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NIOSH
Fire Fighter Fatality Investigation and Prevention Program

Death in the line of duty...

A summary of a NIOSH fire fighter fatality investigation *April 2009*

Fire Fighter Suffers Sudden Cardiac Death During Live Fire Training – North Carolina

SUMMARY

On June 6, 2008, a 50-year-old male volunteer fire fighter (FF) taught a morning class that consisted of fire suppression topics and personal protective equipment use at the fire training center of a local community college. After lunch, in stressful environmental conditions (i.e., high temperature and high humidity), he stretched 100 feet of uncharged 1½-inch hoseline and prepared the fire engine for the live fire training session. He then led an interior search team during the smoke exercise in the burn building while wearing full bunker gear and his self-contained breathing apparatus (SCBA) on air. After exiting the building and taking a 15-minute break, the FF led the portable fire extinguisher evolution. About halfway through the exercise, the FF complained of not feeling well and took a break in the air-conditioned cab of the fire engine. While the students were performing the next evolution (hose training), the FF remained at the engine and monitored apparatus operation. The FF cancelled the next exercise, the burn box, due to the heat and his not feeling well, but another instructor volunteered to lead this evolution. The FF agreed and stayed with the engine. The training ended at approximately 1530 hours. Shortly after refilling the engine's water tank, the FF collapsed. Despite cardiopulmonary resuscitation (CPR) and advanced life support delivered on scene, in the ambulance, and in the hospital's emergency department, the FF died.

The death certificate, completed by the Coroner, listed "sudden death, probable arrhythmia" as the cause of death and "atherosclerotic heart disease, dilated cardiomyopathy, and atrial fibrillation" as underlying causes. The autopsy, completed by the Medical Examiner, listed "congestive heart failure" as the cause of death and "severe coronary atherosclerotic disease and hypertensive heart disease" as contributing factors. Given the FF's underlying atherosclerotic coronary artery disease (CAD), the stressful environmental conditions and the physical stress of performing fire fighting training duties triggered a heart attack or a cardiac arrhythmia, resulting in his sudden cardiac death.

The NIOSH investigator offers the following recommendations to address general safety and health issues. Had these recommended measures been in place prior to the FF's collapse, perhaps his sudden cardiac death may have been prevented at this time.

- ***Formulate and institute a heat stress program and a rehabilitation (rehab) program in accordance with NFPA 1584, Standard on the Rehabilitation Process for Members During Emergency Operations and Training Exercises.***

- ***Provide on-scene emergency medical service with advanced life support capability during live fire training.***
- ***Provide preplacement and annual medical evaluations to fire fighters consistent with National Fire Protection Association (NFPA) 1582, Standard on Comprehensive Occupational Medical Program for Fire Departments, to determine their medical ability to perform duties without presenting a significant risk to the safety and health of themselves or others.***
- ***Incorporate exercise stress tests following standard medical guidelines into a Fire Department medical evaluation program.***
- ***Ensure fire fighters are cleared for return to duty by a physician knowledgeable about the physical demands of fire fighting, the personal protective equipment used by fire fighters, and the various components of NFPA 1582.***
- ***Phase in a comprehensive wellness and fitness program for fire fighters to reduce risk factors for cardiovascular disease and improve cardiovascular capacity.***
- ***Perform an annual physical performance (physical ability) evaluation to ensure fire fighters are physically capable of performing the essential job tasks of structural fire fighting.***
- ***Provide fire fighters with medical cleaance to wear a self-contained breathing apparatus (SCBA) as part of a Fire Department medical evaluation program.***
- ***Conduct annual respirator fit testing.***

INTRODUCTION & METHODS

On June 6, 2008, a 50-year-old male volunteer FF suffered sudden cardiac death after leading fire training exercises. Despite CPR and advanced life support administered by training center personnel, the ambulance crew, and personnel in the hospital emergency department, the FF died. NIOSH was notified of this fatality on August 19, 2008, by the United States Fire Administration. NIOSH contacted the affected Fire Department to gather additional information on November 7, 2008, and on December 1, 2008, to initiate the investigation. On December 9, 2008, a Safety and Occupational Health Specialist from the NIOSH Fire Fighter Fatality Investigation Team traveled to North Carolina to conduct an on-site investigation of the incident.

