2011
01

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*

Fire Fighter Suffers Heart Attack While Fighting Grass Fire and Dies 2 Days Later – California

Executive Summary

On October 3, 2010, a 52-year-old male career Fire Fighter (FF) responded to five emergency calls. Over the previous 2 days, he had responded to 15 other calls. At the last call, a grass fire, the FF pulled 350 feet of 1½-inch hoseline and began fire suppression activities for about an hour before taking a break. After about a 10-minute break, the FF returned to fire suppression activities. Approximately 30–40 minutes later, complaining of back pain, the FF returned to his engine. After asking the driver/operator to request a medic unit, the FF collapsed. Despite cardiopulmonary resuscitation and advanced life support at the scene, in the ambulance, and in the hospital, the FF died 2 days later. The death certificate listed "acute myocardial infarction with hemorrhagic stroke" as the cause of death. No autopsy was performed. Given the FF's severe underlying coronary artery disease (CAD), NIOSH investigators concluded that the physical stress of responding to 20 calls while working 58 straight hours and performing fire suppression activities at the grass fire triggered a heart attack that led to his death.

NIOSH investigators offer the following recommendations to address general safety and health issues. Had some of these recommended programs been implemented, specifically incorporating exercise stress tests into the Fire Department's medical evaluation program, it is possible the FF's death could have been prevented.

Provide annual medical evaluations to all fire fighters.

Incorporate exercise stress tests following standard medical guidelines into a Fire Department medical evaluation program.

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

Ensure that fire fighters wear appropriate protective clothing for the specific type of incident.

Consider incident scene rehabilitation (rehab) during certain fire operations.

Perform an autopsy on all on-duty fire fighter fatalities.

The National Institute for Occupational Safety and Health (NIOSH), an institute within the Centers for Disease Control and Prevention (CDC), is the federal agency responsible for conducting research and making recommendations for the prevention of work-related injury and illness. In 1998, Congress appropriated funds to NIOSH to conduct a fire fighter initiative that resulted in the NIOSH "Fire Fighter Fatality Investigation and Prevention Program" which examines line-of-duty-deaths or on duty deaths of fire fighters to assist fire departments, fire fighters, the fire service and others to prevent similar fire fighter deaths in the future. The agency does not enforce compliance with State or Federal occupational safety and health standards and does not determine fault or assign blame. Participation of fire departments and individuals in NIOSH investigations is voluntary. Under its program, NIOSH investigators interview persons with knowledge of the incident who agree to be interviewed and review available records to develop a description of the conditions and circumstances leading to the death(s). Interviewees are not asked to sign sworn statements and interviews are not recorded. The agency's reports do not name the victim, the fire department or those interviewed. The NIOSH report's summary of the conditions and circumstances surrounding the fatality is intended to provide context to the agency's recommendations and is not intended to be definitive for purposes of determining any claim or benefit. For further information, visit the program website at www.cdc.gov/niosh/fire or call toll free 1-800-CDC-INFO (1-800-232-4636).

Fire Fighter Suffers Heart Attack While Fighting Grass Fire and Dies 2 Days Later – California

Introduction & Methods

On October 5, 2010, a 52-year-old male career FF died 2 days after suffering a heart attack while fighting a grass fire. NIOSH contacted the affected Fire Department (FD) on October 12, 2010, to gather additional information, and on January 6, 2011, to initiate the investigation. On January 18, 2011, 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
- Assistant Fire Chiefs
- FD Operations Deputy Chief
- FD Safety Officer
- IAFF Local President and Vice-President
- Crew members
- FF's spouse

NIOSH personnel reviewed the following documents:

- FD training records
- FD standard operating procedures
- FD annual report for 2010
- FD incident report
- FD medical records
- Emergency medical service (ambulance) incident report
- Hospital ED records
- Death certificate
- Primary care physician records

Investigative Results

Incident. On October 1, 2010, the FF reported for duty at 0800 hours for a 24-hour overtime shift and was assigned to Medic 110. During this shift the FF responded to seven medical calls; the first call was at 0834 hours, and the last call was at 0217 hours on October 2, 2010. The FF began his regular 48-hour shift at 0800 hours on October 2, 2010. During the first 24 hours, the FF responded to eight calls (five medical, one vehicle crash, one structure fire, and one false alarm) from 1054 hours until the last call at 0602 hours on October 3, 2010. During the second 24 hours (October 3, 2010), the FF responded to three medical calls (1041 hours, 1320 hours, and 1543 hours), an assistance call (1127 hours), and a grass fire described in detail below.

