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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 *December, 2013*

Fire Fighter Trainee Suffers Sudden Cardiac Death During Physical Ability Training – Texas

Executive Summary

On March 6, 2013, a 63-year-old male volunteer fire fighter trainee ("Trainee") participated in physical ability training as part of the Fire Department's (FD) 13-week cadet program. The Trainee, wearing full turnout gear and self-contained breathing apparatus (SCBA) (not on-air) completed all of the 15 training components over a 15-minute period. At no point during the training did the Trainee express any unusual signs or symptoms. Then, while doffing his turnout gear, he collapsed. Instructors began cardiopulmonary resuscitation, requested an ambulance (1956 hours), and retrieved an automated external defibrillator. One shock (defibrillation) was administered prior to ambulance arrival at 2001 hours. Ambulance paramedics provided advanced life support on-scene and en route to the local hospital's emergency department (ED). The ambulance arrived at the ED at 2028 hours, and after 13 minutes of resuscitation efforts inside the ED, the Trainee was pronounced dead at 2041 hours.

The death certificate and autopsy report listed "hypertensive and atherosclerotic cardiovascular disease" as the cause of death. Given the Trainee's occult heart disease, NIOSH investigators concluded that the physical stress of physical ability training probably triggered a heart arrhythmia, which resulted in sudden cardiac death.

NIOSH investigators offer the following recommendations to prevent future similar incidents and to address general safety and health issues.

Include medical monitoring in rehabilitation programs.

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

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

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

Introduction & Methods

On March 6, 2013, a 63-year-old male volunteer Trainee suffered sudden cardiac death while participating in physical ability training. NIOSH contacted the affected FD on March 7, 2013, to gather additional information, and on May 14, 2013, to initiate the investigation. On May 20, 2013, 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
- Training academy coordinator
- Trainee's spouse

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Introduction & Methods (cont.)

NIOSH personnel reviewed the following documents:

- FD standard operating procedures
- FD annual report for 2012
- Emergency medical service (ambulance) report
- Hospital ED records
- Death certificate
- Autopsy report
- Primary care physician records

Investigative Results

Incident. On March 6, 2013, the FD scheduled physical ability training as a component of a 13-week cadet training program to become a fire fighter. Fire fighters arrived at about 1915 hours to set up the course, and the training began at 1930 hours. There were seven instructors and ten cadets. Weather conditions included a temperature of 59 degrees Fahrenheit (°F) and relative humidity of 24% [NOAA 2013].

The cadets stretched as a group for approximately 5 minutes before donning their turnout gear (coat, pants, boots, helmet, hood, and gloves) and SCBA. The training involved 15 stations (Appendix A), and cadets completed as much as possible within 15 minutes. The Trainee completed the training in 15 minutes then walked to his gear bag to doff his turnout gear. As he stepped out of his boots, he collapsed. Instructors assessed him and found him to be unresponsive and pulseless with apneic (snoring) respirations. Cardiopulmonary resuscitation was begun as dispatch was notified to request an ambulance (1956 hours). An automated external defibrillator was retrieved and applied, revealing a shockable heart rhythm; one shock was administered with no change in the Trainee's clinical status.

The ambulance arrived on scene at 2001 hours, and paramedics began advanced life support. Cardiac monitoring revealed ventricular fibrillation, and a shock was administered. The Trainee was intubated, and an intravenous line was placed. Intubation tube placement was verified by capnography [Neumar et al. 2010]. Cardiac resuscitation medications were administered intravenously. The ambulance departed the scene at 2021 hours en route to the hospital's ED. While en route, two additional shocks were administered without change in the Trainee's clinical status. The ambulance arrived at the hospital at 2028 hours where advanced life support continued for 13 minutes. The Trainee was pronounced dead at 2041 hours, and resuscitation efforts were discontinued.

Medical Findings. The death certificate and autopsy report listed "hypertensive and atherosclerotic cardiovascular disease" as the cause of death. Cardiac findings showed a slightly enlarged heart, left ventricular hypertrophy, and a dilated right ventricle with mild to moderate coronary artery disease (Appendix B).

The Trainee was 71 inches tall and weighed 165 pounds, giving him a normal body mass index of 23.0 kilograms per meters squared [CDC 2011]. According to medical records, the Trainee's only risk factor for coronary heart disease (CHD) was hyperlipidemia, diagnosed in 1999. He was not prescribed a cholesterol-lowering medication, but a low cholesterol diet had been recommended by his primary care physician. The Trainee underwent a nuclear exercise stress test (EST) in 2003 because of an abnormal electrocardiogram (EKG). He exercised for 13 minutes, 13 seconds on the Bruce protocol, achieving 16 metabolic equivalents and 92% of his maximal predicted heart

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Investigative Results (cont.)

rate with normal wall motion and no evidence of stress-induced ischemia. Because of an abnormal EKG in December 2007 he underwent an echocardiogram in January 2008, which revealed borderline left ventricular hypertrophy with normal ejection fraction, function, chamber sizes, and valves. No additional tests were performed, and the Trainee never complained of cardiac symptoms.