During the investigation, NIOSH personnel interviewed the following people:

- Fire Chief
- Area State Fire-Rescue Coordinator
- Dean of Continuing Education at the community college

NIOSH personnel reviewed the following documents:

- Fire Department policies and operating guidelines
- Fire Department training records
- Fire Department annual report for 2007
- Fire Training Center incident report
- Emergency medical service (ambulance) incident report
- Hospital emergency department records
- Death certificate
- Autopsy report
- Primary care provider medical records

RESULTS OF INVESTIGATION

Community College Fire Training Center. The fire training center, a North Carolina state-accredited training facility, teaches the following fire service courses: Fire Fighter I and II, Emergency Vehicle Driving, Hazardous Materials I, Driver Operator Pumps and Aerial, Instructor II, and Rescue Technician. In 2008, 52 fire classes were conducted at the community college, 16 of which were live burn classes. Prior to the incident described in this report, no students from this facility had been transported to the hospital due to heat illness.

Rehabilitation. The fire training center had shade shelters, drinking water, and Gatorade® available. Bales of hay were also available for students to sit on. However, no written policy addressed rehab or heat injury prevention.

Incident. On June 6, 2008, the FF arose at 0445 hours and ate breakfast. He left home at approximately 0730 hours en route to the Fire Training Center. He called his spouse while en route, telling her of his plans for the day; he did not complain of heart-related problems during the phone call.

Arriving at approximately 0745 hours, the FF and another instructor set up the classroom for Day 2 of the U.S. Coast Guard-approved 2-day Basic Fire Fighting course. The course included 12 students and two instructors, including the FF. Students arrived by 0800 hours, and the FF began the classroom portion (introductions, welcome, SCBA, bunker gear, smoke-filled space search and rescue procedure, fighting small Class B and C fires, and fighting Class A fires in an enclosed space) [NFPA 2007a]. For a complete course description, see Appendix A. Instructors advised the class to drink adequate amounts of fluids for hydration; water and Gatorade® were available. The class lasted until approximately 1200 hours, when the students were dismissed for lunch.

The FF, the other instructor, and a student ate lunch at a fast food restaurant. Returning to the fire training center, the FF and the instructor prepared for the afternoon's practical exercises. The weather conditions at 1300 hours included a temperature of 95 degrees Fahrenheit (°F) and 49% relative humidity, giving a heat index of 104°F [NOAA 2008]. The FF laid out about 100 feet of uncharged 1½-inch fire hose and prepared the engine for use.

The smokehouse evolution began (Appendix A), and the FF entered the burn building, staying approximately 15 minutes. The FF exited the building and went to the rehab shelter for rest and rehydration. The time was approximately 1400 hours. After removing his bunker gear, drinking some Gatorade, and applying an ice pack to his neck, the FF did not appear to be refreshed; he was pale and reported that he didn't feel well. A student took the FF's pulse; it was reported to be unremarkable (regular and strong).

After a 10-minute rest, the students went to the burn tank for the portable fire extinguisher evolution. The instructor poured the combustible liquid into the tank, and an ignition officer lit the fire. The FF, dressed in bunker gear without SCBA, led six of the students in this evolution. After the training, the group took a break and the instructor discussed the heat. The FF stated that he did not feel well and that he should not have eaten onion rings for lunch; he was having indigestion. The FF went to the air conditioned engine and sat inside.

The hose movement and fire stream evolution were next (Appendix A). The instructor met with the FF at the engine to discuss the evolution. The FF stated it was hot, he did not feel well, was tired, and that the instructor should continue the evolution without him.

The last evolution was the burn box (fire in an enclosed space) (Appendix A). The FF wanted to cancel the remainder of the training due to the heat and his not feeling well. However, the instructor stated that he was feeling fine and that he could provide a brief demonstration with the students who were outside and not in bunker gear and SCBAs. The FF agreed to this and remained at the engine only to control the pressure on the hose line. The burn box evolution ended at approximately 1530 hours. Weather conditions included a temperature of 94°F and 58% relative humidity, giving a heat index of 108°F [NOAA 2008]. Wind speed ranged from 0–8 miles per hour during the afternoon [NOAA 2008]. The fire training ground was inside a wooded area where the trees minimized wind speed to near zero. According to witnesses, the FF was very conscious of the heat, and one student nearly fainted due to the extreme heat. Students and the instructor put the gear back in the storage trailer as the FF rolled the hose lines. The FF stated again that he did not feel well and would refill the engine's water tank. He advised the instructor to lock the equipment trailer and the gate and meet him at the hydrant.

