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Death in the line of duty...

NIOSH
Fire Fighter Fatality Investigation and Prevention Program

A summary of a NIOSH fire fighter fatality investigation *September, 2011*

Fire Fighter Suffers On-Duty Sudden Cardiac Death – Missouri

Executive Summary

On October 23, 2010, a 37-year-old male career fire fighter (FF) was working a 24-hour shift as the driver/operator of the tanker. During the shift he responded to two emergency calls. At the first call, a dwelling fire, the FF participated in interior structural fire fighting. At the second fire, a mutual aid call, the FF provided water supply. During the remainder of the shift, the FF performed about 2 hours of physical fitness training. That evening, he was having trouble falling asleep and remained in the day room where he sent a text message to a friend at midnight. The next morning crew members found the FF deceased and notified the coroner.

The death certificate listed "sudden cardiac death probably exasperated (sic) or induced by overexertion fighting two structure fires while on duty" as the cause of death. The autopsy listed "cardiac arrhythmia secondary to dilated hypertrophic cardiomyopathy and severe arteriosclerotic cardiovascular disease" as the cause of death. Given the FF's underlying dilated hypertrophic cardiomyopathy, NIOSH investigators concluded that the physical stress of fire suppression activities and physical fitness training triggered a fatal heart arrhythmia.

NIOSH investigators offer the following recommendations to address general safety and health issues. It is unclear, however, whether these recommendations could have prevented the FF's death.

NIOSH investigators offer the following recommendations to address general safety and health issues. It is unlikely, however, that any of these recommendations would have prevented the Trainee's death.

Provide preplacement and annual medical evaluations to all fire fighters in accordance with NFPA 1582, Standard on Comprehensive Occupational Medical Program for Fire Departments.

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.

Phase in a mandatory comprehensive wellness and fitness program for fire fighters.

Perform a candidate and an annual physical performance (physical ability) evaluation for all members.

Provide fire fighters with medical clearance to wear a self-contained breathing apparatus (SCBA) as part of the Fire Department's medical evaluation program.

Fire Fighter Suffers On-Duty Sudden Cardiac Death – Missouri

Introduction & Methods

On October 24, 2010, a 37-year-old male career FF suffered an on-duty sudden cardiac death at his fire station. NIOSH contacted the affected Fire Department (FD) on November 10, 2010, to gather additional information, and on May 10, 2011, to initiate the investigation. On May 16, 2011, 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
- Crew members
- FF's spouse

NIOSH personnel reviewed the following documents:
- FD standard operating procedures
- FD annual report for 2010
- FD incident reports
- Death certificate
- Autopsy report
- Primary care physician records

Investigative Results

Incident. On October 23, 2010, the FF reported for his 24-hour shift at 0700 hours. He was assigned as the driver/operator of the tanker. During the shift the FF responded to two fire calls.

The first call (1307 hours) was a residential fire. Arriving at the scene as the second-in apparatus, the FF connected the water supply and assisted the engine crew in interior fire suppression wearing full turnout gear and SCBA (on-air). The fire was extinguished, and the companies were released at 1412 hours to return to the station.

Investigative Results (cont.)

The second response (1539 hours) was a mutual aid call for a residential garage fire. The FF drove the tanker to the scene and assisted with water supply. The fire was extinguished, and the crews were released at 1711 hours to return to the station. No additional calls came in during the shift. However, the FF performed physical fitness training by jogging on a treadmill and lifting weights for approximately 2 hours (1800 hours to 2000 hours).

At the end of the day, the FF complained to crew members of being tired but was unable to sleep. He remained in the day room for the night, and at 2400 hours he sent a text message to a friend. Crew members arose at approximately 0600 hours and upon entering the day room, found the FF deceased. Resuscitation efforts were not begun due to the obvious signs that the FF had died many hours earlier. The county coroner was notified; time of death was estimated at 0300 hours.

Medical Findings. The death certificate, completed by the county coroner, listed "sudden cardiac death probably exasperated (sic) or induced by overexertion fighting two structure fires while on duty" as the cause of death. The autopsy, completed by the state medical examiner, listed "cardiac arrhythmia secondary to dilated hypertrophic cardiomyopathy and severe arteriosclerotic cardiovascular disease" as the cause of death. Specific findings from the autopsy are listed in Appendix A.

