



Fire Fighter Trainee Suffers Sudden Cardiac Death During Maze Training – Arkansas

Executive Summary

On January 26, 2011, a 38-year-old male career fire fighter recruit (“Trainee”) participated in an entry-level fire fighter certification class. The training included maneuvering through a tunnel maze while wearing full turnout gear and self-contained breathing apparatus (SCBA). After he completed most of the maze evolution, the Trainee’s SCBA became stuck inside the tunnel. He tried to free himself for several minutes; meanwhile, his SCBA became low on air. Instructors removed the Trainee from the maze and noted that he was breathing hard and complaining of nausea. After rehabilitation, his symptoms resolved, and his vital signs returned to normal. The Trainee went on to complete the basement search portion of the smokehouse training without difficulty.

After lunch, the Trainee repeated the maze evolution and became stuck in the same location. After assuring instructors he was okay, the Trainee suddenly became unresponsive. Instructors removed the Trainee from the maze and found him unresponsive, not breathing, and without a pulse. An ambulance was requested, cardiopulmonary resuscitation (CPR) was begun, and an automated external defibrillator was utilized; no shock was advised. Paramedics assigned to a nearby flight ambulance responded and began advanced life support including the administration of intravenous cardiac resuscitation medications. A cardiac monitor was placed, revealing asystole (no heart beat) and pulseless electrical activity.

The ambulance arrived about 11 minutes later and transported the Trainee to the hospital’s emergency department (ED), where CPR and advanced life support treatment continued. Approximately 47 minutes after his collapse, despite CPR and advanced life support, the Trainee died. The death certificate and the autopsy, completed by the medical examiner, listed “dilated cardiomyopathy” due to “hypertensive cardiovascular disease” as the cause of death. NIOSH investigators concluded that the Trainee’s underlying cardiomyopathy coupled with the physical exertion involved in performing the fire fighter training triggered his sudden cardiac death.

NIOSH investigators offer the following recommendations to address general safety and health issues. It is unlikely, however, that any of these recommendations would have prevented the Trainee’s death.

Provide preplacement and annual medical evaluations compliant with National Fire Protection Association (NFPA) 1582 to fire fighters.

Perform an annual physical performance (physical ability) evaluation.

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.

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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).

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Executive Summary (cont.)

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

Provide fire fighters with medical clearance to wear a self-contained breathing apparatus (SCBA) as part of the Fire Department's medical evaluation program.

Ask an independent third party entity such as the NIOSH National Personal Protective Technology Laboratory (NPPTL) to perform post-incident SCBA inspection and testing.

Introduction & Methods

On January 26, 2011, a 38-year-old male career fire fighter trainee suffered sudden cardiac death during fire fighter training. Despite CPR and advanced life support, the Trainee died. NIOSH was notified of this fatality on January 27, 2011, by the U.S. Fire Administration. NIOSH contacted the affected fire department (FD) and the state fire training academy (SFTA) on January 27, 2011, to gather additional information and on April 19, 2011, to initiate the investigation. On April 26, 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:

- SFTA director
- SFTA assistant director
- SFTA instructors
- Fire chief of the Trainee's career FD
- FD emergency medical chief
- Trainee's spouse

Introduction & Methods (cont.)

NIOSH personnel reviewed the following documents:

- SFTA policies and training procedures
- FD policies and operating guidelines
- FD training records
- FD annual report for 2010
- Witness statements
- Police report
- Emergency medical service (ambulance) incident report
- Hospital ED records
- Death certificate
- Autopsy report
- Personal physician medical records

Investigative Results

Background

State Fire Training Academy. The SFTA provides fire and emergency medical service (EMS) training for career and volunteer members. A variety of training courses are offered at the SFTA including the Fire Fighter I and II course in which the Trainee was participating. The 25-acre facility is composed of a 1-story smokehouse with a basement (Figure 1), a 5-story drill tower, a 1-story burn building, liquid propane props, auto extrication props, a cascade system, and a fire station (under construction), all built according to NFPA 1402, Guide to Building Fire Service Training Centers [NFPA 2007a]. Also located on the SFTA grounds is a flight ambulance staffed 24 hours a day with a flight nurse, paramedics, and a pilot. The air ambulance is an independent agency not associated with the SFTA.