An instructor's assistant drove the FF's truck to the hydrant and offered to help. The FF advised the Assistant to go home, saying that he had done enough that day and that the instructor and the FF would finish. The FF told the instructor's assistant that he felt better but was a little sore and was going home to take a shower. The instructor arrived to assist; as he walked toward the engine the FF was turning off the hydrant. As the instructor uncoupled the hose from the engine, the FF dropped to one knee and then fell backward and was unresponsive.

The instructor, thinking the FF had fainted due to the heat, opened the hydrant to deflect water onto the FF to cool him. The FF jerked in response to the water. The instructor shook the FF, who moaned but did not otherwise respond. The instructor radioed Dispatch at 1614 hours, requesting a rescue unit for "a man down at the college with heat stroke."

The instructor began CPR but had difficulty establishing an airway because the FF's jaw was rigid. Two additional persons arrived to assist. The FF gasped for air, and the instructor thought the FF was breathing. Dispatch asked via radio for the college location. As the instructor provided the address, the FF stopped breathing. CPR was resumed.

The ambulance arrived 11 minutes later (1625 hours) and emergency medical technician-intermediates found the FF unresponsive, pulseless, and not breathing, with CPR in progress. A second unit with paramedic assistance was requested. Advanced life support, including cardiac monitoring, intubation (successful on the fourth attempt "due to secretions and the FF's stiff jaw") and 100% oxygen, and intravenous line placement, was begun. The intubation tube placement was confirmed by secondary technological testing (end tidal CO_2) [AHA 2000]. Seven shocks, the first at 1629 hours, were delivered during scene treatment and transport. The FF's heart rhythms included ventricular fibrillation, asystole, and pulseless electrical activity. The ambulance departed the scene at 1635 hours en route to the hospital emergency department. The ambulance met the second medic unit while en route at approximately 1645 hours. Treatment continued as the ambulance continued the transport. At 1705 hours, cardiac pacing was attempted without success.

The ambulance arrived at the hospital at 1709 hours. Inside the emergency department, advanced life support treatment continued until 1723 hours, when the FF was pronounced dead by the attending physician. No internal body core temperature was taken at any time during resuscitation efforts.

Medical Findings. The death certificate, completed by the Coroner, listed "sudden death, probable arrhythmia" as the cause of death and "atherosclerotic heart disease, dilated cardiomyopathy, and atrial fibrillation" as underlying causes. The autopsy, completed by the Medical Examiner, listed "congestive heart failure" as the cause of death and "severe coronary atherosclerotic disease and hypertensive heart disease" as contributing factors. Findings from the autopsy are listed in Appendix B.

The FF was 71 inches tall and weighed 190 pounds, giving him a body mass index (BMI) of 26.5. A BMI of 25.0–29.9 kilograms per meters squared (kg/m2) is considered overweight [CDC 2008]. Medical records showed the FF had a history of hypertension dating back to 1989, but he was not prescribed an antihypertensive medication. The FF had not seen his primary care physician since 2001. Medical records did not indicate whether the FF had his blood cholesterol level checked. However, he was not prescribed cholesterol-lowering or lip-

id-lowering medications. The FF smoked 2–4 packs of cigarettes per day for approximately 30 years and did not exercise. His duties as an instructor at the fire training center required heavy physical exertion. The FF expressed no symptoms of angina or shortness of breath on exertion to his physician, his family, the Fire Department, or the community college.

DESCRIPTION OF THE FIRE DEPARTMENT

At the time of the NIOSH investigation, the volunteer Fire Department consisted of one fire station with 25 uniformed personnel that served a population of 3,000 residents in a geographic area of 144 square miles.

In 2007, the Fire Department responded to 44 calls: 8 structure fires, 11 grass/brush/trash fires, 18 motor vehicle accidents, 1 emergency medical call, and 6 other calls.

