2012
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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 *July, 2012*

Fire Apparatus Operator Suffers Sudden Cardiac Death During Physical Fitness Training – Hawaii

Executive Summary

On January 18, 2012, a 50-year-old male career fire apparatus operator (FAO) was working a 24-hour shift. During the day he responded to one emergency call, a reported structure fire near his home. Later that afternoon, the FAO began working out as part of the FD's wellness/fitness program. Approximately 3 hours later a crew member found the FAO unresponsive in the station's exercise room. CPR was initiated, and an automated external defibrillator (AED) was placed, but no shock was advised. Approximately 2 minutes later, paramedics arrived, assessed the FAO, and concluded that the FAO had been dead for a significant time. They pronounced him dead.

The death certificate and autopsy listed "ischemic heart disease due to hypertensive and kidney disease and an old myocardial infarction" as the cause of death. Given the FAO's underlying cardiovascular disease, NIOSH investigators concluded that the physical stress of physical fitness training probably triggered his sudden cardiac death.

NIOSH investigators offer the following recommendations to address general safety and health issues. It is unclear whether these recommendations could have prevented the FAO's death, however his underlying cardiac disease may have been identified sooner, possibly allowing for further evaluation and treatment.

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

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

The following recommendations would not have prevented the FAO's death, but they address safety and health issues that all fire departments should consider.

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

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

Discontinue lumbar spine x-rays as a screening test administered during the preplacement medical evaluation.

Introduction & Methods

On January 18, 2012, a 50-year-old male career FAO collapsed during physical fitness training and died. NIOSH contacted the affected Fire Department (FD) on January 20, 2012, to gather information, and again on February 2, 2012, to initiate the investigation. On February 7, 2012, a safety and occupational health specialist from the NIOSH Fire Fighter Fatality Prevention and Investigation Program conducted an on-site investigation of the incident.

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Introduction & Methods (cont.)

During the investigation, NIOSH personnel interviewed the following people:

- Fire Chief
- FD Training Officer
- FD Health and Safety Officer
- County Loss Control Specialist
- County Safety Specialist
- Hawaii Firefighters Association Local Division Chair
- Crew members
- FAO's spouse

NIOSH personnel reviewed the following documents:

- FD standard operating procedures
- FD annual report for 2011
- FD incident reports
- Emergency medical service (ambulance) report
- Death certificate
- Autopsy
- Primary care physician records

Investigative Results (cont.)

Incident. On January 18, 2012, the FAO reported for his 24-hour shift at 0730 hours. The FAO was part of a five-person crew at his fire station and was assigned as the fire apparatus operator of Engine 5. After the morning briefing, the FAO inspected Engine 5 and its equipment. At approximately 0900 hours, the FAO operated a weed eater to trim grass for approximately 30 minutes.

At 1401 hours Engine 5 was dispatched to a report of smoke emitting from a single family home. Upon arrival at the residence, Engine 5 determined that the smoke originated from cooking on a hot plate but no fire had occurred. The FAO and crew returned to quarters at 1437 hours.

Investigative Results (cont.)

At approximately 1530 hours, the FAO entered the weight room to begin his exercise program of lifting weights, walking/jogging on the treadmill, pedaling a stationary bike, and jumping rope. At approximately 1600 hours, a crew member entered the weight room for a short time and spoke with the FAO. The FAO did not report any symptoms or exhibit any signs of a medical problem. No one else entered the weight room until approximately 1820 hours, when a crew member saw the FAO lying on the floor. The crew member entered the weight room and found the FAO unresponsive, not breathing, and pulseless.

The crew member notified the Captain, other crew members, and Dispatch, who notified Medic 2. Oxygen equipment and an AED were retrieved from the station as CPR was begun. The AED was placed, but no shock was advised. As the crew continued cardiac resuscitation efforts, it became clear that livor mortis was present. After a few minutes, cardiac resuscitation efforts were discontinued as Medic 2 arrived and confirmed the FAO's death (1822 hours). There was no transport to the hospital.

Medical Findings. The death certificate and autopsy, completed by the county medical examiner, listed "ischemic heart disease due to hypertensive and kidney disease and an old myocardial infarction" as the cause of death. Findings from the autopsy are listed in Appendix A.

