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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 *April, 2011*

Fire Fighter/Paramedic Suffers Sudden Cardiac Death After Rescue Training – California

Executive Summary

On September 16, 2010, a 56-year-old male career Fire Fighter/Paramedic (FF/P) participated in rescue training that included classroom lectures, stretching exercises, and lifting/moving heavy concrete blocks. During the stretching exercises, the FF/P experienced chest discomfort. He and his paramedic partner administered and interpreted an electrocardiogram (EKG). The EKG revealed a slow heart rate but no changes suggestive of cardiac ischemia. The FF/P resumed the training, which, at that time, involved lifting and moving concrete blocks. This evolution lasted approximately 25 minutes after which crews were debriefed and dismissed for lunch. After walking to his vehicle, the FF/P collapsed. Despite cardiopulmonary resuscitation (CPR) and advanced life support (ALS) at the scene, in the ambulance, and in the hospital's emergency department (ED), the FF/P died. The death certificate and the autopsy listed "severe coronary atherosclerosis" as the cause of death with "cardiomegaly" as a significant other condition. Given the FF/P's severe underlying coronary artery disease (CAD), NIOSH investigators concluded that the physical exertion involved in performing the rescue training probably triggered his sudden cardiac death.

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

Report signs or symptoms consistent with a heart attack to authorities for prompt medical evaluation.

Provide mandatory annual medical evaluations to all fire fighters consistent with the current edition of National Fire Protection Association (NFPA) 1582, Standard on Comprehensive Occupational Medical Program for Fire Departments.

Consider reviewing the fire department's policy for conducting member exercise stress tests.

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

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

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Introduction & Methods

On September 16, 2010, a 56-year-old male career FF/P died shortly after performing rescue training. NIOSH was notified of this fatality on September 17, 2010, by the U.S. Fire Administration. NIOSH contacted the affected Fire Department (FD) on September 21, 2010, to gather additional information and on October 25, 2010, to initiate the investigation. On November 3, 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
- FD Operations Assistant Chief
- D Medical Director
- FD operations Training & Safety Battalion Chief
- Risk Manager
- IAFF Local Vice President
- Crew members
- F/P's spouse

NIOSH personnel reviewed the following documents:

- FD training records
- FD annual report for 2009
- FD incident report
- Witness statements
- FD medical records
- Emergency medical service (ambulance) incident report
- Hospital ED records
- Death certificate
- Autopsy report

Investigative Results

Incident. On September 16, 2010, at about 0800 hours, the FF/P arrived at his fire station for his 24-hour shift as an FF/P on Truck 4 (a 4-person unit). Because of the rescue training scheduled that day, the FF/P changed assignments to be the driver of Medic 4 (a 2-person paramedic unit). At approximately 0900 hours, Medic 4 drove to the training center, joining Engine 20 (4-person crew), Truck 22 (4-person crew), and Engine 7 (3-person crew). The training included indoor classroom instruction, stretching exercises, and lifting/moving heavy concrete blocks. The classroom instruction began at 0930 hours. The FF/P reported no symptoms and appeared fine to crew members during this time.

At 1025 hours, the group began stretching exercises. The FF/P complained of chest discomfort he thought to be related to a chest cold that had persisted for the past 2 weeks. As reassurance, however, the FF/P asked his paramedic partner to run a 12-lead EKG. The EKG revealed a sinus bradycardia rhythm (slow heart beat with no ischemic changes). The FF/P disconnected the leads and stated "See, it looks fine." His paramedic partner agreed, and the FF/P returned to the stretching exercises.

The stretching exercises were completed at 1045 hours, and the crews were released to the nearby outdoor training grounds. The weather at this time included a temperature of 66.2°F and 78% relative humidity [Weather Underground 2010]. The FF/P was dressed in wildland fire fighter's boots, uniform pants, wildland Nomex® jacket, wildland fire fighting gloves, and a structural fire fighter helmet. The FF/P walked briskly to the training grounds and was the first of 13 fire fighters to arrive at the training area.

Investigative Results (cont.)

The Training Captain gave a safety briefing and provided an overview of the first evolution, lifting and moving a 3′ x 3′ concrete cube weighing 2,000 pounds. The 13 fire fighters were divided into two squads each instructed to move the cube using 8-pound pry and roller bars. During this evolution the FF/P was responsible for moving the pipes from the back of the rolling cube to the front as the cube was pushed forward. The exercise lasted for 20–30 minutes, and the FF/P successfully performed his task with no health complaints.

After completion of this first evolution the fire fighters were released for lunch (approximately 1120 hours). As the FF/P walked back to his assigned vehicle (Medic 4), he collapsed (1127 hours). A witness notified a dispatcher via cell phone, who dispatched Truck 43, Medic 21, and an ambulance. Engine 7, on-scene at the training grounds, was also assigned to the call at 1128 hours. Remaining crew members at the training ground responded and provided assistance.