On November 25, 2009, the FF suffered a cardiopulmonary arrest while on duty. The FF was successfully resuscitated and underwent emergency cardiac catheterization. The cardiac catheterization

Investigative Results (cont.)

showed (1) an enlarged heart with mild to moderate coronary artery disease (CAD) but no heart attack, (2) dilated cardiomyopathy with severe left ventricular dysfunction (left ventricular ejection fraction [LVEF] of about 25%), and (3) regional wall motion hypokinesis and akinesis. Subsequent echocardiograms showed the wall motion and LVEF returned to normal upon his discharge on November 30, 2009. The cause of his arrest was thought to be either dilated cardiomyopathy or anaphylactic reaction to an unknown antigen resulting in respiratory arrest and subsequent cardiac arrest. The only residual cardiac abnormality appeared to be a conduction disorder known as left bundle branch block.

The FF exercised 11 minutes, 46 seconds on the Bruce protocol, achieving 12.8 metabolic equivalents 6 weeks later during a treadmill stress echocardiogram. The FF reported no symptoms, and the EKG showed no arrhythmias and a normal blood pressure response to exercise. Ischemic changes on the EKG could not be determined because of the left bundle branch block.

The FF was 69 inches tall and weighed 218 pounds, giving him a body mass index of 32.2 kilograms per meters squared. A body mass index > 30.0 kilograms per meter squared is considered obese [CDC 2011]. The FF's other risk factors for CAD included hypercholesterolemia (high blood cholesterol) and hypertension (high blood pressure), both diagnosed in 2009. He was prescribed a cholesterol-lowering medication and blood pressure-lowering medication since that time. The FF never complained about any cardiac symptoms, but he did have a family history of dilated cardiomyopathy of undetermined cause.

Description of the Fire Department

At the time of the NIOSH investigation, the FD consisted of one fire station with 28 career uniformed personnel and served 13,000 residents in a geographic area of 9 square miles. In 2010, the FD responded to 440 incidents: 29 fire calls, 6 extrication calls, 78 standbys, 326 miscellaneous calls, and 1 false alarm.

Membership and Training. The FD requires new full-time fire fighter applicants to be 21 years of age, have a valid state driver's license, and pass a preplacement medical evaluation and a drug screen. After receiving a job offer, the new hire is placed in the state's 11–12 week rookie school for Fire Fighter 1 and 2 training. Upon graduation, the new hire is on probation for a year and works a 24 hours on-duty/48 hours off-duty schedule. The FF was certified as a Fire Fighter 2, Apparatus Operator, Emergency Medical Technician, First Responder, and in Hazardous Materials Operations and Technical Rescue. He had 6 years of fire fighting experience.

Preplacement Medical Evaluations. The FD requires preplacement medical evaluations for all applicants. Components of the medical evaluation are determined by the applicants' personal physician. Medical records available to NIOSH indicate a preplacement medical evaluation had not been performed on this fire fighter.

Periodic Medical Evaluations. The FD does not require periodic (annual) medical evaluations or medical clearance to wear a respirator. An annual SCBA facepiece fit test is required. Members injured on duty must be evaluated by the city contract physician who forwards his or her determination for return to duty to the FD. The FD has a light duty program while the injured member goes

Description of the FD (cont.)

through rehabilitation with the workers' compensation physician.

Health and Wellness Programs. The FD has a voluntary wellness/fitness program, and exercise equipment is available in the fire station. Exercise time is available (30 minutes per shift) but is not protected time (i.e., the employee is not taken out of service). No annual physical ability test is required. The FD offers 1 extra day off every 6 months as an incentive to exercise every shift. Additionally, the city will pay for use of the YMCA if the member utilizes the facility three times weekly. The FF participated in this program by jogging and lifting weights in the station approximately 2 hours per shift and at the YMCA at least 3 days per week.

Discussion

Cardiomyopathy and Sudden Cardiac Death. The autopsy revealed dilated cardiomyopathy. Cardiomyopathies are conditions that involve damage to the heart muscle not due to hypertension, ischemia (coronary artery disease), valvular, pericardial, or congenital heart disease [Wynne and Braunwald 2008]. The three types of cardiomyopathy based on functional impairment are as follows:

1) dilated, the most common form, which accounts for 60% of all cardiomyopathies
2) hypertrophic, recognized by left ventricular hypertrophy, often with involvement of the interventricular septum and right ventricle
3) restrictive, the least common form in Western countries, marked by impaired diastolic filling and in some cases with endocardial scarring of the ventricle [Wynne and Braunwald 2008]

Discussion (cont.)