The FAO's risk factors for coronary artery disease (CAD) included hypercholesterolemia (high blood cholesterol) diagnosed in 1991, hypertension (high blood pressure) diagnosed in 1999, diabetes mellitus diagnosed in 1999, and obesity. He was prescribed diet modification, a blood pressure-

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Investigative Results (cont.)

lowering medication, and an oral medication to control his blood sugar.

The FAO had annual FD medical evaluations. His most recent was in November 2011 at which time he was cleared for fire fighting duties. The FAO never complained about cardiac symptoms and participated in the FD's wellness/fitness program by lifting weights, walking/jogging on the treadmill, pedaling a stationary bike, and jumping rope every shift for approximately 2 hours.

The FAO was 68 inches tall and weighed 210 pounds, giving him a body mass index of 31.9 kilograms per meters squared. A BMI of >30.0 kg/m2 is considered obese [CDC 2011]. Many researchers consider the skinfold thickness test a more accurate method of determining obesity, particularly in muscular individuals [Pollock et al. 1984; Nooyens et al. 2007; CDC 2011]. A skinfold thickness test was not performed on the FAO.

Description of the Fire Department

At the time of the NIOSH investigation, the FD consisted of 14 fire stations with 296 career uniformed personnel serving 152,000 residents in a geographic area of 1,128 square miles. In 2011, the FD responded to 8,532 incidents, including 528 fires and 4,865 medical calls.

Membership and Training. The FD requires new full-time fire fighter applicants to be 18 years of age; have a valid state driver's license; and pass a written exam, a candidate physical ability test (components are listed below), and an interview. After receiving a conditional job offer, the new hire must pass a preplacement medical evaluation, a background check, and a drug screen. The new

Description of the FD (cont.)

hire receives training and must attain Fire Fighter I status within 6 months. The new hire is placed on probation for 1 year working a 24 hours on-duty/24 hours off-duty schedule for three shifts, then off-duty for 4 days. The FAO was certified as a Fire Fighter III, Driver/Operator, First Responder, and in Hazardous Materials Awareness. He had 20 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:

- Complete medical history
- Physical examination (including vital signs)
- Blood tests: complete blood count, lipid panel
- Urinalysis
- Urine drug screen
- Spirometry
- Resting electrocardiogram (EKG)
- Hearing (audiometric) test
- Vision screen
- Tuberculosis (PPD) test
- Lumbar spine x-ray

The evaluations are performed by a County-contracted physician. Once this evaluation is completed, the contract physician makes a determination regarding medical clearance for fire fighting duties and forwards this decision to the FD.

Candidate Physical Ability Test. All fire fighter candidates must pass a candidate physical abilty (physical condition) test. The components are as follow:

- 100-meter swim. Swim 100 meters within 2 minutes, 15 seconds (two lengths of the pool)

Description of the FD (cont.)

- Dive. Without exiting the pool and within 1 minute of completing the 100-meter swim, dive to the bottom of the pool and retrieve an object (weighing approximately 15 pounds)
- One mile run. Run 1 mile on a level course within 8 minutes

Annual Medical Evaluations. The FD requires annual medical evaluations. The components of this medical evaluation are the same as the preplacement medical evaluation except resting EKGs are not performed and chest x-rays are performed as clinically indicated. Medical clearance to wear a respirator and an annual SCBA facepiece fit test are required.

Members injured on duty are evaluated by the attending emergency department physician or their primary care physician. The physician is given a job profile (i.e., list of essential job tasks) to determine if the member is physically capable of performing their assigned tasks. The physician then forwards their medical clearance opinion to the County Human Resources Office, which ensures the clearance forms are complete and accurate. The Human Resource Office makes the final determination regarding return to work.

Members who are ill and miss two or more shifts must provide a medical clearance statement from their personal physician using the member's job profile. Final determination regarding return to work is made by the County Human Resources Office. The FD maintains a "modified special assignment" program (i.e., light duty) until the member is released to full duty.

Health and Wellness Programs. The FD has a voluntary wellness/fitness program, and exercise equipment is available in the fire stations. Additionally, the FD has contracted with a local fitness center for members to exercise at that facility 2 days each week for 1 hour. Members may go as a group or individually. The FD does not require an annual physical ability test. The FAO walked and jogged on the treadmill, pedaled the stationary bike, lifted weights, and jumped a rope during his work shift for approximately 2 hours.