Crew members assessed the FF/P, finding him unresponsive, not breathing, and without a pulse. CPR and ALS were begun and a cardiac monitor was applied, revealing ventricular fibrillation. Two shocks were delivered without change in his heart rhythm. An intravenous line was placed, and cardiac resuscitation medications were administered.

The ambulance arrived on the scene at 1131 hours, and ALS continued. The FF/P was loaded onto a stretcher and placed into the ambulance. An additional shock was administered, and the ambulance departed the scene en route to the hospital ED at 1138 hours. After two unsuccessful intubation attempts, a Combitube® was inserted with placement verified by positive lung sounds and capnography. A cardiac monitor continued to reveal ventricular fibrillation, and a fourth defibrillation attempt was made without positive change in the FF/P's heart rhythm.

The ambulance arrived at the ED (1148 hours), where ALS continued. The FF/P's heart rhythm alternated between atrial fibrillation and asystole. After more than 30 minutes of treatment, the FF/P was pronounced dead by the attending physician (1222 hours), and resuscitation efforts were discontinued.

Medical Findings. The death certificate and the autopsy listed "severe coronary atherosclerosis" as the cause of death with "cardiomegaly" as a significant condition. Specific findings from the autopsy are listed in Appendix A.

The FF/P was 75 inches tall and weighed 239 pounds, giving him a borderline obese body mass index of 29.9 kilograms per meters squared. 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 2010]. A skinfold thickness test was performed on the FF/P in July 2010. His body fat percentage was calculated at 34.1%; a reading consistent with the borderline obese reading by body mass index [ACE 2010].

The FF/P participated in a biannual medical evaluation as part of the FD's Wellness Fitness Initiative (WFI). During these evaluations the FF/P was found to have high blood cholesterol for which the FF/P was counseled and referred to his primary care physician for further evaluation and treatment, and left axis deviation on his resting

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Investigative Results (cont.)

electrocardiogram (EKG). As part of WFI, the FF/P underwent a biannual aerobic capacity test [IAFF, IAFC 2008]. This test was conducted on a treadmill using the Gerkin protocol with electrocardiographic and blood pressure monitoring. The test was last performed in July 2010, two months prior to his death. The FF/P exercised for 4 minutes achieving 11.3 metabolic equivalents (METs) when the test was stopped due to his reaching 85% of his maximum predicted heart rate. He reported no angina, his blood pressure showed a normal increase with exercise, and the EKG showed no arrhythmias or signs of ischemia. The FF/P was counseled and mailed copies of the WFI findings along with follow-up recommendations. The WFI medical evaluation is not structured to medically clear fire fighters for duty (discussed in more detail in the next section of this report).

Descreiption of the Fire Department

At the time of the NIOSH investigation, the FD consisted of 62 fire stations in 22 cities with 1,072 career and 475 reserve uniformed personnel. The FD served 1.4 million residents in a geographic area of 550 square miles, including 175,000 acres of wildland. In 2009, the FD responded to 85,787 emergency incidents with 163,050 individual unit responses: 1,540 fire calls, 60,197 emergency medical calls, 1,144 hazardous condition calls, 5,437 service calls, 12,424 good intent calls, 4,249 false alarms, and 796 miscellaneous calls. The FF/P was usually assigned to Medic 4, which responded to 2,170 calls in 2009.

Membership and Training. The FD requires new full-time fire fighter applicants to be 18 years of age (21 years old to drive fire apparatus); have a valid State driver's license; complete an interest card, pass a written examination, complete an application and provide a resumé, pass a physical agility test, and pass an interview. The successful candidate is placed into a group of potential new hires. The new hire is given a preplacement medical evaluation (described below) and sent to the 16-week Fire Fighter Academy to become State-certified as a Fire Fighter 1. After successfully completing the Fire Academy, the new hire is placed on a shift working 24 hours on-duty, 24 hours off-duty, 24 hours on-duty, 48 hours off-duty, 24 hours on-duty, 24 hours off-duty, 24 hours on-duty, and 96 hours off-duty (0800 hours to 0800 hours). The FF/P was certified as a Fire Fighter 2 and a Paramedic. He had 30 years of fire fighting experience.

Descreiption of the FD (cont.)

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)
- Complete blood count with lipid panel
- Pulmonary function test
- Resting EKG
- Chest x-ray (baseline)
- Urinalysis
- Urine drug screen
- Audiogram
- Vision screen
- Immunization and infectious disease screening
- Baseline aerobic capacity test

Descreiption of the FD (cont.)