Description of the Fire Department

At the time of the NIOSH investigation, the FD consisted of five fire stations with 116 volunteer uniformed personnel. The FD served 91,000 residents in a geographic area of 53 square miles. In 2012, the FD responded to 935 incidents: 114 fire calls, 132 emergency medical calls, and 689 other calls including hazardous conditions, false alarms, and service calls.

Membership and Training. The FD requires new fire fighter applicants to be 18 years of age, have a valid state driver's license and pass a background check, an interview, and a preplacement medical evaluation prior to being voted on/accepted as a member. The new member then begins the 13-week Fire Fighter I training. The Trainee had 1 month of fire fighting experience and had just begun Fire Fighter I training.

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

1) Complete medical history
2) Physical examination (including vital signs – height, weight, blood pressure, pulse, and respirations)
3) Vision test (acuity, color, peripheral fields, and depth perception)
4) Audiogram
5) Spirometry
6) Electrocardiogram
7) Urinalysis
8) Blood tests (complete blood count, lipids)
9) Chest x-ray (baseline)

The medical evaluation can be performed by a contracted physician. Once this evaluation is complete, the physician makes a determination regarding medical clearance for fire fighting duties and forwards this decision to the FD. The Trainee had a baseline medical evaluation when he joined the FD in January 2013. No medical problems were identified, and he was cleared for unrestricted duty as a fire fighter.

Periodic medical evaluations are required for members every 3 years. The components are the same as the preplacement medical evaluation. Medical clearance to wear a respirator is not required for suppression fire fighters. Members injured on duty or who become ill and miss FD responses, training, or meetings must be evaluated by the member's primary care physician who forwards his or her determination for return-to-duty to the FD.

Health and Wellness Programs. The FD does not have a wellness/fitness program, but exercise equipment is available in the fire stations. An annual physical ability test is required for all members. The Trainee participated in a fitness/wellness program and worked part time in a local fitness facility.

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Discussion

Atherosclerotic Coronary Heart Disease. In the United States, atherosclerotic CHD 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 coronary artery disease, smoking, high blood pressure, high blood cholesterol, obesity/physical inactivity, and diabetes [NHLBI 2012; AHA 2013]. The Trainee had one modifiable CHD risk factor (high blood lipids). Mild to moderate CHD was found on autopsy.

The narrowing of the coronary arteries by atherosclerotic plaques occurs over many years, typically decades [Libby 2008]. However, the growth of these plaques probably occurs in a nonlinear, often abrupt fashion [Shah 1997]. 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 [Fuster et al. 1992]. This sudden blockage is primarily due to blood clots (thromboses) forming on top of atherosclerotic plaques. Establishing a recent (acute) heart attack requires any of the following: characteristic EKG changes, elevated cardiac enzymes, or coronary artery thrombus. In this case, the Trainee's cardiac enzymes were not tested, he did not have a heart rhythm to conduct an EKG, and the autopsy did not identify a thrombus. Given that heart attacks can occur without a coronary thrombus, it is possible that the Trainee had a heart attack [Davies 1992; Farb et al. 1995; Mehta et al. 1997; Thygesen and Uretsky 2004]. However, the Trainee (1) reported no angina (chest pain); (2) had only mild to moderate coronary atherosclerosis on autopsy; (3) had a negative stress thallium 10 years previously; and (4) had only one risk factor for CHD (elevated cholesterol in 2011 and 2012 that returned to normal in 2013). Therefore, his sudden death was probably due to a cardiac arrhythmia possibly associated with left ventricular hypertrophy and right ventricular dilation, which were discovered at autopsy.

Epidemiologic studies have found that heavy physical exertion sometimes immediately precedes and triggers the onset of acute heart attacks and sudden cardiac death [Mittleman et al. 1993; Willich et al. 1993; Albert et al. 2000]. Heart attacks in fire fighters have 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 Trainee had completed a 15-station physical ability training evolution while wearing full turnout gear and SCBA. This activity expended about 12 metabolic equivalents, which is considered heavy physical activity [Gledhill and Jamnik 1992; Ainsworth et al. 2011].

