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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 *March, 2011*

Deputy Chief Suffers Sudden Cardiac Death During Physical Fitness Training - Illinois

Executive Summary

On September 20, 2010, a 55-year-old male career Deputy Chief (DC) responded to a medical call and provided assistance. Later in the day, the DC exercised as part of the Fire Department (FD) fitness program. The DC was about 5 minutes into his exercise program when the duty crew was dispatched to a call in which the DC did not respond. Approximately 90 minutes later, the DC was found unresponsive lying alongside the Stairmaster®. Despite cardiopulmonary resuscitation (CPR) and advanced life support (ALS) at the fire station, in the ambulance, and in the hospital's emergency department (ED), the DC died. The death certificate and the autopsy listed "hypertrophic cardiomyopathy" as the cause of death with "arteriosclerotic coronary artery disease" as a contributing condition. Given the DC's severe underlying heart disease, NIOSH investigators concluded that moderately strenuous physical exertion during exercise probably triggered an arrhythmia causing his sudden cardiac death.

NIOSH investigators offer the following recommendations to address general safety and health issues. It is unclear, however, if these recommended programs would have prevented the DC's death.

Ensure fire fighters are cleared for return to duty by a healthcare provider knowledgeable about the physical demands of fire fighting, the personal protective equipment used by fire fighters, and the various components of National Fire Protection Association (NFPA) 1582.

Ensure on-duty fire fighters exercise in pairs or within viewing/hearing distance of another crew member.

Introduction & Methods

On September 20, 2010, a 55-year-old male career DC died while exercising in the fire station as part of the FD physical fitness program. NIOSH contacted the affected FD on September 21, 2010, to gather additional information and on October 12, 2010, to initiate the investigation. On October 18, 2010, a safety and occupational health specialist from the NIOSH Fire Fighter Fatality Investigation Team conducted an on-site investigation of the incident.

During the investigation, NIOSH personnel interviewed the following people:

- Fire Chief
- Crew members
- The DC's spouse

NIOSH personnel reviewed the following documents:

- FD training records
- FD standard operating procedures
- FD annual report for 2009
- FD incident report
- FD medical records
- Emergency medical service (ambulance) incident report
- Hospital ED records
- Death certificate
- Autopsy report
- Cardiologist records

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Investigative Results

Incident. On September 20, 2010, the DC arrived for duty at 0700 hours for his 8-hour shift. Eight other people were on duty (six fire fighter/paramedics, the Fire Chief, and the Fire Inspector). The DC spent the morning completing paperwork and other management duties. At 1128 hours, the FD was dispatched for a medical call. The DC, also a paramedic, responded and assisted the ambulance crew. As the ambulance transported the patient to the hospital, the DC returned to the fire station.

The DC continued with office duties until approximately 1515 hours when he went downstairs to exercise. The DC typically began his exercise program by lifting weights for 30 minutes followed by use of the Stairmaster®. About 19 minutes after the DC went downstairs to exercise, the duty crew was dispatched to a fire alarm call. The DC was not needed on this call, so he continued his workout. The crew returned to the station at approximately 1547 hours, readied the equipment, and completed paperwork. Shortly thereafter, the crew was dispatched to a medical call (1605 hours). The ambulance returned to quarters at 1617 hours. At 1650 hours, the FD was dispatched to assist a neighboring FD. The call was cancelled at 1651 hours, prior to the engine leaving the station. The crew assembled in the downstairs exercise room at approximately 1700 hours and exercised for approximately 10 minutes. As they began the next circuit, a crew member discovered the DC lying unconscious, hidden between the Stairmaster and the wall (1710 hours).

Crew members moved the DC to the open floor where he was found to be unresponsive, not breathing, and without a pulse. Crew members began CPR and ALS. A cardiac monitor was placed, revealing asystole (no heart beat), and the DC was intubated. Tube placement was verified by visualizing the vocal cords, positive lung sounds, negative epigastric sounds, and misting noted in the tube, but no capnography [AHA 2000]. An intraosseous (IO) line was placed, and cardiac resuscitation medications were administered via IO line.

Dispatch was notified of the incident (1711 hours), and the Chief moved the ambulance to the rear of the building, closer to the exercise room. Crew members positioned the DC onto a backboard and carried him upstairs and into the ambulance, which departed the station at 1728 hours en route to the hospital's ED.

The ambulance arrived at the ED at 1731 hours where ALS continued. The DC's condition did not improve. At 1739 hours, the DC was pronounced dead by the attending physician, and resuscitation efforts were discontinued.