At the time of this incident, medical clearance was not required for trainees, however, on their SFTA application, trainees were asked to list allergies or medical conditions that would require special consideration during attendance at the Academy.

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Investigative Results (cont.)

The Trainee did not list any conditions. Since this incident, applicants must now be medically cleared by a physician (personal or FD) within the past year. The medical clearance statement is given to the SFTA deputy director who makes the final determination whether to clear the fire fighter for training.

The Fire Fighter I and II courses consist of a progressive combination of classroom work, fitness exercises, and fire fighter drills lasting 8 hours per day for 8 weeks. At the conclusion of the Fire Fighter II training, students must pass the Fire Fighter Encounter Agility Test (FEAT) within the allotted time (Appendix A).

The training scheduled for January 26, 2011, consisted of navigating the maze tunnel while wearing full turnout gear and SCBA (on-air) and conducting a simulated search in heavy smoke conditions using a right-hand search pattern. The maze tunnel, where the Trainee became stuck and unresponsive, was inside the smokehouse. The tunnel was constructed of three plywood sections in an inverted “U” arrangement (Figure 2). The three sections could be quickly opened and disassembled so that fire fighters could be assisted quickly if needed (Figure 3). The tunnel’s interior measures 2 feet by 2 feet (Figure 4) and tests students for claustrophobia, Fire Fighter I critical performance standards, and restricted passage negotiation as required in NFPA 1001, Standard for Fire Fighter Professional Qualifications [NFPA 2008a].

Incident. On Wednesday, January 26, 2011, 28 students met at 0745 hours to begin their 8th day of Fire Fighter I and II training. Weather conditions included a temperature of 27 degrees Fahr-

enheit and 96% relative humidity [Weather Underground 2011]. Two instructors discussed the day’s scheduled training, which included a maze tunnel and basement search. Instructors then inspected participants’ turnout gear and SCBAs. The Trainee’s SCBA was a Scott PosiChek3® with integrated personal alert safety system. His SCBA was full of air (2,216 pounds per square inch [psi] capacity), and he had been fit tested.

Students entered the maze tunnel individually. The course was typically completed within 5 minutes, but it could take up to 10 minutes if problems were encountered. The Trainee was the last student to enter the tunnel and had his hand on the leg of the student ahead of him. While moving through the maze, instructors remained in voice contact with the Trainee from just outside the maze wall. He was near the end of the tunnel at the second 90-degree turn when he became stuck (Figure 2). The Trainee’s SCBA was caught on a wooden cross beam and became low on air as he attempted to free himself. At that point the instructors pulled the tunnel apart, and the Trainee crawled out.

Once outside the smokehouse, the Trainee doffed his SCBA and turnout coat and complained of nausea. His vital signs were taken (blood pressure of 120/78 millimeters of mercury [mmHg], pulse rate of 100 beats per minute) as he entered rehab (hydration and rest). After a 10-minute rest, he donned his gear and completed the basement right-hand search component of the training without incident. The class was dismissed for lunch at 1150 hours.

At 1300 hours participants reassembled to repeat the maze tunnel drill. As the Trainee encountered

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Investigative Results (cont.)



Figure 1: Smokehouse



Figure 2: Maze tunnel



Figure 3: Maze sections



Figure 4: Maze tunnel interior

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Investigative Results (cont.)

the second 90-degree turn, he again became stuck. The Trainee told instructors that he was okay while he tried several times to move forward. At this point an instructor reached through a crack in the maze to disengage the Trainee's SCBA bottle. When asked to move forward again, the Trainee did not respond. It appeared that the Trainee was pushing on the inside wall of the tunnel to escape, so the instructors opened the escape hatch and pulled the tunnel apart. An instructor grabbed the Trainee's SCBA strap and pulled him from the maze and outside the building (1537 hours). The Trainee was unresponsive, not breathing, and had no pulse; an ambulance was called.