Membership and Training. The Fire Department votes on all new members and requires new fire fighter applicants to be at least 18 years of age, have a valid state driver's license, and attend four meetings. New members receive weekly fire fighter training in-house and at regional/state fire schools. The State has no minimum requirement for fire fighter certification. The FF was certified as an International Fire Service Accreditation Congress (IFSAC) Fire Fighter II, Driver Operator, IFSAC HazMat Level I, Advanced Rescue Technician, IFSAC Instructor Level II; he had 31 years of fire fighting experience.

Medical Evaluation Program. The Fire Department currently does not require a preplacement or an annual medical evaluation. No annual SCBA facepiece fit test is required for interior structural fire fighters. Annual SCBA medical clearance is not required. Members injured on duty must be evaluated by their primary care physician who makes the final determination regarding return to duty.

Health and Wellness Programs. The Fire Department has a voluntary wellness/fitness program, and exercise (strength and aerobic) equipment is available in the fire station. Health maintenance programs are available from the County.

DISCUSSION

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 sex, family history of CAD, smoking, high blood pressure, high blood cholesterol, obesity/physical inactivity, and diabetes [AHA 2008]. The FF had four known risk factors (age older than 45, male sex, smoking, and high blood pressure).

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 EKG changes, elevated cardiac enzymes, or coronary artery thrombus. In the FF's case, he did not have a heart rhythm on which to conduct an EKG; cardiac enzymes were not tested due to his death prior to cardiac enzymes becoming positive (> 4 hours), and no coronary artery thrombus was found at autopsy. Clinically, it is probable that he suffered a heart attack, but we cannot definitely make this conclusion.

Epidemiological 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]. The FF had set up the classroom and taught for 4 hours, laid out the 1½-inch uncharged fire hose and prepared the engine for use, observed the smokehouse evolution for 15 minutes, led the fire extinguisher evolution, rolled the hoselines after the training was completed, and drove the engine to the hydrant. These activities, combined with the stressful environmental conditions (Heat Index of 104°F-108°F) while wearing bunker gear and SCBA through portions of the training, expended about 9 metabolic equivalents, which is considered moderate to heavy physical activity [AIHA 1971; Gledhill and Jamnik 1992]. 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]. Given the FF's underlying CAD, the stressful environmental conditions and the physical stress of performing fire fighting training duties probably triggered a heart attack or a cardiac arrhythmia, resulting in his sudden cardiac death.

Cardiomegaly/Left Ventricular Hypertrophy. On autopsy, the FF was found to have left ventricular hypertrophy (LVH) and an enlarged heart. This finding was not identified prior to his death. Both LVH and cardiomegaly 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 high blood pressure, a heart valve problem, or chronic cardiac ischemia (reduced blood supply to the heart muscle) [Siegel 1997]. The FF had high blood pressure but not a heart valve problem; therefore, his LVH was probably due to high blood pressure. Although the EKG is not a very sensitive screening test for LVH, if one had been performed, perhaps his LVH would have been identified and additional evaluation and treatment been performed.

Environmental Heat Exposure. Environmental heat exposure is directly related to climatic and seasonal conditions [USFA 2008]. Most

fire departments operate in locations that can subject members to occasional summer environmental temperatures greater than 90°F. Research conducted by the U.S. Army shows that the effects of high heat on personnel are cumulative. Volunteer fire fighters who work outdoors or in hot atmospheric jobs and respond to fire calls after extended periods of heat exposure fall into this category [USFA 2008]. The longer a person is exposed to elevated temperatures, the greater the chance of experiencing heat-related illnesses and injuries.

Over time, humans have the ability to adapt and become more proficient in handling extreme environmental conditions (acclimatization). Historically, acclimatization has not been a major problem for structural fire fighters. Most fire fighters serve in the same geographical location and climate in which they grew up (or have lived for a long time). In this case, the FF grew up in and lived in this area.

Closely linked with heat stress is dehydration. Most heat stress illnesses are due, in major part, to a failure to maintain adequate hydration. When dehydrated, the body's ability to thermoregulate is impaired [USFA 2008]. Sweating and excreting fluids faster than the body can absorb new fluids is physiologically possible. Therefore, hydrating at least 2 hours before, during, and 2 hours following the training event is essential.