The FF had components of both dilated and hypertrophic cardiomyopathy.

Dilated Cardiomyopathy. Dilated cardiomyopathy is characterized by cardiac enlargement and impaired systolic function of one or both ventricles, congestive heart failure, arrhythmias, and emboli [Dec and Fuster 1994]. Microscopic findings are nonspecific, typically being myocyte hypertrophy (best appreciated as nuclear hypertrophy ["boxcar nuclei"]) with varying degrees of interstitial fibrosis [Dec and Fuster 1994; Virmani 1997]. As the ventricular function deteriorates, the following signs and symptoms of congestive heart failure appear: shortness of breath with exertion or when lying flat, ankle swelling, fatigue, and/or weakness. Laboratory studies, cardiac catheterization, echocardiogram, or imaging studies are necessary to reveal left ventricular enlargement and dysfunction, mitral and/or tricuspid regurgitation, elevated left-sided and often right-sided filling pressures, elevated pulmonary artery wedge pressures, and diminished cardiac output [Dec and Fuster 1994; Wynne and Braunwald 2008].

Although the FF was asymptomatic, his hospitalization in November 2009 for cardiopulmonary arrest revealed severe left ventricular dysfunction (LVEF of 20%–25%) with wall motion abnormalities by cardiac catheterization. After 5 days of treatment in the hospital, the FF's LV dysfunction resolved (LVEF of 45%–50% by echocardiogram at discharge). At autopsy, the FF had an enlarged, dilated heart with hypertrophy of the left ventricle. Microscopic examination of the heart muscle revealed boxcar nuclei.

The incidence rate of dilated cardiomyopathy in the United States is 5 to 8 cases per 100,000 per year, with an age-adjusted prevalence of 36 cases

Discussion (cont.)

per 100,000 [Virmani 1997]. Although most cases of dilated cardiomyopathy are of unknown etiology (idiopathic), a variety of acquired or hereditary disorders can cause the disorder. These secondary and potentially reversible forms are listed in Appendix B [Dec and Fuster 1994], but anaphylactic reaction and cardiopulmonary arrest are not among them.

Inherited factors account for approximately one third of all idiopathic dilated cardiomyopathy cases, and 20% of patients with idiopathic dilated cardiomyopathy have at least one first-degree relative with a decreased ejection fraction and cardiomegaly [Michels et al. 1992; Keeling et al. 1995; Grunig et al. 1998]. Although idiopathic dilated cardiomyopathy can be transmitted as a recessive or X-linked trait, autosomal dominant inheritance occurs most frequently and exhibits both clinical variability and genetic heterogeneity [Fatkin et al. 1999]. The FF had a family history of idiopathic dilated cardiomyopathy; therefore, first-degree relatives should consult with their physicians regarding when, or if, an echocardiogram is warranted for screening purposes.

The prognosis for idiopathic dilated cardiomyopathy is poor; studies report an average 5-year death rate of 20% [Ikram et al. 1987; Di Lenarda et al. 1990; Komajda et al. 1990; Sugrue et al. 1992]. Dilated cardiomyopathy is also associated with an increased incidence of sudden cardiac death, mostly from arrhythmias [Dec and Fuster 1994; Bansch et al. 2002; Wynne and Braunwald 2008]. Although sudden death is rarely the initial presentation [Komajda et al. 1990; Sugrue et al. 1992], it is a common cause of death among idiopathic dilated cardiomyopathy patients, accounting for 28% of all idiopathic dilated cardiomyopathy deaths [Dec and Fuster 1994]. Although a variety of symptoms and medical tests can provide prognostic information, patients at greatest risk of sudden cardiac death are hard to identify [Dec and Fuster 1994].

Hypertrophic Cardiomyopathy. Hypertrophic cardiomyopathy (HCM) is a rare heart condition, affecting approximately 0.2% of the population [Spirito et al. 1997]. Diagnosis is typically made by echocardiogram and EKG findings of left ventricular hypertrophy by voltage. The FF had an enlarged heart with borderline left ventricular hypertrophy by echocardiogram in November 2009. His left ventricular hypertrophy was more pronounced at autopsy. Most patients are asymptomatic, and sudden cardiac death is often the first clinical manifestation [Wynne and Braunwald 2001].