The Trainee's SCBA, helmet, and turnout coat were removed. His SCBA contained approximately 2,000 psi of air. CPR was begun as the medical bag and an AED were retrieved. The AED advised "no shock." Paramedics from the air ambulance arrived within 2 minutes and began advanced life support including placing an intravenous line and administering cardiac medications. A cardiac monitor was placed revealing asystole and pulseless electrical activity. The ambulance arrived at 1548 hours; after three unsuccessful intubation attempts, a Combitube® was placed. The ambulance departed the scene at 1600 hours en route to the hospital's ED. The ambulance arrived at the ED at 1610 hours where advanced life support continued with no change in his clinical condition. At 1622 hours the Trainee was pronounced dead by the attending physician (45 minutes after his collapse), and resuscitation efforts were stopped.

Medical Findings. The death certificate and the autopsy, completed by the medical examiner, listed "dilated cardiomyopathy" due to "hypertensive cardiovascular disease" as the cause of death. Key

findings from the autopsy included cardiomegaly, biventricular dilatation, and no coronary artery disease. Histologic (microscopic) examination revealed "mild increased inflammation between cardiomyocyte fibers" and "widening of the myocardial fiber and enlarged boxcar nuclei," findings consistent with cardiomyopathy. Specific findings from the autopsy report are listed in Appendix B.

The Trainee was 72 inches tall and weighed 308 pounds, giving him a body mass index of 41.8 kilograms per meters squared (kg/m²). A body mass index greater than 30.0 is considered obese [CDC 2011]. In April 2007, a single episode of hyperlipidemia (a low density lipoprotein level of 137 milligrams per deciliter) was identified during an annual checkup with his personal physician, but subsequent tests were normal. He was found to have high blood pressure (130/92 mmHg) in March 2010 but was not prescribed a blood pressure-lowering medication. Subsequent visits to his personal physician in September 2010 and at the FD preplacement medical evaluation in November 2010 revealed blood pressures of 120/80 mmHg and 138/88 mmHg, respectively. According to medical records, no electrocardiogram or echocardiogram was ever performed.

The Trainee did not report heart-related symptoms (chest pain, chest pressure, angina, shortness of breath on exertion, etc.) at any time to his physicians, his family, the FD, or the SFTA. The SCBA the Trainee was wearing was tested by the manufacturer, and no problems were identified.

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Description of the Fire Department

At the time of the NIOSH investigation, the career FD consisted of four fire stations with 60 uniformed personnel serving 28,000 residents in a geographic area of 29 square miles.

Membership and Training. The FD requires new fire fighter applicants to be 18 years of age; complete an application; and pass a candidate physical ability test (Appendix C), an oral interview, a drug screen, and a psychological evaluation prior to being approved. The candidate is then offered a job and, if the job is accepted, the new member begins training. After CPR training, the new member is sent to SFTA for the 8-week, 380-hour course to become certified to the Fire Fighter I and II, EMT-Ambulance, and Hazardous Materials Technician levels. Once the member graduates, the FD places the member on a shift, working 24 hours on duty, 24 hours off duty for three tours, then off duty for 4 days. The state requires career firefighters to be certified as a Firefighter II within the first year of employment. There is no minimum training requirement for volunteer firefighters. The Trainee was attending the SFTA for FFI and FFII certification. The Trainee had previously taken CPR and First Aid courses and was hired by his FD 2 months earlier.

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)
- Urinalysis
- Urine drug screen
- Hearing (whisper) test
- Vision screen

The evaluations are performed by a contract physician. Once this evaluation is complete, the contract physician makes a determination regarding medical clearance for fire fighting duties and forwards this decision to the FD. The Trainee had his medical evaluation on November 16, 2010, and was cleared for fire fighting duties.