The key to managing heat stress is to be familiar with controls used to prevent it and minimize its effect. Controls for heat stress include (1) fluid intake (hydration), (2) work rotation, (3) active cooling, and (4) rest. These controls are part of a comprehensive rehabilitation program discussed later in this section [NFPA 2008b; USFA 2008].

Whether this fire fighter suffered heat-related illness (heat cramps, heat exhaustion, or heat stroke) cannot be determined. Although he did not feel well, he never mentioned cramps (a symptom of heat cramps), faintness or nausea (symptoms of heat exhaustion), and he was still sweating (inconsistent with heat stroke). His body core temperature was not taken at any time during rehab or resuscitation efforts to document hyperthermia. The autopsy did not mention hyperthermia as a contributing factor to his sudden death, but the environmental conditions were present to cause heat stress and NIOSH investigators feel that heat stress was a possible contributory factor to his sudden cardiac death.

A standard operating guideline (SOG) should be written that outlines a systematic approach for rehab at incidents and training exercises [NFPA 2008b]. A lesson plan was written, however, it did not include a medical component.

Rehab operations should consider hot weather conditions, including temperature, relative humidity, and direct sunlight [NFPA 2008b]. Humans can easily exceed a sweat rate of 64 ounces per hour in hot and humid conditions. Firefighting gear interferes with heat dissipation and traps moisture next to the skin. Hence, sweating begins and continues, even after work is stopped and the fire fighter enters rehab [NFPA 2008b].

There must be an awareness of weather conditions, wind velocity, and wind direction before initiating live fire training. The instructors were aware of the weather, including temperature and humidity, but there was no written guideline for when to cancel live fire training in a hot environment.

According to NFPA 1584, with a temperature of 94°F and a humidity level of 58%, the Humidex (Canadian heat index) would be 45-46. This would place the Alert Level between 2 and 3. At Alert Level 3, "All outdoor training activities are considered nonessential and shall be rescheduled or cancelled." At Alert Level 2, "All outdoor training activities are considered nonessential except recruit training." Live burns are restricted and rehab is increased. Thus, if following NFPA 1584, training should have stopped and rescheduled for morning hours (0700 hours – 1200 hours). Since this incident, the Community College has instituted a heat injury prevention policy in compliance with NFPA 1584.

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. Neither the Fire Department nor the Fire Training Center required medical clearance to participate in the live fire training. Of particular importance is the use of exercise stress tests to identify fire fighters with CAD and at risk for sudden cardiac death. NFPA 1582 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 sub maximal (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 sub maximal 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 mg/dL), hypertension (diastolic blood pressure greater than 90 mm Hg), 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). This exercise stress test recommendation is similar to that recommended by the American College of Cardiology/American Heart Association (ACC/AHA) and the U.S. DOT [Gibbons et al. 2002; Blumenthal et al. 2007].

A stress test was indicated and had one been performed, perhaps the FF's underlying cardiac condition would have been identified, and he would have been referred for further evaluation and treatment. This may have prevented his sudden cardiac death at this time.

Physical Fitness Programs for Structural Fire Fighters. The National Volunteer Fire Council (NVFC) and the U.S. Fire Administration (USFA) Health and Wellness Project document Health and Wellness Guide was developed to improve health and wellness within the volunteer fire service [USFA 2004]. This guide provides suggestions for successfully implementing a health and wellness program for volunteer fire departments. The FF's volunteer fire department did not have a physical fitness program. It is unclear if this program would have prevented his sudden cardiac death.

RECOMMENDATIONS

The NIOSH investigator offers the following recommendations to address general safety and health issues. Had these recommended measures been in place prior to the FF's collapse, perhaps his sudden cardiac death may have been prevented at this time.

Recommendation #1: Formulate and institute a heat stress program and a rehabilitation program in accordance with NFPA 1584, Standard on the Rehabilitation Process for Members During Emergency Operations and Training Exercises.

A number of guides recommend measures and standards for protection from heat stress injuries. A list can be found in the NIOSH Criteria for a recommended standard, Occupational Exposure to Hot Environments [DHHS 1986]. This criteria document contains standards and recommendations from the American Conference of Governmental Industrial Hygienists, Occupational Safety and Health Administration (OSHA), American Industrial Hygiene Association, the Armed Forces, American College of Sports Medicine, and the International Organization for Standardization. Although occupation/industry-specific components are found in each group's documents, the Fire Training Center should examine all the guides to identify policies that fit their unique situation.