Primary Arrhythmia. Risk factors for arrhythmias include heart disease, heart attack, dietary supplements, smoking, alcohol, drug abuse, medications, diabetes, and hyperthyroidism [AHA 2012; Mayo Clinic 2013]. Except for underlying heart disease (right ventricular dilation, left ventricular hypertrophy, and mild to moderate CHD), the Trainee was not known to have any of these conditions.

Occupational Medical Standards for Structural Fire Fighters and Exercise Stress Test. 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 Depart-

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ments [NFPA 2013]. This voluntary industry standard provides the components of a preplacement and annual medical evaluation and medical fitness for duty criteria. The Trainee's underlying cardiac abnormalities were not identified until his autopsy. Although a thallium EST was normal in 2003, a more recent imaging EST may have identified abnormalities that could have led to additional tests to diagnose these findings. However, recommendations for ESTs on asymptomatic individuals without known heart disease are varied. Based on the Trainee's age, high blood cholesterol in 2011–2013, and CHD risk profile, the NFPA and the American College of Cardiology/American Heart Association (ACC/AHA) would have recommended a more recent symptom limiting EST. The following paragraphs summarize the positions of widely recognized organizations on this topic.

NFPA 1582, a voluntary industry standard, recommends an exercise stress test performed "as clinically indicated by history or symptoms" and refers the reader to its Appendix A [NFPA 2013]. Items in Appendix A are not standard requirements, but are provided for "informational purposes only." Appendix A recommends using submaximal (85% of predicted heart rate) stress tests as a screening tool to evaluate a fire fighter's aerobic capacity. Maximal (i.e., symptom-limiting) stress tests with imaging should be used for fire fighters with the following conditions:

- abnormal screening submaximal tests
- cardiac symptoms
- known coronary artery disease (CAD)
- one or more risk factors for CAD (in men older than 45 and women older than 55)

Risk factors are defined as hypercholesterolemia (total cholesterol greater than 240 milligrams per deciliter), hypertension (diastolic blood pressure greater than 90 mm of mercury), smoking, diabetes mellitus, or family history of premature CAD (heart attack or sudden cardiac death in a first-degree relative less than 60 years old).

The ACC/AHA has also published exercise testing guidelines [Gibbons et al. 2002]. The ACC/AHA guideline states that the evidence to conduct stress tests in asymptomatic individuals is "less well established" (Class IIb) for the following groups:

- persons with multiple risk factors (defined similarly to those listed by the NFPA)
- asymptomatic men older than 45 years and women older than 55 years:
    - who are sedentary and plan to start vigorous exercise
    - who are involved in occupations in which impairment might jeopardize public safety (e.g., fire fighters)
    - who are at high risk for coronary artery disease due to other diseases (e.g., peripheral vascular disease and chronic renal failure)

The U.S. Department of Transportation provides guidance for those seeking medical certification for a commercial driver's license. An expert medical panel recommended exercise tolerance tests (stress tests) for asymptomatic "high risk" drivers [Blumenthal et al. 2007]. The panel defines high risk drivers as those with any of the following:

- diabetes mellitus
- peripheral vascular disease
- age 45 and above with multiple risk factors for coronary heart disease
- Framingham risk score predicting a 20% coronary heart disease event risk over the next 10 years

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The U.S. Preventive Services Task Force (USPSTF) does not recommend stress tests for asymptomatic individuals at low risk for coronary heart disease events. For individuals at increased risk for coronary heart disease events, the USPSTF found "insufficient evidence to recommend for or against routine screening with EKG, exercise tolerance test, or electron beam computerized tomography scanning…." Rather, they recommend the diagnosis and treatment of modifiable risk factors (hypertension, high cholesterol, smoking, and diabetes) [USPSTF 2004]. The USPSTF does note that "For people in certain occupations, such as pilots, and heavy equipment operators (for whom sudden incapacitation or sudden death may endanger the safety of others), consideration other than the health benefit to the individual patient may influence the decision to screen for coronary heart disease."

Recommendations

NIOSH investigators offer the following recommendations to prevent similar incidents in the future and to address general safety and health issues.

Recommendation #1: Include medical monitoring into rehabilitation programs.

A model rehabilitation program can be found in NFPA 1584, Standard on the Rehabilitation Process for Members During Emergency Operations and Training Exercises [NFPA 2008a]. Medical monitoring should be part of any rehabilitation program. This would consist of evaluating the symptoms, signs, and vital signs of personnel upon entry to, and discharge from, the rehabilitation program. These findings should be recorded and maintained. Symptomatic members or members with abnormal findings should receive medical monitoring and/or be evaluated for potential transport to the ED. If medical care is given, a medical report should be completed and maintained. In this incident, all participants should have been assigned to rehabilitation after the hose maze drill.