Periodic Medical Evaluations. Because all FD members are hazardous materials certified, an annual medical evaluation is required. Components of the medical evaluation include the following:

- Complete medical history
- Physical examination (including vital signs)
- Electrocardiogram
- Complete blood count with lipid panel
- Pulmonary function test
- Hearing (whisper) test
- Vision screen

The evaluations are performed by a contract physician. Once this evaluation is complete, the contract physician makes a determination regarding medical clearance for fire fighting duties and forwards this decision to the FD. An annual SCBA facepiece fit test is required by the FD. Annual SCBA medical clearance is not required. Members injured on duty must be evaluated by the FD contract physician who makes the final determination regarding return to duty.

Health and Wellness Programs. The FD has no formal wellness/fitness program, but exercise equipment is available in the fire stations, and employees have access to the local high school weight room. No annual physical ability test is required. All SCBAs are tested in accordance with NFPA 1981, Standard on Open-Circuit Self-Con-

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Description of the FD (cont.)

tained Breathing Apparatus (SCBA) for Emergency Services [NFPA 2007b]. Breathing air quality is tested quarterly in accordance with NFPA 1989, Standard on Breathing Air Quality for Emergency Services [NFPA 2008b].

Discussion

Cardiomyopathy. The autopsy revealed dilated cardiomyopathy. Cardiomyopathies are conditions that involve damage to the heart muscle not due to hypertension; ischemia (coronary artery disease); or valvular, pericardial, or congenital heart disease [Wynne and Braunwald 2008]. There are three types of cardiomyopathy based on functional impairment:

- dilated, the most common form, which accounts for 60% of all cardiomyopathies
- hypertrophic, recognized by inappropriate left ventricular hypertrophy, often with involvement of the interventricular septum
- restrictive, the least common form in Western countries, marked by impaired diastolic filling and in some cases with endocardial scarring of the ventricle [Wynne and Braunwald 2008]

The Trainee had components of dilated and hypertrophic cardiomyopathy.

Dilated Cardiomyopathy. Dilated cardiomyopathy is characterized by cardiac enlargement and impaired systolic function of one or both ventricles, congestive heart failure, arrhythmias, and emboli [Dec and Fuster 1994]. Microscopic findings are nonspecific, typically being myocyte hypertrophy (best appreciated as nuclear hypertrophy [i.e., “boxcar nuclei”]) with varying degrees of interstitial fibrosis [Dec and Fuster 1994; Virmani 1997]. As the ventricular function deteriorates, the following signs and symptoms of congestive heart failure appear: shortness

Discussion (cont.)

of breath with exertion or when lying flat, ankle swelling, fatigue, weakness, etc. Laboratory studies (radionuclide and cardiac catheterization) are necessary to diagnose left ventricular enlargement and dysfunction, mitral and/or tricuspid regurgitation, elevated left-sided and often right-sided filling pressures, elevated pulmonary artery wedge pressures, and diminished cardiac output [Dec and Fuster 1994; Wynne and Braunwald 2008]. The Trainee was asymptomatic and had no laboratory studies conducted, but was found to have dilated cardiomyopathy and enlarged boxcar nuclei on autopsy.

The incidence rate of dilated cardiomyopathy in the United States is 5 to 8 cases per 100,000 per year, with an age-adjusted prevalence of 36 cases per 100,000 [Virmani 1997]. Although most cases of dilated cardiomyopathy are of unknown etiology (idiopathic), a variety of acquired or hereditary disorders can cause the disorder. These secondary and potentially reversible forms are listed in Appendix D [Dec and Fuster 1994].

Inherited factors account for approximately one third of all idiopathic dilated cardiomyopathy cases, and 20% of patients with idiopathic dilated cardiomyopathy have at least one first-degree relative with a decreased ejection fraction and cardiomegaly [Michels et al. 1992; Keeling et al. 1995; Grunig et al. 1998]. Although idiopathic dilated cardiomyopathy can be transmitted as a recessive or X-linked trait, autosomal dominant inheritance occurs most frequently and exhibits both clinical variability and genetic heterogeneity [Fatkin et al. 1999]. It is unclear if the Trainee’s idiopathic dilated cardiomyopathy was due to inherited factors or an acquired condition such as viral myocarditis. The Trainee had no medical history consistent with viral myocarditis and no known relatives with cardiomyopathy. In either case,

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Discussion (cont.)

because of the possibility of the condition being inherited, first-degree relatives should consult with their physicians regarding when, or if, a screening echocardiogram is warranted.