When to restrict or cancel live fire training should be determined based on the heat stress index. NFPA 1584 provides information regarding temperature and relative humidity, which make up the basic heat index. When protective clothing is worn, 10°F is added to the index. When in direct sunlight, 10°F is added to the index. The final number is termed the heat stress index. The training should be monitored carefully when the temperature exceeds 90°F and modified or suspended when temperature exceeds 105°F. At 1530 hours on the date of this incident, the basic heat index was 108°F. With the FF occasionally wearing bunker gear and the sun shining, the heat stress index was 128°F (the danger zone). Heat cramps or exhaustion are likely, and heat stroke is possible if exposure is prolonged during physical ac-

tivity [NFPA 2008b]. Therefore, in high-heat environments, the NFPA recommends (1) significantly reducing both heavy and moderate work; (2) minimizing bunker suit use whenever possible; (3) considering cessation of nonessential operations that involve moderate physical activity; and (4) ceasing all nonessential operations that involve heavy physical activity [NFPA 2008b].

The Fire Training Center provided a rehab program for this training session. However, the program could be improved by including the following components as recommended by NFPA 1584:

- Remove PPE
- EMS evaluation
- Vital signs
- Accountability
- Release from rehab
- Documentation (time in/time out and vital signs)
- Transport capable EMS should be available
- Consider having advanced life support available

Medical monitoring of trainees and instructors should be part of the training. At the start of training, take vital signs and document pertinent medical information such as history, complaints, or symptoms. Predetermined vital sign criteria should be established for admittance to training, assignment to rehab, discharge from rehab, and transport to the hospital. NFPA 1584, Annex A provides guidance on these vital sign criteria (temperature, heart rate, respiratory rate, blood pressure, pulse oximetry).

Emergency medical personnel should evaluate personnel arriving at rehab for symptoms of a health and/or safety concern. Time-in/time-out and vital signs should be recorded and compared. Symptomatic fire fighters or fire fighters with abnormal findings should receive additional monitoring. Fire fighters treated for heat-related injuries should be removed from active duties. Members should also be evaluated prior to release from rehab. If medical care is given, a medical report should be completed and maintained. Documentation prepared in rehab should be compared to documentation prepared at the start of training: vital signs, complaints, symptoms, etc. [NFPA 2008b].

Personnel in rehab should remove all bunker clothing including helmets, gloves, and bunker pants prior to entering the rehab area. Active cooling methods must be provided (e.g., cold and wet towels, forearm immersion, misting), and used if appropriate.

Recommendation #2: Provide on-scene emergency medical services with advanced life support and transport capability during live fire training.

NFPA 1403 requires an ambulance and emergency medical personnel be on scene during all live fire exercises. It defines emergency medical services as "the provision of treatment, such as first aid, CPR, basic life support, advanced

life support, and other pre-hospital procedures including ambulance transportation, to patients." These EMS personnel must remain on scene until all exercises are concluded, equipment is restored to an in-service condition, and students are released [NFPA 2007c].

The fire training center does not have an ambulance, and the closest emergency medical transport unit and advanced life support unit is more than 8 minutes away. Furthermore, the fire training center does not operate under the supervision of a Medical Director or have medical protocols other than the State First Responder Protocol. Therefore, a paramedic may be on site, but could only provide care at the first responder level (check vital signs, administer oxygen through a nonrebreather mask, provide CPR with a pocket mask, and use an AED). Given the essentially immediate use of the AED, basic life support, and CPR, it is unclear if on-scene advanced life support and transport would have changed the outcome in this case.

Recommendation #3: Provide preplacement and annual medical evaluations to fire fighters consistent with National Fire Protection Association (NFPA) 1582, Standard on Comprehensive Occupational Medical Program for Fire Departments, to determine their medical ability to perform duties without presenting a significant risk to the safety and health of themselves or others.