Approximately half of HCM cases are transmitted genetically, typically as an autosomal dominant trait. Because of this, medical evaluation of first-degree relatives is warranted to determine whether screening tests (e.g., echocardiogram) are appropriate.

Atherosclerotic Coronary Artery Disease. The FF also had mild to moderate CAD. This was identified during his hospitalization in 2009 and his autopsy in 2010. NIOSH investigators do not believe CAD played a role in his sudden cardiac death.

The FF also had a cardiac conduction abnormality known as left bundle branch block diagnosed in 2009 by EKG. Approximately 80% of patients with dilated cardiomyopathy show this type of conduction abnormality [Dec and Fuster 1994].

Epidemiologic studies have found that heavy physical exertion sometimes precedes and triggers sudden cardiac death [Albert et al. 2000]. The FF had worked 21 hours, during which time he responded

Discussion (cont.)

to two calls, including the structure fire at which he participated in interior structural fire fighting. The activity at this fire expended about 12 metabolic equivalents, which is considered heavy physical activity [AIHA 1971; Gledhill and Jamnik 1992]. The FF also performed 2 hours of physical fitness training. NIOSH investigators conclude that the FF probably had a fatal cardiac arrhythmia associated with his dilated cardiomyopathy and triggered by his heavy physical activity.

Occupational Medical Standards for Structural Fire Fighters. To reduce the risk of sudden cardiac arrest or other incapacitating medical conditions among fire fighters, the NFPA developed NFPA 1582, Standard on Comprehensive Occupational Medical Program for Fire Departments [NFPA 2007a]. This voluntary industry standard provides the components of a preplacement and annual medical evaluation and medical fitness for duty criteria. According to NFPA 1582, the FF had a number of medical conditions that could have precluded his working as a fire fighter. These include dilated cardiomyopathy, hypertrophic cardiomyopathy, left bundle branch block, and history of sudden cardiac arrest [NFPA 2007a].

The FF's personal physician conducted a stress echocardiogram in January 2010. The FF showed excellent aerobic capacity by exercising for 11 minutes, 46 seconds and achieving 12.8 metabolic equivalents. He was asymptomatic during the test, although his left bundle branch block precluded an assessment of his EKG for ischemia. On the basis of this result and the FF's essentially normal echocardiogram on November 30, 2009, he was given medical clearance and returned to unrestricted duty.

Recommendations

NIOSH investigators offer the following recommendations to address general safety and health issues. It is unclear, however, whether these recommendations could have prevented the FF's death.

Recommendation #1: Provide preplacement and annual medical evaluations to all fire fighters in accordance with NFPA 1582, Standard on Comprehensive Occupational Medical Program for Fire Departments.

Guidance regarding the content and frequency of these medical evaluations can be found in NFPA 1582 and in the International Association of Fire Fighters (IAFF)/International Association of Fire Chiefs (IAFC) Fire Service Joint Labor Management Wellness/Fitness Initiative [NFPA 2007a; IAFF, IAFC 2008]. These evaluations are performed to determine fire fighters' medical ability to perform duties without presenting a significant risk to the safety and health of themselves or others. To ensure improved health and safety of candidates and members, and to ensure continuity of medical evaluations, it is recommended the FD comply with this recommendation. However, the FD is not legally required to follow the NFPA standard or the IAFF/IAFC initiative.

Recommendation #2: 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.

Guidance regarding medical evaluations and examinations for structural fire fighters can be found in NFPA 1582 and in the IAFF/IAFC Fire Service Joint Labor Management Wellness/Fitness

Recommendations (cont.)

Initiative [NFPA 2007a; IAFF, IAFC 2008]. According to these guidelines, the FD 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. The physician should review job descriptions and essential job tasks required for all FD positions and ranks to 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 FD currently utilizes the workers' compensation physician to clear fire fighters injured on duty. However, for other injuries or illnesses, the FD relies on the member's personal physician to clear the fire fighter for duty. As mentioned in the discussion section, the FF had a number of medical conditions that could have precluded his working as a fire fighter. These include dilated cardiomyopathy, hypertrophic cardiomyopathy, left bundle branch block, and history of sudden cardiac arrest [NFPA 2007a].