Discussion

Atherosclerotic Coronary Artery Disease. In the United States, atherosclerotic 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 [AHA 2011; NHLBI 2011]. The FAO had six CAD risk factors (age older than 45, male gender, high blood pressure, high blood cholesterol, obesity, and diabetes).

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 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,

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Discussion (cont.)

elevated cardiac enzymes, or coronary artery thrombus. In this case, an EKG was not performed because the FAO had no heart beat, cardiac enzymes were not tested, and no coronary artery thrombus was identified at autopsy. However, heart attacks can occur without a coronary thrombus [Davies 1992; Farb et al. 1995], and the FAO had microscopic evidence of an old (remote) heart attack at autopsy. Thus, a heart attack could have been responsible for the FAO's sudden death.

Epidemiologic studies have found that heavy physical exertion sometimes immediately precedes and triggers the onset of acute heart attacks and sudden cardiac death [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 FAO had responded to one alarm and performed physical fitness training by lifting weights, walking and running on the treadmill, pedaling a stationary bike, and jumping rope for an undetermined time. Resistance (weight) training with vigorous effort expends about 6 metabolic equivalents (METs); jogging on the treadmill at about 7 miles per hour expends 11 METs, which is considered moderate-heavy physical activity; bicycling a stationary bike with vigorous effort expends about 7 METs; and rope skipping expends about 11 METs [AIHA 1971; Ainsworth et al. 2011]. NIOSH investigators conclude that the FAO's sudden cardiac death was probably triggered by his physical activity and his underlying CAD.

Primary Arrhythmia. A primary cardiac arrhythmia (e.g., ventricular tachycardia/fibrillation) could also have been responsible for the FAO's sudden cardiac death. Risk factors for arrhythmias include heart disease, heart attack, dietary supplements, smoking, alcohol, drug abuse, medications, diabetes, and hyperthyroidism [Mayo Clinic 2011; AHA 2012]. Although the FAO did not have known heart disease prior to his death, his autopsy confirmed significant CAD, cardiomegaly, left ventricular hypertrophy (discussed below), and evidence of an old heart attack. These conditions increase the risk for a primary arrhythmia.

Cardiomegaly/Left Ventricular Hypertrophy. On autopsy, the FAO was found to have left ventricular hypertrophy and an enlarged heart. These conditions increase the risk for sudden cardiac death [Levy et al. 1990]. Hypertrophy of the heart's left ventricle is a relatively common finding among individuals with long-standing hypertension, a heart valve problem, or chronic cardiac ischemia (reduced blood supply to the heart muscle) [Siegel 1997]. The FAO had a history of hypertension.

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. The FAO had two factors related to medical clearance, CAD (unknown to the FAO and his physicians) and diabetes mellitus.

Coronary Heart Disease (CHD) and Exercise Stress Tests. The FAO had three risk factors for CHD (hypertension, high blood cholesterol, and diabetes mellitus). Despite being asymptomatic,

Discussion (cont.)

the FAO should have been considered for an exercise stress test to screen for CHD. Recommendations for conducting exercise stress tests on asymptomatic individuals without known heart disease are varied. The following paragraphs summarize the positions of widely recognized organizations on this topic.

National Fire Protection Association (NFPA) 1582, a voluntary industry standard, recommends an exercise stress test be performed "as clinically indicated by history or symptoms" and refers the reader to Appendix A [NFPA 2007a]. 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 (e.g., symptom-limiting) stress tests with imaging should be used for fire fighters with the following conditions:

- abnormal screening submaximal tests
- cardiac symptoms
- known CAD
- two 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 American College of Cardiology/American Heart Association (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 with diabetes mellitus is "Class IIa," which is defined as "conflicting evidence and/or a divergence of opinion about the usefulness/efficacy but the weight of the evidence/opinion is in favor." The ACC/AHA guideline states the evidence 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 CAD 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

The U.S. Preventive Services Task Force (USPSTF) does not recommend stress tests for asymptomatic individuals at low risk for coronary heart

Discussion (cont.)

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, the USPSTF recommends 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."