The prognosis for idiopathic dilated cardiomyopathy is poor; studies report an average 5-year death rate of 20% [Ikram et al. 1987; Di Lenarda et al. 1990; Komajda et al. 1990; Sugrue et al. 1992]. Dilated cardiomyopathy is also associated with an increased incidence of sudden cardiac death, mostly from arrhythmias [Dec and Fuster 1994; Bansch et al. 2002; Wynne and Braunwald 2008]. Although sudden death is rarely the initial presentation [Komajda et al. 1990; Sugrue et al. 1992], it is a common cause of death among idiopathic dilated cardiomyopathy patients, accounting for 28% of all idiopathic dilated cardiomyopathy deaths [Dec and Fuster 1994]. Although a variety of symptoms and medical tests can provide prognostic information, patients at greatest risk of sudden cardiac death are hard to identify [Dec and Fuster 1994].

Hypertrophic Cardiomyopathy. Hypertrophic cardiomyopathy (HCM) is a rare heart condition affecting approximately 0.2% of the population [Spirito et al. 1997]. Diagnosis is typically made by echocardiogram and EKG findings of left ventricular hypertrophy by voltage. The Trainee was asymptomatic, and no screening EKG was performed. Most patients are asymptomatic, and sudden cardiac death is often the first clinical manifestation [Wynne and Braunwald 2001]. Risk factors for sudden death among HCM patients include young age (less than 30 years old) at diagnosis, a family history of HCM with sudden death, an abnormal blood pressure response to exercise, severe symptoms, nonsustained ventricular tachycardia, marked hypertrophy, marked left atrial dilatation, and genetic abnormalities associated with

increased prevalence of sudden death [Spirito et al. 1997; Olivotto et al. 1999; Wynne and Braunwald 2001].

Approximately half of HCM cases are transmitted genetically, typically as an autosomal dominant trait. Because of this, medical evaluation of first-degree relatives is warranted to determine whether screening tests (e.g., echocardiogram) are appropriate. Although hypertension can cause both cardiomegaly and left ventricular hypertrophy, given the Trainee's mild and short duration of high blood pressure, it is unlikely that hypertension was responsible for either of these conditions. A much more likely cause was the Trainee's cardiomyopathy (dilated and/or hypertrophic).

Sudden Cardiac Death. Epidemiologic studies have found that heavy physical exertion sometimes immediately precedes and triggers sudden cardiac death [Albert et al. 2000]. The Trainee performed maze training while wearing full turnout gear and SCBA. The training is considered heavy physical activity [AIHA 1971; Gledhill and Jamnik 1992]. NIOSH investigators conclude that the Trainee probably had a fatal cardiac arrhythmia associated with his dilated and hypertrophic cardiomyopathy; this likely was triggered by the physical stress of the maze tunnel training.

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 2007c]. This voluntary industry standard provides the components of a preplacement and annual medical evaluation and medical fitness for duty criteria.

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Discussion (cont.)

Dilated cardiomyopathy is not specifically mentioned in NFPA 1582. However, it is one type of cardiomyopathy, a Category A condition for candidates that “precludes a person from performing as a member in a training or emergency operational environment by presenting a significant risk to the safety and health of the person or others” [NFPA 2007c].