The evaluation is performed by the medical clinic also under contract to conduct the WFI medical evaluations (see below). Once this evaluation is complete, the contracted clinic's physician makes a determination regarding the applicant's medical clearance to wear a respirator and medical clearance to perform fire fighting duties. This determination is then forwarded to the FD. The FF/P joined this FD in 1980. It is unclear if a preplacement medical evaluation was conducted at that time he joined the FD.

Periodic Medical Evaluations. As part of the WFI, the FD offers voluntary biannual medical evaluations for all members. Approximately 94% of the fire fighters participate in this voluntary evaluation. The components of this medical evaluation are the same as for the preplacement evaluation except that: 1) the urine drug screen is not done unless clinically indicated, 2) the chest x-ray is done every 5 years [more frequently for HAZMAT and urban search and rescue (USAR) teams], and 3) a prostate specific antigen (PSA) test is done on all male fire fighters beginning at age 40. Fire fighters at high risk for a cardiac event (based on age, number and severity of CAD risk factors) are referred to cardiologist for a symptom limiting exercise stress test. Once completed, the clinic's physician provides results of the evaluation to the FD member verbally and in writing. The clinic's physician does not, however, release findings of the WFI medical evaluation to the FD medical director or the FD-contracted physicians doing "return-to-work" evaluations unless the fire fighter signs a medical release form.

Return-to-Work Medical Evaluations. Members injured/ill on duty and are off duty for one shift must be evaluated by the FD-contracted occupational medicine physician who forwards a determination for return to duty to the FD. Members who are injured/ill off duty and are off duty for five shifts or 14 calendar days must also be cleared for return to duty by the FD-contracted occupational medicine physician. The FD has a rehabilitation program for injured members provided through a third party vendor. The program is paid for by the FD, but FFs attend during their off-duty time.

The local union offers a full-body scan (to detect disease, tumors, and abnormalities throughout the torso) as part of its voluntary medical evaluation program every 5 years at a reduced cost to its members. Finally, a self-contained breathing apparatus (SCBA) facepiece fit test is conducted annually for all fire fighters.

Health and Wellness Programs. The FD has a voluntary wellness/fitness program, and exercise equipment is available in most fire stations. However, exercise time is not protected time (i.e., the employee is not taken out of service). The FD offers free local gym membership for employees working in fire stations without fitness equipment. No annual physical ability tests are required.

Discussion

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 [AHA 2010a; NHLBI 2010]. The FF/P had three CAD risk factors (age over 45, male gender, and hypercholesterolemia) and severe CAD 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 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 the occurrence of a recent (acute) heart attack requires any of the following: characteristic electrocardiogram (EKG) changes, elevated cardiac enzymes, or coronary artery thrombus. The FF/P did not have a heartbeat on which to conduct an EKG, cardiac enzymes were not tested, and no thrombus was identified at autopsy. However, occasionally (16%–27% of the time) postmortem examinations do not reveal the coronary artery thrombus/plaque rupture during acute heart attacks [Davies 1992; Farb et al. 1995]. The FF/P suffered either sudden cardiac death due to an acute heart attack without a thrombus being present at autopsy or a primary heart arrhythmia (discussed below).

Epidemiologic studies have found that heavy physical exertion sometimes immediately precedes and triggers the onset of acute heart attacks and sudden cardiac death [Siscovick et al. 1984; Tofler et al. 1992; 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 FF/P participated in rescue training. This activity expended about 7 metabolic equivalents, which is considered light-moderate physical activity [AIHA 1971; Gledhill and Jamnik 1992]. Given the FF/P's severe underlying CAD, NIOSH investigators concluded that the light to moderate physical exertion during rescue training probably triggered either a heart attack or a heart arrhythmia resulting in sudden cardiac death.

Primary Arrhythmia. A primary cardiac arrhythmia (e.g., ventricular tachycardia/fibrillation) could have also been responsible for the FF/P'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 2009; AHA 2010b]. Although the FF/P did not have known heart disease prior to his death, his autopsy confirmed severe CAD and left ventricular

Discussion (cont.)

hypertrophy (discussed below). Both conditions increase the risk for a primary arrhythmia.

Left Ventricular Hypertrophy. On autopsy, the FF/P was found to have LVH, which increases 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 high blood pressure (hypertension), a heart valve problem, or chronic cardiac ischemia (reduced blood supply to the heart muscle) [Siegel 1997]. The FF/P did not have a history of hypertension or a heart valve problem. Therefore, the FF/P's LVH was most likely the result of chronic cardiac ischemia associated with CAD.

Aerobic Capacity and Exercise Stress Tests. Two months prior to his death the FF/P had an aerobic capacity test performed by the clinic performing the WFI medical evaluations. As noted previously, the FF/P exercised for 4 minutes and stopped when he reached 85% of his maximal heart rate achieving 11.3 METS with no signs of ischemia. This test was considered an aerobic capacity test rather than an exercise stress test because the test was stopped when the FF/P's heart rate reached a predetermined level [85% of his maximum heart rate (i.e., a submaximal test)]. Given the FF/P's severe CAD at autopsy and sudden death 2 months after the test, perhaps a symptom-limiting exercise stress test would have identified his underlying CAD [Gibbons et al. 2002; Grundy 2003; NFPA 2007a].