At 1816 hours, Engines 101, 103, and 19; Grass Units 103 and 19; and Battalion Chief 3 were dispatched to a grass fire at a golf course. Weather conditions at this time included a temperature of 71ºF and a relative humidity level of 47% [Weather Underground 2010]. Engine 101 (Captain, Engineer, and the FF) responded, arriving at 1822 hours to find a 1-acre grass/brush fire burning between a golf course and a railroad track. The FF and a crew member, wearing bunker pants and boots, and a wildland jacket, stretched two 350-foot progressive hose lays of 1½-inch hoseline down a 50-foot embankment with an approximate slope of 45º. Fire fighters began to attack the fire from two sides. Approximately 1 hour later, the FF walked back up the hill to take a 10-minute break at which time he hydrated and smoked a cigarette. Then he descended the hill and resumed fire fighting. Approximately 30–40 minutes later, the FF came back up the hill and informed the engineer that his back hurt. The engineer questioned the FF about his symptoms and suggested the FF

Investigative Results (cont.)

be evaluated by a medic unit. The FF initially declined the medic evaluation but then agreed, and a medic unit was requested at 2007 hours.

After requesting the medic unit, the engineer saw the FF slump over the tailboard of Engine 101. Crew members laid him on the ground as two nearby fire fighter-paramedics evaluated the FF. A cardiac monitor was attached, and an intravenous (IV) line was placed. His vital signs included a heart rate of 22 beats per minute, a systolic blood pressure of 60 millimeters of mercury (mmHg) by palpation, and delayed capillary refill (2 seconds). Atropine was administered via the IV line, and the FF's heart rate increased to 80 beats per minute. The FF regained consciousness and complained of chest pain and upper back pain. At 2016 hours, his heart rate suddenly dropped to 32 beats per minute, and he became unresponsive as the medic unit arrived on the scene.

The cardiac monitor revealed third degree heart block; additional IV medications were administered. The FF was positioned onto a backboard/cot and placed into the ambulance, which departed the scene at 2023 hours en route to the hospital ED. In the ambulance an external pacemaker was placed that resulted in the FF's pulse rate increasing to 80 beats per minute. He regained consciousness.

As the ambulance arrived at the ED (2034 hours), the FF lost consciousness again. Vital signs included a blood pressure of 89/52 mmHg with a pulse of 40 beats per minute. A cardiac monitor revealed complete heart block with a ventricular escape rhythm with marked ST-segment depression in the anterolateral leads consistent with a posterior myocardial infarction (heart attack). This diagnosis was confirmed by subsequent (October 4, 2010) cardiac enzyme elevations and cardiac catheterization described below. Clinically, the FF was in cardiogenic shock. The FF was intubated with tube placement verified by capnography [AHA 2000].

The FF was taken immediately to the cardiac catheterization laboratory where a total occlusion of the proximal dominant circumflex coronary artery was found, along with 20%–50% narrowing of the left anterior descending coronary artery. The circumflex artery was opened with a stent and some clot extraction, but reflow was slow. The FF had reduced left ventricle function (estimated ejection fraction of 45%), and an intra-aortic balloon pump was inserted to treat his cardiogenic shock. A temporary pacemaker was inserted.

On October 5, 2010, a neurologist was consulted regarding the extent of the FF's brain damage due to his prolonged period of cardiogenic shock. A computed tomography scan of the FF's head revealed a large hemorrhagic stroke, probably due to a blood clot in his heart embolizing to his brain. An electroencephalograph showed no evidence of focal brain activity, and the FF was declared brain dead at 1633 hours. After discussion with family members, life support systems were removed, and the FF was taken to the operating room for organ donation. The time of death was 1751 hours.

Medical Findings. The death certificate listed "acute myocardial infarction with hemorrhagic stroke" as the cause of death. No autopsy was performed. Blood tests in the ED revealed a normal carboxyhemoglobin level for a smoker (3.4%–5%), suggesting the FF was not exposed to excessive levels of carbon monoxide.