NFPA considers HCM a category B medical condition for fire fighter candidates. Category B is defined as “a medical condition that, based on its severity or degree, could (emphasis ours) preclude a person from performing as a fire fighter in a training or emergency operational environment by presenting a significant risk to the safety and health of the person or others.” NFPA 1582 notes this distinction in its members section when it states, “Hypertrophic obstructive cardiomyopathy (idiopathic hypertrophic subaortic stenosis) might compromise the member’s ability to function as an integral component of a team, where sudden incapacitation can result in mission failure or in risk of injury or death to civilians or other team members” [NFPA 2007c]. The final decision for clearing an individual with HCM for duty lies with the FD physician.

The Trainee was asymptomatic, and prior medical evaluations detected no cardiac abnormality. NFPA 1582 recommends an EKG and a chest x-ray as part of its candidate medical evaluation. Had an EKG or chest x-ray been conducted as part of the FD’s candidate or member medical evaluation, it is remotely possible the Trainee’s enlarged heart could have been detected. However, both EKG and chest x-ray have very low sensitivities to detect cardiomegaly [Kerber and Sherman 1975].

Recommendations

NIOSH investigators offer the following recommendations to address general safety and health issues. However, it is unlikely that any of these recommendations would have prevented the Trainee’s death.

Recommendation #1: Provide preplacement and annual medical evaluations compliant with National Fire Protection Association (NFPA) 1582 to fire fighters.

Guidance regarding the content and frequency of these medical evaluations can be found in NFPA 1582 and in the International Association of Fire Fighters (IAFF)/International Association of Fire Chiefs (IAFC) Fire Service Joint Labor Management Wellness/Fitness Initiative [NFPA 2007c; IAFF, IAFC 2008]. 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. To ensure improved health and safety of candidates and members, and to ensure continuity of medical evaluations, it is recommended the FD and the SFTA comply with this recommendation. However, the FD and the SFTA are not legally required to follow the NFPA standard or the IAFF/IAFC initiative.

Recommendation #2: Perform a preplacement and an annual physical performance (physical ability) evaluation.

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

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Recommendations (cont.)

[NFPA 2007d]. Members who engage in emergency operations must be annually qualified (physical ability test) as meeting these physical performance standards for structural fire fighters [NFPA 2007d]. This Trainee completed a physical ability test in October 2010; his fitness level was appropriate for unrestricted duty as a structural fire fighter.

Recommendation #3: Ensure that 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 and in the IAFF/IAFC Fire Service Joint Labor Management Wellness/Fitness Initiative [NFPA 2007c; IAFF, IAFC 2008]. According to these guidelines, the FD 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. The physician should review job descriptions and essential job tasks required for all FD positions and ranks 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. This recommendation is made based on review of the FD health and medical programs.

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

Guidance for fire department wellness/fitness programs to reduce risk factors for cardiovascular disease and improve cardiovascular capacity is found in NFPA 1583, Standard on Health-Related Fitness Programs for Fire Fighters and the IAFF/IAFC Fire Service Joint Labor Management Wellness/Fitness Initiative [IAFF, IAFC 2008; NFPA 2008c]. 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 coronary artery disease 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].

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Recommendations (cont.)

Recommendation #5: *Provide fire fighters with medical clearance to wear SCBA as part of the Fire Department's medical evaluation program.*

The Occupational Safety and Health Administration (OSHA) Revised Respiratory Protection Standard requires employers to provide medical evaluations and clearance for employees using respiratory protection [29 CFR 1910.134]. These clearance evaluations are required for private industry employees and public employees in states operating OSHA-approved state plans. Arkansas does not operate an OSHA-approved state plan; therefore, neither the FD nor the SFTA is required to ensure all members have been medically cleared to wear an SCBA. However, we recommend voluntary compliance with this recommendation to improve fire fighter health and safety.

Recommendation #6: *Ask an independent third party entity such as the NIOSH National Personal Protective Technology Laboratory to perform post-incident SCBA inspection and testing.*

The NIOSH NPPTL has the expertise to test the function of respiratory protective equipment used in this incident. The NPPTL staff can evaluate the performance of the SCBA as a system and provide an independent, third party opinion regarding the functionality of the SCBA and whether it contributed to the injury/death [NIOSH 2009]. The SCBA in this incident was tested by the manufacturer and was found to be in proper working order. While NIOSH did not suspect any SCBA problem, we recommend testing by an independent entity.

