Braunwald 1997]
      - Normal by echocardiographic measurement is 0.6–1.0 cm [Connolly and Oh 2012]
    - Right ventricle thickening (0.7-0.8 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]
      - Normal by echocardiography 0.7–2.3 cm [Armstrong and Feigenbaum 2001]
- Normal cardiac valves
- No evidence of a pulmonary embolus (blood clot in the lung arteries)
- Negative blood test for drugs and alcohol

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Appendix B
Candidate and Annual Physical Ability Test

The physical agility tests consist of the following components:

- Climb stairs while carrying a hose bundle
- Drag a charged hoseline
- Pull a 175-pound rescue mannequin
- Carry a fan
- Perform an exercise which simulates ventilation or chopping through a roof

Maximum allowed time total for modified Candidate Physical Ability Test: 7 minutes.