Fire Fighter Suffers Heart Attack While Fighting Grass Fire and Dies 2 Days Later – California

Investigative Results (cont.)

The FF was 61 inches tall and weighed 134 pounds, giving him a body mass index of 25.3 kilograms per meters squared. A body mass index > 25.0 kilograms per meter squared is considered overweight [CDC 2010]. The FF's other risk factors for CAD included hypercholesterolemia (high blood cholesterol) and smoking. According to medical records, he had not been prescribed cholesterol-lowering medications since his diagnosis in 1993, and no subsequent laboratory tests were conducted. During a March 2010 visit to his primary care physician, a heart murmur was identified. The FF related that he had a heart murmur in childhood and was told it would go away. A stress echocardiogram was recommended by his primary care physician as follow up to the heart murmur, but medical records did not indicate this test was ever performed.

Description of the Fire Department

At the time of the NIOSH investigation, the FD consisted of 42 fire stations with 550 career uniformed personnel. The FD served 640,000 residents in a geographic area of 417 square miles. In 2010, the FD responded to 76,065 incidents: 2,930 fire calls; 51,051 emergency medical calls; 10,662 good intent calls; 5,475 service calls; 3,393 false alarm/false calls; 1,662 special incident calls; 835 hazardous condition calls; 51 overpressure, explosion, overheat calls; and 6 weather-related calls.

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, and pass a candidate physical ability test and an oral interview. The candidate then receives a job offer. The new hire must then pass a medical screen, a background

Description of the FD (cont.)

check, and a psychological evaluation. The new hire is placed in the Fire District's 16-week fire training academy to be trained to the Fire Fighter 1 level. During the academy, trainees must pass several physical ability tests. Upon graduation, the new hire is placed on a 1-year probation during which time the new hire is trained to the Fire Fighter 2 level and must pass additional physical ability tests. The new hire is placed on a shift working 48 hours on duty (0800 hours to 0800 hours) and 96 hours off duty. The FF was certified as a Fire Fighter 2, Fire Officer, Emergency Medical Technician, Wildland Fire Fighter, Fire Instructor, and a Fire Investigator. 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)
- Complete blood count with lipid panel
- Limited spirometry
- Respirator clearance
- Resting electrocardiogram (EKG)
- Urinalysis
- Urine drug screen
- Audiogram
- Vision screen

These evaluations are performed by a physician contracted with the Fire District. Once the 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 FF joined this FD in 1990. His preplacement

Description of the FD (cont.)

medical evaluation results were not available to NIOSH at the time of this report.

Periodic Medical Evaluations. The FD requires periodic (age-based) medical evaluations for members of the hazardous materials (Hazmat) team and the urban search and rescue (USAR) team but not for all fire fighters. These evaluations occur every 3 years for members < age 40, every 2 years for members age 40-50, and annually for members > age 50. The evaluations are performed by a physician contracted with the Fire District. Once complete, the contracted physician determines medical clearance for Hazmat and USAR response and forwards this decision to the FD. The FD plans to implement mandatory age-tiered medical evaluations for all fire fighters in July 2011. The evaluations will be performed by a FD-contracted physician who will make the final determination regarding fitness for duty. If members elect to have the evaluation performed by their primary care physician, the clearance for duty will be reviewed by the FD contract physician. Components of the periodic medical evaluation will include the following:

- Medical history
- Vision screening
- Audiometry
- Urinalysis
- Vital signs
- 12-lead electrocardiogram
- Baseline chest x-ray
- Pulmonary function test
- Blood chemistry profile including complete blood count and lipid panel
- Cancer screening
- Immunizations and infectious disease screening

An annual self-contained breathing apparatus (SCBA) medical clearance and an annual SCBA facepiece fit test are required. Members injured on duty must be evaluated by the Fire District contract physician who forwards his or her determination for return to duty to the FD. The FD has a light duty program while the injured member goes through rehabilitation with the FD exercise physiologist. The FD is currently considering a policy change where the member must pass task-level training prior to being released for full fire fighting duties.