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Fire Fighter Trainee Suffers Sudden Cardiac Death During Maze Training – Arkansas

Investigator Information

This incident was investigated by the NIOSH Fire Fighter Fatality Investigation and Prevention Program, Cardiovascular Disease Component in Cincinnati, Ohio. Mr. Tommy Baldwin (MS) led the investigation and co-authored the report. Mr. Baldwin is a Safety and Occupational Health Specialist, a National Association of Fire Investigators (NAFI) Certified Fire and Explosion Investigator, an International Fire Service Accreditation Congress (IFSAC) Certified Fire Officer I, and a former Fire Chief and Emergency Medical Technician. Dr. Thomas Hales (MD, MPH) provided medical consultation and co-authored the report. Dr. Hales is a member of the NFPA Technical Committee on Occupational Safety and Health, and Vice-Chair of the Public Safety Medicine Section of the American College of Occupational and Environmental Medicine (ACOEM).

Fire Fighter Trainee Suffers Sudden Cardiac Death During Maze Training – Arkansas

Appendix A

Firefighter Encounter Agility Test (FEAT) [SFTA 2011]

Wearing full turnout gear including SCBA, the fire fighter must complete the following tests within 12 minutes:

- (1) Drag a 100-foot length of uncharged 2½-inch hoseline (started with hose on shoulder), and connect and disconnect the nozzle;
- (2) Roll and unroll a 50-foot length of 2½-inch hoseline;
- (3) Move three 2½-inch hoseline rolls in circles (three rolls stacked on top of each other), (1) one roll moved to a second location 20 feet away, (2) another roll moved from the first location to the third location 20 feet away, (3) roll moved from first location to third location, (4) roll moved from second location to third location to form a stack of three donut hoses;
- (4) Ladder the 2nd story window, ascend ladder and touch window sill, implement leg lock, then descend;
- (5) Pound wooden block with 16-pound sledge hammer (30 times) as in a ventilation chop;
- (6) Carry a high rise pack (50 feet of 2½-inch hoseline) to the fourth floor. Set the high rise pack down and hoist the high rise pack tied to a rope with the other end of the rope tied to the hand rail on the fourth floor. Lower the hoisted high rise pack to the ground or the starting position. Pick up the original high rise pack, descend the stairs to ground level, and set the pack down;
- (7) Drag the rescue manikin 30 feet and then back 30 feet to the starting position. Once the manikin is dropped, travel approximately 75 feet to the finish line.

If students are unsuccessful on their first attempt, they receive immediate remedial training and are given a second chance to complete the evolution. Students are allowed two evolution attempts. Students unsuccessful students after the second attempt do not pass the training program.

REFERENCE

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Fire Fighter Trainee Suffers Sudden Cardiac Death During Maze Training – Arkansas

Appendix B

Autopsy Findings

- Dilated cardiomyopathy
 - Focal areas of mildly increased inflammation between the cardiomyocyte fibers
 - Cardiomyocyte hypertrophic change characterized by widening of the myocardial fiber and enlarged boxcar nuclei
- Cardiomegaly (enlarged heart)(heart weighed 615 grams [g]; predicted normal weight is 463 g [ranges between 351 g and 611 g as a function of sex, age, and body weight]) [Silver and Silver 2001]
- Left ventricular hypertrophy (1.0 centimeter [cm])
 - Normal at autopsy is 0.76–0.88 cm [Colucci and Braunwald 1997]
 - Normal by echocardiographic measurement is 0.6–1.0 cm [Connolly and Oh 2012]
- Normal cardiac valves
- No focal narrowing of the coronary arteries
- No evidence of a coronary artery thrombus (blood clot)
- No evidence of a pulmonary embolus (blood clot in the lung arteries)
- Blood tests for drugs and alcohol were negative

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Fire Fighter Trainee Suffers Sudden Cardiac Death During Maze Training – Arkansas