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

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, the IAFF/IAFC Fire Service Joint Labor Management Wellness/Fitness Initiative, and in Firefighter Fitness: A Health and Wellness Guide [IAFF, IAFC 2008; NFPA 2008; 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 work days [Stein et al. 2000; Aldana 2001]. Fire service health promotion programs have been shown to reduce CAD 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]. 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 2007]. The FD currently has a voluntary wellness/fitness program. NIOSH recommends a formal, mandatory wellness/fitness program to ensure all members receive the benefits of a health promotion program. During exercise time, employees should be taken out of service to ensure uninterrupted participation.

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

NFPA 1500, Standard on Fire Department Occupational Safety and Health Program, requires the FD to develop physical performance requirements for candidates and members who engage in emergency operations [NFPA 2007b]. Members who engage in emergency operations must be annually qualified (physical ability test) as meeting these physical performance standards for structural fire fighters [NFPA 2007b]. This could be incorporated into the annual task-level training program.

Recommendations (cont.)

Recommendation #5: Provide fire fighters with medical clearance to wear SCBA as part of the Fire Department's medical evaluation program.

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 public employees in states operating OSHA-approved state plans. Missouri does not operate an OSHA-approved state plan; therefore the FD is not required to ensure all members have been medically cleared to wear an SCBA. However, we recommend voluntary compliance with this recommendation to improve fire fighter health and safety.

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Investigator Information

This incident was investigated by the NIOSH Fire Fighter Fatality Investigation and Prevention Program, Cardiovascular Disease Component in Cincinnati, Ohio. Mr. Tommy Baldwin (MS) led the investigation and co-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. Dr. Thomas Hales (MD, MPH) provided medical consultation and co-authored the report. Dr. Hales is a member of the NFPA Technical Committee on Occupational Safety and Heath, and Vice-Chair of the Public Safety Medicine Section of the American College of Occupational and Environmental Medicine (ACOEM).

Appendix A

Autopsy Findings

- Dilated hypertrophic cardiomyopathy
  - Four heart chambers dilated
  - Slight boxcar change of nuclei
- Coronary artery atherosclerosis
  - Severe (75%) focal narrowing of the left anterior descending coronary artery
  - Mild (10%) focal narrowing of the right coronary artery
- Left ventricular hypertrophy
  - Left ventricle and septum thickened (1.4 centimeter [cm] and 1.2 cm respectively)
    - 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]
- Cardiomegaly (enlarged heart; heart weighed 580 grams [g]; predicted normal weight is 389 g [ranges between 294 g and 513 g as a function of sex, age, and body weight]) [Silver and Silver 2001]
- Normal cardiac valves
- No evidence of a coronary artery thrombus (blood clot)
- No evidence of a pulmonary embolus (blood clot in the lung arteries)
- Blood tests for drugs and alcohol were negative
- Blood test for carbon monoxide <10%

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Appendix B

Known Causes of Dilated Cardiomyopathy [Dec and Fuster 1994]

Toxins

- Ethanol
- Chemotherapeutic agents (doxorubicin, bleomycin)
- Cobalt
- Anti-retroviral agents (zidovudine, didanosine, zalcitabine)
- Phenothiazines
- Carbon monoxide
- Lead
- Cocaine
- Mercury

Metabolic Abnormalities

- Nutritional deficiencies (thiamine, selenium, carnitine)
- Endocrinologic disorders (hypothyroidism, acromegaly, thyrotoxicosis, Cushing disease, pheochromocytoma, diabetes mellitus)
- Electrolyte disturbances (hypocalcemia, hypophosphatemia)

Infectious

- Viral (coxsackie virus, cytomegalovirus, human immunodeficiency virus)
- Rickettsial
- Bacterial (diphtheria)
- Mycobacterial
- Fungal
- Parasitic (toxoplasmosis, trichinosis, Chagas disease)

Noninfectious

- Collagen vascular disorders (scleroderma, lupus erythematosus, dermatomyositis)
- Hypersensitivity myocarditis
- Sarcoidosis
- Peripartum dysfunction

Neuromuscular Causes

- Duchenne muscular dystrophy
- Facioscapulohumeral muscular dystrophy
- Erb limb-girdle dystrophy
- Myotonic dystrophy