Health and Wellness Programs. The FD has a mandatory wellness/fitness program, and exercise equipment is available in the fire stations. Exercise time is available (1 hour per shift) but is not protected time (i.e., the employee is not taken out of service). No annual physical ability test is required. The FD has an exercise physiologist on staff and plans to offer annual fitness assessments beginning in July 2011. These fitness assessments are non-job-specific functional assessments and incorporate the voluntary U.S. Forest Service Pack Test (Appendix A) and the Firefighter Functional Challenge (Appendix B). These tests will be nonpunitive and incorporated into the FD training program. The FD's health and fitness program offers the following components:

- Personal exercise prescription
- Monthly company-level health and fitness drills
- Personal fitness assessments
- Nutritional assistance
- E-mail and phone consultations
- Post-injury job specific return to work programs
- Fitness challenges
- Fitness e-mail list

Discussion

Atherosclerotic Coronary Artery Disease (CAD). 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 FF had four CAD risk factors (age over 45, male gender, smoking, and hypercholesterolemia), and severe CAD was identified during his hospitalization.

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. The FF had a heart attack confirmed by EKG, cardiac enzymes, and coronary artery thrombus.

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 had worked 58 hours, during which time he responded to 20 calls, including the grass fire described in this report. The activity at the grass fire expended about 10 metabolic equivalents, which is considered heavy physical activity [AIHA 1971; Gledhill and Jamnik 1992]. Given the FF's severe underlying CAD, NIOSH investigators concluded that the physical exertion involved in working 58 hours, responding to 20 calls, and performing fire suppression duties during the grass fire triggered a heart attack leading to his 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 FF's elevated blood cholesterol was identified in 1993, but this condition by itself would not have caused fire fighter duty restrictions. However, elevated blood cholesterol with the FF's other CAD risk factor of smoking warranted a referral for an exercise stress test beginning in 2003.

Exercise stress tests screen people at risk for CAD and sudden cardiac death. The 2007 edition of NFPA 1582 recommends performing an exercise stress test "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. Diagnostic stress tests (maximal or symptom-limiting stress tests) with imaging should be used for fire fighters with the following conditions:

Discussion (cont.)

- 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 [mg/dL]), hypertension (diastolic blood pressure greater than 90 millimeters of mercury [mmHg]), smoking, diabetes mellitus, or family history of premature coronary artery disease (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 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 driver's 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's age and CAD risk profile, the NFPA, AHA/ACC, and the DOT would have all recommended a symptom-limiting exercise stress test. Had an exercise stress test been performed, perhaps his underlying CAD would have been identified and treated prior to this episode.

Recommendations

NIOSH investigators offer the following recommendations to address general safety and health issues. Had some of these recommended programs been implemented, specifically incorporating exercise stress tests into the Fire Department's medical evaluation program, it is possible the FF's death could have been prevented.

Recommendation #1: Provide annual medical evaluations to all fire fighters.

Guidance regarding the content and frequency of these medical evaluations can be found in NFPA 1582 [NFPA 2007a]. 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. However, the FD is not legally required to follow this standard. Applying this recommendation involves economic repercussions and may be difficult to implement. Despite the financial barriers, the FD plans to implement a tiered medical evaluation program for all fire fighters in July 2011.

Recommendation #2: Incorporate exercise stress tests following standard medical guidelines into a Fire Department medical evaluation program.

NFPA 1582, the IAFF/IAFC Fire Service Joint Labor Management Wellness/Fitness Initiative, and the ACC/AHA recommend an exercise stress test for male fire fighters older than 45 with two or more CAD risk factors [IAFF, IAFC 2008; Gibbons et al. 2002; NFPA 2007a]. The FF was over the age of 45 and had two of the risk factors for CAD (high blood cholesterol and smoking) listed by these organizations.

The exercise stress test could be conducted by the fire fighter's personal physician or the FD contract physician. If the fire fighter's personal physician conducts the test, the results must be communicated to the FD physician, who should be responsible for decisions regarding medical clearance for fire fighting duties.

Recommendation #3: 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]. The FD plans to incorporate this recommendation into the annual task-level training program.

Recommendation #4: Ensure fire fighters wear appropriate protective clothing for the specific type of incident.