Medical Findings. The death certificate and the autopsy listed "hypertrophic cardiomyopathy" as the cause of death with "arteriosclerotic coronary artery disease" as a contributing condition. The DC's coronary arteries showed "mild" atherosclerosis of his left anterior descending artery and "no significant narrowing" of his two other main coronary arteries. No blood carboxyhemoglobin was detected suggesting the DC had not inhaled significant amounts of carbon monoxide. Toxicology results for drugs and alcohol were also negative. Specific findings from the autopsy are listed in Appendix A.

On autopsy, the DC was found to have mild/minimal CAD, for which his only risk factor was

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Investigative Results (cont.)

obesity (body mass index of 36.0 kilograms per meters squared) [CDC 2011]. The DC underwent annual FD medical evaluations including exercise stress tests (ESTs) with periodic echocardiography using the Bruce protocol [Sport Fitness Advisor 2011]. Table 1 lists the dates and results of his ESTs. An EST with echocardiography was performed 1 month prior to his death. The DC exercised for 11 minutes, 37 seconds on the Bruce protocol, expending 11.6 metabolic equivalents. The DC reached a maximum heart rate of 148 beats per minute, 89% of his age-predicted maximum heart rate, before stopping due to fatigue and dyspnea (shortness of breath). He reported no angina, and his blood pressure response was normal. The EKG revealed rare isolated premature ventricular complexes with exercise. Because of a previously noted resting ST-segment abnormality, changes in the ST-segment with exercise could not be definitively interpreted for ischemia. His echocardiogram was reported to show a normal left ventricular size and function. Overall, the test was interpreted as normal with good exercise capacity.

At his annual exam 1 month prior to death, a spirometry test revealed moderate obstructive disease. The physician recommended the DC follow up with a pulmonologist. He was cleared to wear a respirator but the FD restricted from fire response that would require wearing a self-contained breathing apparatus.

Description of the Fire Department

At the time of the NIOSH investigation, the FD consisted of one fire station with 22 career uniformed personnel that served 18,000 residents in a geographic area of 5 square miles. In 2009, the FD responded to 2,408 incidents: 776 fire calls, 1,033 emergency medical calls, and 599 other emergency calls.

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; be a State-licensed paramedic; complete an initial orientation program; and pass a physical ability test, a written test, an initial oral interview, a background check including a polygraph, an assessment center (task oriented in a group setting), and an interview with the police and fire commission panel. The candidate is then ranked. The top ranked candidate(s) is/are given a conditional offer of employment. The candidate must then pass a psychological evaluation and a preplacement medical evaluation (described below) prior to being hired. The new hire, if not a State-certified Fire Fighter 2, then receives training at the regional fire academy to become certified as a Fire Fighter 2. The new hire then receives FD training on policies and equipment and is on probation for 1 year. The new hire is placed on a shift working 24 hours on duty and 48 hours off duty, 0700 hours to 0700 hours. The DC was certified as a Fire Fighter 3, Fire Officer, Driver/ Operator, Paramedic, Fire Instructor, Fire Inspector, in hazardous materials awareness, and in technical rescue awareness. He had 24 years of fire fighting experience.

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

Description of the FD (cont.)

- Complete medical history
- Physical examination (including vital signs)
- Complete blood count with lipid panel
- Pulmonary function test
- Resting EKG
- Chest x-ray (baseline)
- Urinalysis
- Urine drug screen
- Audiogram
- Vision screen

These evaluations are performed by a physician contracted with the City. Once this evaluation is complete, the contracted physician makes a determination regarding medical clearance for wearing a respirator and fire fighting duties and forwards this decision to the FD. The DC joined this FD in 1986 and had a preplacement medical evaluation at that time.

Periodic Medical Evaluations. The FD requires periodic (annual) medical evaluations for all members based on the age of the member. The components of this medical evaluation are the same as the preplacement medical evaluation except that chest x-rays are performed every 4 years, and stress tests are conducted every 2 years for members age 30–39, annually for members age 30–39 with two or more risk factors for CAD, and annually for members over the age of 40. These evaluations are performed by a physician contracted with the City. Once this evaluation is complete, the contracted physician makes a determination regarding medical clearance for wearing a respirator and fire fighting duties and forwards this decision to the FD. An annual SCBA medical clearance and an annual SCBA facepiece fit test are required. Members injured on duty or who are ill for three or more shifts must be evaluated by the FD-contracted physician, who makes the final determination regarding return to duty.

Health and Wellness Programs. The FD has a mandatory wellness/fitness program, and exercise equipment is available in the fire station. Exercise time, however, is not protected time (taken out of service). An annual physical ability test is required.

Discussion

Cardiomyopathies (CM) constitute a group of diseases involving damage to the heart muscle that is not due to hypertension, ischemia (coronary artery), or valvular conditions [Wynne and Braunwald 2001a]. Cardiomyopathy is classified into one of three types on the basis of functional impairment:

1) Dilated, the most common form, accounts for 60% of all CMs

2) Hypertrophic (HCM), recognized by inappropriate left ventricular hypertrophy, often with involvement of the interventricular septum (as in this case)

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 2001a]

The DC was diagnosed with HCM at autopsy, although the results of an echocardiogram 1 month prior to his death reported left ventricular size as normal.