Given the FAO's age and CAD risk profile, the NFPA, the ACC/AHA, and the DOT would have recommended a symptom-limiting exercise stress test.

Diabetes Mellitus. NFPA 1582 provides guidance for fire department physicians to follow when evaluating fire fighters with diabetes. The standard states that fire fighters with diabetes mellitus controlled by oral hypoglycemic agents should be restricted from duty unless the member meets all of the following criteria:

- If on oral hypoglycemic agents, has no episodes of severe hypoglycemia (defined as requiring assistance of another in the preceding year)
- Has achieved a stable blood glucose as evidenced by HA_1C level less than 8 during the prior 3-month period
- Has a dilated retinal exam by a qualified ophthalmologist or optometrist that shows no higher grade of diabetic retinopathy than microaneurysms
- Has normal renal function on the basis of a calculated creatinine clearance greater than 60 milliliters per minute and absence of proteinuria
- Has no autonomic or peripheral neuropathy
- Has normal cardiac function without evidence of myocardial ischemia on cardiac stress testing (to at least 12 METs) by EKG and cardiac imaging [NFPA 2007a].

The FAO was diagnosed with diabetes in 1999. Diet and exercise failed to adequately control his blood sugars, so in 2007 he was prescribed an oral agent (Metformin®). Although the FAO did not report any hypoglycemic episodes, he was not tested for many of these complications (e.g., stress test, renal function, retinal exam, HA_1C level, etc.).

Recommendations

NIOSH investigators offer the following recommendations to address general safety and health issues. It is unclear whether these recommendations could have prevented the FAO's death, however his underlying cardiac disease may have been identified sooner, possibly allowing for further evaluation and treatment.

Recommendation #1: 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

Recommendations (cont.)

Chiefs (IAFC) Fire Service Joint Labor Management Wellness/Fitness Initiative [NFPA 2007a; IAFF, IAFC 2008]. While the FD does comprehensive annual evaluations, it does not perform exercise stress tests for fire fighters at risk for coronary heart disease (see Discussion Section). NIOSH investigators recommend the FD conduct exercise stress tests for fire fighters at increased risk for coronary heart disease [Gibbons et al. 2002; NFPA 2007a]. In addition, NIOSH investigators recommend that additional medical testing of fire fighters with diabetes be performed [NFPA 2007a]. However, the FD is not legally required to follow the NFPA standard or the IAFF/IAFC initiative.

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, if capable, 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 (or a commonly occupied location) may be helpful.

The following recommendations would not have prevented the FAO's death, but they address safety and health issues that all fire departments should consider.

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

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. Consider taking employees out of service during their workout to ensure uninterrupted participation.

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].

Recommendations (cont.)

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

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

Recommendation #5: Discontinue lumbar spine x-rays as a screening test administered during the preplacement medical evaluation.

The FD currently performs preplacement physical evaluations, which include routine lumbar spine x-rays. While these x-rays may be useful in evaluating individuals with existing problems, the American College of Radiology, American College of Occupational and Environmental Medicine, and NIOSH investigators have concluded that lumbar spine x-rays have no value as a routine screening measure to determine risk for back injuries [Present 1974; Lincoln et al. 1979; Gibson 1998]. This procedure involves both an unnecessary radiation exposure for the applicant and an unnecessary expense for the FD.

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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 Health, and Vice-Chair of the Public Safety Medicine Section of the American College of Occupational and Environmental Medicine (ACOEM).

Appendix A

Autopsy Findings

- Hypertensive heart disease
  - Cardiomegaly (enlarged heart; heart weighed 540 grams [g]; predicted normal weight is 383 g [ranges between 290 g and 506 g as a function of sex, age, and body weight]) [Silver and Silver 2001]
  - Concentric left ventricular hypertrophy
    - Left ventricle thickened (2.0 centimeter [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]
- Coronary artery atherosclerosis
  - Moderate to severe (70%) focal narrowing of the left anterior descending coronary artery
  - Moderate to severe (70%) focal narrowing of the right coronary artery
  - Moderate to severe (70%) focal narrowing of the circumflex coronary artery
  - Microscopic evidence of fibrosis affecting the posterior left ventricle free wall (old heart attack)
- 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

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