NFPA 1500, Fire Department Occupational Safety and Health Program, states that the fire department shall provide each member with protective clothing and protective equipment that is designed to provide protection from the hazards to which the member is likely to be exposed and is suitable for the tasks that the member is expected to perform [NFPA 2007b]. The protective clothing and protective equipment shall also be used whenever the member is exposed or potentially exposed to the hazards for which it is provided

Recommendations (cont.)

[NFPA 2007b]. In this incident, the FF wore boots and pants meant for structural fire fighting, which are heavier than wildland fire fighting gear. This equipment hinders movement and places extra physical stress on the fire fighter. If the FD frequently responds to grass and brush fires, the FD should consider purchasing wildland fire fighting gear as recommended in NFPA 1977, Standard on Protective Clothing and Equipment for Wildland Fire Fighting [NFPA 2011].

Recommendation #5: Consider incident scene rehabilitation (rehab) during certain fire operations.

The Incident Commander considers the circumstances of each incident in determining the need for rehabilitation [NFPA 2007b]. As recommended in NFPA 1584, members performing intense work for 40 minutes without SCBA should receive at least 10 minutes of self-rehab [NFPA 2008]. Rehab should be located sufficiently far away from the effects of the operation so that members can safely remove their personal protective equipment and SCBA [NFPA 2008]. On-scene rehab should be staffed, include at least basic life support, and have fluid and food available [NFPA 2008]. Members entering rehab should receive medical monitoring including rating of perceived exertion, heart rate, blood pressure, and temperature [NFPA 2008]. The fire at this incident was a 1-acre grass/ brush fire where fire fighters performed heavy physical exertion while performing fire suppression activities. The FF performed self-rehab. However, NIOSH investigators believe a more structured rehab should have been considered. It is unclear if his medical condition would have been identified sooner had the FF's vital signs been monitored as part of a rehab program

Recommendation #6: Perform an autopsy on all on-duty fire fighter fatalities.

In 2008, the USFA published the Firefighter Autopsy Protocol [USFA 2008]. With this publication, the USFA hopes to provide "a more thorough documentation of the causes of firefighter deaths for three purposes:

1. to advance the analysis of the causes of firefighter deaths to aid in the development of improved firefighter health and safety equipment, procedures, and standards;

2. to help determine eligibility for death benefits under the Federal government's Public Safety Officer Benefits Program, as well as state and local programs; and

3. to address an increasing interest in the study of deaths that could be related to occupational illnesses among firefighters, both active and retired."

References

AHA [2000]. Advanced cardiovascular life support: section 3: adjuncts for oxygenation, ventilation, and airway control. Circ 102(8)(Suppl):I-95 –I-104.

AHA [2011]. AHA scientific position, risk factors for coronary artery disease. Dallas, TX: American Heart Association. [http://www.americanheart.org/presenter.jhtml?identifier=4726]. Date accessed: March 2011.

AIHA [1971]. Ergonomics guide to assessment of metabolic and cardiac costs of physical work. Am Ind Hyg Assoc J 32(8):560–564.

Albert CM, Mittleman MA, Chae CU, Lee IM, Hennekens CH, Manson JE [2000]. Triggering of sudden death from cardiac causes by vigorous exertion. N Engl J Med 343(19):1355–1361.

Blumenthal RS, Epstein AE, Kerber RE [2007]. Expert panel recommendations. Cardiovascular disease and commercial motor vehicle driver safety. [http://www.mrb.fmcsa.dot.gov/documents/CVD_Commentary.pdf]. Date accessed: March 2011.

CDC (Centers for Disease Control and Prevention) [2010]. BMI – Body Mass Index. [http://www.cdc.gov/healthyweight/assessing/bmi/index]. Date accessed: March 2011.

Fuster V, Badimon L, Badimon JJ, Chesebro JH [1992]. The pathogenesis of coronary artery disease and the acute coronary syndromes. N Engl J Med 326(4):242–250.

Gibbons RJ, Balady GJ, Bricker JT, Chaitman BR, Fletcher GF, Froelicher VF, Mark DB, McCallister BD, Mooss AN, O'Reilly MG, Winters WL Jr., Antman EM, Alpert JS, Faxon DP, Fuster V, Gregoratos G, Hiratzka LF, Jacobs AK, Russell RO, Smith SC Jr. [2002]. ACC/AHA 2002 guideline update for exercise testing: a report of the American College of Cardiology/American Heart Association Task Force on Practice Guidelines. Circulation 106(14):1883–1892.