Guidance regarding the content and frequency of these evaluations can be found in NFPA 1582 and in the International Association of Fire Fighters (IAFF)/International Association of Fire Chiefs (IAFC) Fire Service Joint Labor Management Wellness/Fitness Initiative [IAFF, IAFC 2000; NFPA 2007a]. However, the Fire Department and the community college are not legally required to follow this standard or this initiative. Applying this recommendation involves economic repercussions and may be particularly difficult for small volunteer fire departments to implement. NFPA 1500, Standard on Fire Department Occupational Safety and Health Program, paragraphs A.10.6.4 and A.11.1.1 and the National Volunteer Fire Council (NVFC) Health and Wellness Guide address these issues [USFA 2004; NFPA 2007d].

To overcome the financial obstacle of medical evaluations, the Fire Department could urge current members to get annual medical clearances from their private physicians. Another option is having the annual medical evaluations completed by paramedics and emergency medical technicians (EMTs) from the local EMS (vital signs, height, weight, visual acuity, and electrocardiogram [EKG]). This information could then be provided to a community physician (perhaps volunteering his or her time), who could review the data and provide medical clearance (or further evaluation, if needed). The more extensive portions of the medical evaluations could be performed by a private physician at the fire fighter's expense (personal or through insurance), provided by a physician volunteer, or paid for by the Fire Department, City, or State. Sharing the financial responsibility for these evaluations between fire fighters, the Fire Department, the City, the

State, and physician volunteers may reduce the negative financial impact on recruiting and retaining needed fire fighters.

This recommendation is intended for the FF's volunteer Fire Department as well as the community college. Because the FF was an instructor of fire fighting classes at the community college (and a college employee) and performed heavy physical activity in stressful environmental conditions while conducting training, compliance with this recommendation would be relevant to the community college as well.

Recommendation #4: 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 2000; Gibbons et al. 2002; NFPA 2007a]. The exercise stress test could be conducted by the fire fighter's personal physician or the Fire Department contract physician. If the fire fighter's personal physician conducts the test, the results must be communicated to the Fire Department physician, who should be responsible for decisions regarding medical clearance for fire fighting duties.

Recommendation #5: Ensure fire fighters are cleared for return to duty by a physician knowledgeable about the physical demands of fire fighting, the personal protective equipment used by fire fighters, and the various components of NFPA 1582.

Guidance regarding medical evaluations and examinations for structural fire fighters can be found in NFPA 1582 [NFPA 2007a] and in the IAFF/IAFC Fire Service Joint Labor Management Wellness/Fitness Initiative [IAFF, IAFC 2000]. According to these guidelines, the Fire Department should have an officially designated physician who is responsible for guiding, directing, and advising the members with regard to their health, fitness, and suitability for duty as required by NFPA 1500, Standard on Fire Department Occupational Safety and Health Program [NFPA 2007d]. The physician should review job descriptions and essential job tasks required for all Fire Department positions and ranks, in order to understand the physiological and psychological demands of fire fighters and the environmental conditions under which they must perform, as well as the personal protective equipment they must wear during various types of emergency operations.

Recommendation #6: Phase in a comprehensive wellness and fitness program for fire fighters to reduce risk factors for cardiovascular disease and improve cardiovascular capacity.

Guidance for fire department wellness/fitness programs is found in NFPA 1583, Standard on Health-Related Fitness Programs for Fire Fighters, and the IAFF/IAFC Fire Service Joint

Labor Management Wellness/Fitness Initiative [IAFF, IAFC 2000; NFPA 2008a]. NFPA 1583 establishes the minimum requirements for the development of a health-related fitness and exercise program and health promotion for fire department members involved in emergency operations [NFPA 2008a]. Members must be cleared annually for participation in a fitness assessment by the fire department physician and are required to participate in a periodic fitness assessment under the supervision of the fire department health and fitness coordinator [NFPA 2008a]. The fitness assessment includes (1) aerobic capacity, (2) body composition, (3) muscular strength, (4) muscular endurance, and (5) flexibility. The exercise and fitness program must include (1) education, (2) individualized participation, (3) warm-up and cool-down exercise guidelines, (4) aerobic exercise, (5) muscular strength and endurance, (6) flexibility exercise, (7) healthy back exercise, and (8) safety and injury prevention [2008a].

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 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 recent 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 non-occupational health-care costs [Kuehl 2007].