Discussion (cont.)

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. Most patients are asymptomatic, and sudden cardiac death is often the first clinical manifestation [Wynne and Braunwald 2001b]. Risk factors for sudden death among HCM patients include young age (less than 30 years old) at diagnosis, a family history of HCM with sudden death, an abnormal blood pressure response to exercise, severe symptoms, nonsustained ventricular tachycardia, marked hypertrophy, marked left atrial dilatation, and genetic abnormalities associated with increased prevalence of sudden death [Spirito et al. 1997; Olivotto et al. 1999; Wynne and Braunwald 2001b].

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.

The DC was asymptomatic. Inconsistent findings were reported from medical exams done over the 10-year period prior to his death. Some records report a finding of left ventricular hypertrophy (LVH) by EKG or echocardiography, and others do not. This finding is not consistent with the natural history of LVH; the condition does not go away. On autopsy the DC was found to have marked cardiac hypertrophy.

Atherosclerotic Coronary Artery Disease. In the United States, atherosclerotic coronary artery disease (CAD) is the most common risk factor for cardiac arrest and sudden cardiac death [Meyerburg and Castellanos 2008]. Risk factors for its development include age older than 45, male gender, family history of CAD, smoking, high blood pressure, high blood cholesterol, obesity/physical inactivity, and diabetes [NHLBI 2009; AHA 2011]. The DC was obese and older than age 45. His autopsy revealed mild/minimal CAD.

Epidemiologic studies have found that heavy physical exertion sometimes immediately precedes and triggers sudden cardiac death [Albert et al. 2000]. Sudden cardiac death in fire fighters has been associated with alarm response, fire suppression, and heavy exertion during training (including physical fitness training) [Kales et al. 2003; Kales et al. 2007; NIOSH 2007]. The DC performed weight training, expending approximately 6 metabolic equivalents (considered light to moderate physical activity) and then exercised on the Stairmaster machine, expending approximately 9 metabolic equivalents, which is considered moderate physical activity [AIHA 1971; Gledhill and Jamnik 1992; Ainsworth et al. 2000]. Given the DC's underlying HCM, the NIOSH investigators conclude that the moderate physical exertion associated with exercise probably triggered a cardiac arrhythmia resulting in his sudden cardiac death.

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 (1) the components of a preplacement and annual medical evaluation and (2) medical fitness for duty criteria. The DC had two conditions

Discussion (cont.)

relevant to medical clearance for duty. In August 2010 spirometry found that the DC had moderate obstructive lung disease. This finding resulted in his being restricted from "being physically cleared for work." The Fire Chief was aware of this condition and was awaiting an updated diagnosis from a pulmonologist.

The second condition, HCM, was not diagnosed until the DC's autopsy. During the FD's stress echocardiogram tests in 2002 and 2003, the DC was found to have unexplained moderate LVH, but this finding was not reported on subsequent stress echocardiograms in 2008–2010. It is unclear why the LVH was not seen on these subsequent tests, particularly the test 1 month prior to his death. Again, LVH takes time to develop and is not a reversible condition.

NFPA considers HCM a category B medical condition for fire fighter candidates. Category B is defined as "a medical condition that, based on its severity or degree, could (our emphasis) preclude a person from performing as a fire fighter in a training or emergency operational environment by presenting a significant risk to the safety and health of the person or others." NFPA 1582 notes this distinction in its members section when it states, "Hypertrophic obstructive cardiomyopathy (idiopathic hypertrophic subaortic stenosis) might compromise the member's ability to function as an integral component of a team, where sudden incapacitation can result in mission failure or in risk of injury or death to civilians or other team members" [NFPA 2007a]. However, the final decision for clearing an individual with HCM for duty lies with the FD physician.

It is unclear if earlier recognition of the DC's HCM would have prevented his death. Although the presence of certain symptoms and the results of medical tests can provide prognostic information, patients at greatest risk of sudden death or who may benefit from antiarrhythmic therapy are hard to identify. Given the DC's lack of risk factors for sudden death and lack of symptoms, it is unclear that an HCM diagnosis would have led to treatment. Moreover, even if treated with antiarrhythmic agents, sudden death may occur.

Recommendations

NIOSH investigators offer the following recommendations to address general safety and health issues. It is unclear, however, if these recommended programs would have prevented the DC's death.

Recommendation #1: Ensure that fire fighters are cleared for return to duty by a healthcare provider knowledgeable about the physical demands of fire fighting, the personal protective equipment used by fire fighters, and the various components of NFPA 1582.