Gledhill N, Jamnik VK [1992]. Characterization of the physical demands of firefighting. Can J Spt Sci 17(3):207–213.

IAFF, IAFC [2008]. The fire service joint labor management wellness/fitness initiative. 3rd ed. Washington, DC: International Association of Fire Fighters, International Association of Fire Chiefs.

Kales SN, Soteriades ES, Christoudias SG, Christiani DC [2003]. Firefighters and on-duty deaths from coronary heart disease: a case control study. Environ health: a global access science source. 2:14. [http://www.ehjournal.net/content/2/1/14]. Date accessed: March 2011.

Kales SN, Soteriades ES, Christophi CA, Christiani DC [2007]. Emergency duties and deaths from heart disease among fire fighters in the United States. N Engl J Med 356(12):1207–1215.

Libby P [2008]. The pathogenesis, prevention, and treatment of atherosclerosis. In: Fauci AS, Braunwald E, Kasper DL, Hauser SL, Longo DL, Jameson JL, Loscalzo J, eds. Harrison's principles of internal medicine. 17th ed. New York: McGraw-Hill, pp. 1501–1509.

References (cont.)

Meyerburg RJ, Castellanos A [2008]. Cardiovascular collapse, cardiac arrest, and sudden cardiac death. In: Fauci AS, Braunwald E, Kasper DL, Hauser SL, Longo DL, Jameson JL, Loscalzo J, eds. Harrison's principles of internal medicine. 17th ed. New York: McGraw-Hill, pp. 1707–1713.

Mittleman MA, Maclure M, Tofler GH, Sherwood JB, Goldberg RJ, Muller JE [1993]. Triggering of acute myocardial infarction by heavy physical exertion. N Engl J Med 329(23):1677–1683.

NFPA [2007a]. Standard on comprehensive occupational medical program for fire departments. Quincy, MA: National Fire Protection Association. NFPA 1582.

NFPA [2007b]. Standard on fire department occupational safety and health program. Quincy, MA: National Fire Protection Association. NFPA 1500.

NFPA [2008]. Standard on the rehabilitation process for members during emergency operations and training exercises. Quincy MA: National Fire Protection Association. NFPA 1584

NFPA [2011]. Standard on Protective Clothing and Equipment for Wildland Fire Fighting. Quincy, MA: National Fire Protection Association. NFPA 1977.

NHLBI [2011]. Who is at risk for coronary artery disease? National Heart, Lung, and Blood Institute. [http://www.nhlbi.nih.gov/health/dci/Diseases/Cad/CAD_WhoIsAtRisk.html]. Date accessed: March 2011.

NIOSH [2007]. NIOSH alert: preventing fire fighter fatalities due to heart attacks and other sudden cardiovascular events. Cincinnati, OH: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 2007-133.

NWCG [2003]. Work capacity test administrator's guide (NFES 1109). By Sharkey BJ. Missoula, MT: U.S. Department of Agriculture, Forest Service, Technology & Development Program, 5100 Fire, National Wildfire Coordinating Group.

Shah PK [1997]. Plaque disruption and coronary thrombosis: new insight into pathogenesis and prevention. Clin Cardiol 20(11 Suppl2):II-38–44.

Siscovick DS, Weiss NS, Fletcher RH, Lasky T [1984]. The incidence of primary cardiac arrest during vigorous exercise. N Engl J Med 311(14):874–877.

Tofler GH, Muller JE, Stone PH, Forman S, Solomon RE, Knatterud GL, Braunwald E [1992]. Modifiers of timing and possible triggers of acute myocardial infarction in the thrombolysis in myocardial infarction phase II (TIMI II) study group. J Am Coll Cardiol 20(5):1049–1055.

USFA [2008]. Firefighter autopsy protocol. Emmitsburg, MD: Federal Emergency Management Agency; United States Fire Administration. [http://www.usfa.dhs.gov/downloads/pdf/publications/firefighter_autopsy_protocol.pdf]. Date accessed: March 2011.

References (cont.)

USPSTF [2004]. U.S. Prevention Services Task Force. Screening for coronary heart diease: Recommendation Statement. Ann Intern Med 140(7):569–572.