This 56-year-old firefighter was not known to have signs or symptoms of CAD and conducting exercise stress tests on asymptomatic individuals without known heart disease is controversial. 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 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 coronary artery disease
- 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

Discussion (cont.)

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 coronary artery disease due to other diseases (e.g., peripheral vascular disease and chronic renal failure)

The **U.S. Department of Transportation** (DOT) provides guidance for those seeking medical certification for a commercial drivers' license. An expert medical panel recommended exercise tolerance tests (stress tests) for asymptomatic "high risk" drivers [Blumenthal 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 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."

Given the FF/P's age and CAD risk profile, only the ACC/AHA would have "recommended" a symptom limiting exercise stress test. This recommendation, however, was based on a "category IIb" indication: "usefulness/efficacy is less well established by evidence/opinion" [Gibbons et al. 2002].

Recommendations

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

Recommendation #1: Report signs or symptoms consistent with a heart attack to authorities for prompt medical evaluation.

The FF/P was a certified Emergency Medical Technician-Paramedic. His training included recognizing the signs and symptoms of heart attacks [American Red Cross 1997]. But recognizing these signs and symptoms in oneself is difficult, particularly if the symptoms are mild and nonspecific (e.g., similar to a chest cold, or physical exertion during training). In addition, self-diagnosis is prone to error. Even physicians have been discouraged from engaging in self-diagnosis. Although the EKG performed by the FF/P and his medic partner did not reveal changes suggestive of a heart attack, a normal resting EKG does not necessarily mean that the pain or discomfort is from a noncardiac source. Perhaps if the FF/P had been evaluated in the ED, additional testing or monitoring may have been conducted. It is possible this could have led to the identification and treatment of this underlying CAD prior to his sudden cardiac death.

Recommendation #2: Provide mandatory annual medical evaluations to all fire fighters consistent with the current edition of National Fire Protection Association (NFPA) 1582, Standard on Comprehensive Occupational Medical Program for Fire Departments.

Both the WFI and NFPA 1582 seek to determine a fire fighters' medical ability to perform duties without presenting a significant risk to the safety and health of themselves or others. We applaud the FD and the union for implementing the WFI. However, the FD is currently conducting the medical evaluations every 2 years, not every year, and while the program is called "mandatory nonpunitive," it is, in fact, voluntary. In addition, by not sharing the WFI medical evaluation findings with the FD medical director or equivalent, the goal of identifying fire fighters at risk to themselves or others is compromised. We recommend the FD require annual member medical evaluations and the results be shared with the appropriate FD medical personnel to ensure fire fighters are medically cleared for structural fire fighting.

Recommendation #3: Consider reviewing the FD's policy for conducting member exercise stress tests.

The FD currently provides voluntary biannual aerobic capacity tests as specified in the WFI. Fire fighters at high risk for a cardiac event are referred to a cardiologist for a symptom-limiting exercise stress test. "High risk" is determined by the age of the fire fighter and the number and severity of CAD risk factors [NFPA 2007a; NHLBI 2011]. The Framingham risk score takes into account age, the number, and severity of CAD risk factors. By using the Framingham risk score, members with a 10%–20% risk of a coronary heart event over the next 10 years could be referred for a symptom-limiting exercise stress test with or without imaging studies [NFPA 2007a].

Recommendation #4: Phase in a mandatory comprehensive wellness and fitness program for fire fighters.

Recommendations (cont.)

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 has a voluntary wellness/fitness program. However, NIOSH recommends a formal, structured wellness/fitness program to ensure all members receive the benefits of a health promotion program. In addition, during exercise time, employees should be taken out of service to ensure uninterrupted member participation.

Recommendation #5: Perform 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]. While the biannual aerobic capacity test determines the member's aerobic capacity, this is just one requirement of a structural fire fighter. Once developed by the FD, this evaluation could be performed as part of the FD annual training program.

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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

- Atherosclerotic cardiovascular disease
  - Severe (>80%) focal narrowing of the left anterior descending coronary artery
  - Left ventricular hypertrophy (LVH)
    Left ventricular wall and interventricular septum thickened (1.7 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]
- Normal heart weight of 480 grams (g); predicted normal weight is 406 g (between 308 g and 536 g as a function of sex, age, and body weight) [Silver and Silver 2001]
- Normal cardiac valves
- No evidence of a thrombus (blood clot in the coronary arteries)
- No evidence of a pulmonary embolus (blood clot in the lung arteries)
- Hepatosplenomegaly
- Toxicology results were not available at the time of this report

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