Recommendation #2: Provide 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 [IAFF, IAFC 2008; NFPA 2013]. 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. While the FD is following most of the components of NFPA 1582, it is not conducting stress tests for fire fighters at increased risk of coronary heart disease. Applying this recommendation involves economic repercussions and may be particularly difficult for smaller fire departments to implement. The FD is not legally required to follow the NFPA standard or the IAFF/IAFC guideline.

To overcome the financial obstacle of medical evaluations, the FD could urge current members to get annual medical clearances from their private physicians. Another option is having the annual medical evaluations completed by paramedics and emergency medical technicians from the local

Recommendations (cont.)

ambulance service (vital signs, height, weight, visual acuity, and EKG). This information could then be provided to a community physician (perhaps volunteering his or her time), who could review the data and provide medical clearance (or further evaluation, if needed). The more extensive portions of the medical evaluations could be performed by a private physician at the fire fighter's expense (personal or through insurance), provided by a physician volunteer, or paid for by the FD, city, or state. Sharing the financial responsibility for these evaluations between fire fighters, the FD, the city, the state, and physician volunteers may reduce the negative financial impact on recruiting and retaining needed fire fighters.

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, the National Volunteer Fire Council (NVFC) Health and Wellness Guide, and in Firefighter Fitness: A Health and Wellness Guide [USFA 2004; IAFF, IAFC 2008; NFPA 2008b; 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 [Chapman 2005; Mills et al. 2007; Pelletier 2009; Baicker et al. 2010]. 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 2013].

The FD offers a voluntary wellness/fitness program where exercise equipment is available in the fire stations. Given the FD's structure, the NVFC program would apply [USFA 2004], but NIOSH would recommend a formal, mandatory wellness/fitness program to ensure all members receive the benefits of a health promotion program.

Recommendation #4: 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. Because federal OSHA rules apply in Texas [OSHA 2013], 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.

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Appendix A

Physical Ability Training

Training stops at the 15 minute mark regardless of which station the cadet has completed. One by one, cadets begin at station one and move to the next station without stopping.

Station Number; Title	Description
1. Kaiser sled	Move the block from end to end by striking the block with the sledge hammer
2. Pike pole	Raise and lower the 10-pound weighted pike pole 20 times.
3. Manikin drag	Drag the 80-pound manikin backward 25 feet.
4. Tunnel crawl	Crawl through the 2′ × 2′ × 20′ tunnel.
5. Sledgehammer	Strike the tire with the sledge hammer 20 times.
6. Wall breach	Wall breach prop. Sit and swing the sledge hammer one pass.
7. Rafter crawl	Crawl across the waist-high rafter assembly.
8. Pushups	Perform 20 pushups.
9. Tunnel crawl	Crawl back through the 2′ × 2′ × 20′ tunnel.
10. Pike pole	Raise the nonweighted pike pole up and down 20 times.
11. Pushups	Perform 20 pushups.
12. High rise pack	Carry the 25-pound high rise pack up the drill tower stairs to the third floor, lay the pack down.
13. Hoseline raise	Raise the 50′ section of 2½″ hoseline over the rail and lay the hose down. Pick up the high rise pack and carry it down the tower stairs to the ground, lay the pack down.
14. Duck walk	Duck walk 25 feet.
15. Hose drag	Drag the 50′ section of charged 1¾″ hoseline to its limit.

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Appendix B

Autopsy Findings

- Hypertensive heart disease
  - Cardiomegaly (enlarged heart; heart weighed 450 grams [g]; predicted normal weight is 338 g [ranges between 256 g and 447 g as a function of sex, age, and body weight]) [Silver and Silver 2001]
  - Concentric ventricular hypertrophy
    - Left ventricle and interventricular septum thickened (1.5 centimeter [cm] each)
      - 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 dilated (chamber width of 7.5 cm) (new finding since echocardiogram in 2008)
      - Normal by echocardiography 0.7–2.3 cm [Armstrong and Feigenbaum 2001]
  - Microscopic: areas of hypertrophic and vacuolated cardiomyocytes with increased subendocardial, intramyocardial, and perivascular fibrosis in left ventricle
- Coronary artery atherosclerosis
  - Moderate (60%) focal narrowing of the left anterior descending coronary artery
  - Mild (40%) focal narrowing of the right coronary artery
  - Mild (40%) focal narrowing of the left circumflex coronary artery
  - No definitive coronary artery thrombus (blood clot)
- Normal cardiac valves
- No evidence of a pulmonary embolus (blood clot in the lung arteries)
- Blood tests for drugs and alcohol were negative.

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