Willich SN, Lewis M, Lowel H, Arntz HR, Schubert F, Schroder R [1993]. Physical exertion as a trigger of acute myocardial infarction. N Engl J Med 329(23):1684–1690.

Weather Underground [2010]. History for Sacramento, CA. [http://www.wunderground.com/history/airport/KSAC/2010/10/3/DailyHistory.html?req_city=Sacramento+Executive&req_state=CA&req_statename=California]. Date accessed: March 2011.

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

U.S. Forest Service Pack Test

The U.S. Forest Service uses a work capacity test known as the Pack Test to assess individuals for three levels of wildland fire fighting duty. The "arduous" level requires the ability to carry a pack loaded with 45 pounds a distance of 3 miles in 45 minutes or less NWCG [2003]. The Pack Test will be offered prior to the onset of grass/wildland fire season.

Appendix B

Firefighter Functional Challenge

The Firefighter Functional Challenge is a structure fire specific event designed by local firefighters to challenge a participant's ability to perform critical and physical fire ground activities. This event is offered annually at the end of grass/wildland season. Components of the Challenge include the following elements:

1. Personal Protective Equipment (PPE). (This event allows the firefighter to safely don his/her complete issue of PPE. This is not part of the timed event.) The firefighter is to don a complete set of turnout gear (pants, coat, hood, helmet, gloves, boots, and self-contained breathing apparatus). The mask is not worn.

2. Stair Climb/Equipment Carry. (This event simulates the firefighter's ability to carry equipment to an upper story location while dressed in full PPE.) The firefighter lifts and carries a bundled 50' length of 2½-inch hoseline 75 feet to the base of the training tower. The firefighter climbs five flights of stairs. Upon reaching the 5th flight, the firefighter places the hose bundle on the landing, re-lifts the bundle, and then descends the stairs carrying the bundle. The firefighter is required to touch every stair on the way down while holding the handrail with at least one hand. The firefighter then carries the bundle 75 feet back to the starting area.

3-5. Fire Attack. (This event simulates the firefighter's ability to advance and flow water from a 1½-inch charged hoseline.) The firefighter walks 75 feet to the charged hoseline. The firefighter picks up the hoseline and advances 50 feet to the enclosed tunnel. The firefighter drops to their knees and advances the line in a crawling fashion through the tunnel a distance of 15 feet. Upon exiting the tunnel, the firefighter stands and makes a 90-degree turn around the fixed object, walks 10 feet, turns and advances the charged hoseline in a hand-over-hand fashion an additional 25 feet while in a fixed standing position. The firefighter then advances the nozzle by walking an additional 25 feet to the finish line. Upon reaching the finish line, the firefighter opens the bail on the nozzle and knocks over the four cones completing the event.

Appendix B (cont.)

6. Move Heavy Objects to Gain Access to Fire or Free Trapped Persons. (This event simulates the firefighter's ability to move heavy objects to perform critical firefighting functions.) The firefighter walks 75 feet to the large tire. Using a power lifting position, the firefighter squats and places both hands under the tire. The firefighter lifts and flips the tire forward; then moves to the opposite end of the tire and lifts and flips the tire back to the starting position.

7. Remove Victim or Injured Partner From Fire Scene. (This event simulates the critical task of removing an unconscious victim or partner from a fire scene.) The firefighter walks 75 feet to the 6' 1", 165 pound rescue mannequin. Utilizing the provided 3' strap, the firefighter drags the mannequin a distance of 25 feet around a barrel and returns to the starting point. The firefighter then places the entire rescue mannequin in the marked area.

8. Pull Ceiling to Check for Fire Extension. (This event is designed to simulate the critical task of breaching and pulling down a ceiling to check for fire extension.) The firefighter walks 75 feet to the ceiling breech and pull simulator machine and picks up the pike pole hanging from the frame. The firefighter places the pike pole on the breach door, pushes up six times (weight of the door is 80 pounds), steps over to the pull section, and pulls down six times (pull weight is 60 pounds). After 2 complete sets, the firefighter returns the pike pole to its starting position. The firefighter walks 75 feet to the finish line.

The firefighter then moves to the rehabilitation area for post assessment monitoring and recovery.