The annual medical evaluation 1 month prior to the DC's death revealed moderately severe chronic obstructive pulmonary disease. With moderate to severe chronic obstructive pulmonary disease, elevated respiratory workload and lack of respiratory reserve does not provide adequate gas exchange for the safe performance of essential job tasks [NFPA 2007a]. The FD contract physician cleared the DC to wear a respirator but restricted him from being "physically cleared for work." The FD was notified of the DC's restricted duty status and was awaiting further diagnosis from a pulmonologist to assess

Recommendations (cont.)

whether the DC should be restricted from participating in the FD's exercise program.

The second issue involved the finding of LVH during stress echocardiograms in 2002–2004. These findings were not reported during the stress echocardiograms conducted in 2008–2010 for reasons that are unclear. LVH or HCM are considered category B conditions for candidates, and, for members, might compromise the ability to safely perform essential job task 13 (functioning as an integral component of a team) [NFPA 2007a].

Recommendation #2: Ensure on-duty fire fighters exercise in pairs or within viewing/hearing distance of another crew member.

Members should exercise in pairs or at least within viewing/hearing distance of another crew member. If a medical emergency occurs, the other crew member can alert EMS or dispatch promptly. Other, but less desirable, options include use of a PASS device and/or portable radio or remote cameras. PASS devices are portable, lightweight units that, when activated, emit a 95-decibel alarm. The devices, which can be manually activated, automatically activate if no motion is detected for approximately 30 seconds [NFPA 2007b]. Portable radios have the advantage of allowing affected members to specify the problem and their exact location. Even if no one is present in the station, the member could alert Dispatch. Radios, however, are larger and heavier than PASS devices and do not automatically alert anyone if the member suddenly collapses. Remote cameras mounted in the fitness room and monitored in the fire station radio room may be helpful, although when the crew is dispatched, the radio room is unattended.

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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 coauthored 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 coauthored 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

- Hypertrophic cardiomyopathy
  - Cardiomegaly (enlarged heart) (heart weighed 768 grams [g]; predicted normal weight is 446 g [between 338 g and 589 g as a function of sex, age, and body weight]) [Silver and Silver 2001]
  - Nonconcentric left ventricular myocardial hypertrophy
    Left ventricular wall thickened (3.0 cm)
    - normal by autopsy 0.76–0.88 cm [Colucci and Braunwald 1997]
    - normal by echocardiography 0.6–1.1 cm [Armstrong and Feigenbaum 2001]
- Atherosclerotic cardiovascular disease
  - Mild (10%–50%) focal narrowing of the left anterior descending coronary artery
  - No significant focal narrowing of the right coronary artery
  - No significant focal narrowing of the left circumflex artery
- Normal cardiac valves
- No evidence of a pulmonary embolus (blood clot in the lung arteries)
- Blood tests for drugs and alcohol were negative
- Blood tests for carboxyhemoglobin were negative

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Table 1

Exercise stress tests

Date	Time on Treadmill (min:sec)	Metabolic Equivalents Achieved	Left Ventricular Hypertrophy	Electrocardiogram Findings	Echocardiogram Findings
10/08/01	12:00	13.7	No (EKG)	ST-T changes	Normal resting wall motion
10/08/02	12:00	13.7	Yes (echo-cardiogram)	Inferior wall ST depression; occasional PVC	LV moderately hypertrophied; LVEF 83%
06/13/03	11:30	12.9	Yes (echo-cardiogram)	Nonspecific T changes; ST depression	LV moderately hypertrophied; LVEF 50%–60%
06/08/04	11:30	12.9	Yes echo-cardiogram)	Rare PVCs; ST depression	Normal LV; Mild concentric increase in wall thickness; LVEF 50%–60%
07/01/05	11:00	12.9	Yes (EKG)	Isolated PAC; abnormal convex ST depression	Not performed
06/09/06	12:00	12.9	Yes (EKG)	Repolarization abnormality; frequent PACs	Not performed
06/25/07	12:01	13.5	No (EKG)	Repolarization abnormality	Not performed
07/16/08	12:00	17.2	No (EKG)	Generous QRS voltage; nonspecific ST-T abnormality	Not performed
08/20/08	11:00	12.9	No (echo-cardiogram)	Generous voltage; ST abnormalities	Normal LV size, normal systolic function, normal wall thickness; mild left atrial enlargement
10/22/09	12:02	13.4	Yes (EKG)	ST abnormality; occasional PAC; short runs SVT	Normal LV size and normal systolic function; could not exclude apical hypokinesis
08/23/10	11:37	11.6	Yes (EKG)	PACs; nonspecific ST-T abnormalities; rare isolated PVCs	Normal LV size and normal systolic function