Recommendation #7: Perform an annual physical performance (physical ability) evaluation to ensure fire fighters are physically capable of performing the essential job tasks of structural fire fighting.

NFPA 1500, Standard on Fire Department Occupational Safety and Health Program, requires the fire department 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 [NFPA 2007b].

Recommendation #8: Provide fire fighters with medical clearance to wear self-contained breathing apparatus as part of a Fire Department medical evaluation program.

The Occupational Safety and Health Administration (OSHA) Revised Respiratory Protection Standard requires employers to provide medical evaluations and clearance for employees using respiratory protection [29 CFR1 1910.134]. These clearance evaluations are required for private industry employees and public employees in States operating OSHA-

approved State plans. North Carolina operates an OSHA-approved State plan; therefore, public sector employers (including volunteer/paid fire departments) are required to comply with OSHA standards.

Recommendation #9: Conduct annual respirator fit testing.

The OSHA respiratory protection standard requires employers whose employees are required to use a respirator (e.g., an SCBA) to have a formal respiratory protection program, including annual fit testing [42 CFR 1910.134]. As mentioned previously, North Carolina is an OSHA-approved State plan; therefore the fire department is required to follow OSHA standards [OSHA 2008].

[1]Code of Federal Regulations. See CFR in references.

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INVESTIGATOR INFORMATION

This incident was investigated by the NIOSH Fire Fighter Fatality Investigation and Prevention Program, Cardiovascular Disease Component located in Cincinnati, Ohio. Mr. Tommy Baldwin (M.S.) 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 (M.D., M.P.H.) 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: TRAINING DESCRIPTION

- SCBA and bunker gear
  - — Video on SCBA
  - — Discussion about uses of SCBA
  - — Discussion on compressed air breathing apparatus
  - — Donning SCBA and facepiece
  - — Doffing SCBA
  - — Changing SCBA cylinder
  - — SCBA normal and emergency breathing
  - — Bunker gear
  - — Smoke filled space search procedure (Smokehouse evolution)
- Practical demonstrations
  - — Don bunker gear (Nomex® hood, bunker pants and coat, boots, helmet, gloves, eye protection) within 3 minutes
  - — Smokehouse Evolution - Rescue victim in a space filled with non-toxic theatrical smoke
- Don SCBA using either off-the-wall method, partner assist method, coat swing method, or the over-the-head method
- Use SCBA for normal breathing, change the cylinder, and emergency breathing
- Conduct a thorough pattern search in teams of two students each, wearing full bunker gear and SCBA, on air

- Locate rescue mannequin
- Remove rescue mannequin
  - — Portable Fire Extinguisher Evolution - Fire fighting procedures for small fires (Class B And C fires)
- Use hose station and portable fire extinguisher
- Select proper class of fire extinguisher
- Employ safe tactics
- Make effective application of extinguishing agent
  - — Hose Movement and Fire Stream Evolution
  - — Burn Box Evolution - Fight live Class A fire in an enclosed space, a cargo container in which one half of a pallet was set afire.
- Select proper nozzle setting
- Advance the hose line
- Make effective application of water stream
- Extinguish the seat of the fire

Appendix B: Autopsy Findings

- Hypertensive heart disease
  - — Cardiomegaly (enlarged heart) (heart weighed 570 grams [g]; predicted normal weight is between 275 g and 478 g as a function of sex, age, and body weight) [Silver and Silver 2001]
- Atherosclerotic CVD
  - — Severe (80%–90%) focal narrowing of the left anterior descending coronary artery
  - — Severe (80%–90%) focal narrowing of the right coronary artery
  - — Moderate (50%) focal narrowing of the left circumflex coronary artery
  - — No evidence of recent thrombus (blood clot in the coronary arteries)
- Concentric left ventricular hypertrophy (LVH)
  - — Left ventricle wall thickened (2.0 centimeters [cm]);
  - — Normal at autopsy is 0.76–0.88 cm [Colucci and Braunwald 1997];
  - — Normal by echocardiographic measurement is 0.6–1.1 cm [Armstrong and Feigenbaum 2001]
- Normal cardiac valves
- Pulmonary edema

- No evidence of a pulmonary embolus (blood clot in the lung arteries)
- Blood tests for drugs and alcohol were negative

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