Appendix C

Candidate Physical Agility Test (CPAT) [Fire Department 2011]

Candidates must perform all 8 components of the candidate physical agility test on a pass/fail basis. Candidates are fitted with a turnout coat and an SCBA, weighing approximately 30 pounds together. Candidates must complete the untimed ladder climb prior to attempting the timed portion of the test; the time limit is 7 minutes. Time begins when the student takes the first step at the Hose Hoist portion. Components of the CPAT test include the following:

- (1) Ladder Climb (not timed): After receiving a safety belt and instructions for climbing the 75-foot aerial ladder, the applicant shall climb a fully extended ladder, touch the top rung and descend the ladder.
- (2) Hose Hoist (timed): Three taped rolls of 2½-inch hoseline are located 20 feet behind the fire apparatus. The candidate will move the rolls one at a time from the starting point to the rear running board of the fire apparatus. The candidate then steps upon the rear running board and places the hose over the top bar onto the hose bed. After all three hose rolls have been placed on the apparatus, the candidate then removes the hose rolls one at a time and takes the hose back to the starting point.
- (3) Ladder Set-Up (timed): A 14-foot roof ladder, weighing approximately 45 pounds, will be lying on the ground with the feet of the ladder against the building. The ladder will be raised to a vertical position against the building. The candidate will then adjust the ladder to a simulated climbing angle. The ladder will then be returned to its original position.

To pick up the ladder, the candidate will assume a crouching position and grasp the top rung of the ladder with both hands. The candidate will stand upright and raise the end of the ladder above his or her head with the bottom of the ladder remaining on the ground against the building. The candidate will raise the ladder by walking forward grasping consecutive rungs, without dropping or losing control of the ladder, until the ladder is placed in a vertical position against the building. The candidate will then grasp the sides of the ladder and bring the bottom of the ladder out to a comfortable climbing position. The candidate will then place the ladder back against the building and lower the ladder by walking backwards, grasping consecutive rungs and place the ladder in its original position on the ground without dropping or losing control of the ladder.
- (4) Hose Roll (timed): The candidate will position his or herself at the male coupling of the 2½-inch hoseline. The candidate will then bend over and begin rolling the fire hose into a circular roll. The fire hose must be rolled the entire length of 50 feet. The candidate will then unroll the fire hose back to the original position.

Fire Fighter Trainee Suffers Sudden Cardiac Death During Maze Training – Arkansas

Appendix C (cont.)

(5) Ventilation (timed): The candidate stands on the outside rails of the sled and straddles the metal sled. The candidate will strike the metal sled with the sledge hammer until the metal sled is moved 36 inches.

(6) Hose advance (timed): The candidate advances a charged, 100-foot length of 1³/₄-inch hoseline 75 feet, then opens the nozzle, and sprays water. The candidate then closes the nozzle and places the nozzle on the ground.

(7) Stairwell Exercise (timed): The candidate will pick up a roll of 2¹/₂-inch hoseline at the base of the bleachers. The candidate will carry the fire hose to the top of the bleachers and touch the fence. The candidate will carry the fire hose back to the base of the bleachers and return the fire hose to the original position. The candidate will make sure that at least one foot touches each step both going up and coming down the bleachers. Running or skipping is not allowed.

(8) Victim Rescue (timed): The candidate will grasp the 165-pound rescue manikin in a manner that is most compatible with the candidate. The candidate will move the rescue manikin a distance of 100 feet. The neck hook on the rescue manikin may not be used. The event and the timed part of the course is complete when both the victim and the candidate clear the 100 foot mark.

REFERENCE

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Fire Fighter Trainee Suffers Sudden Cardiac Death During Maze Training – Arkansas

Appendix D

Known Causes of Dilated Cardiomyopathy [Dec and Fuster 1994]

Toxins

- Ethanol
- Chemotherapeutic agents (doxorubicin, bleomycin)
- Cobalt
- Anti-retroviral agents (zidovudine, didanosine, zalcitabine)
- Phenothiazines
- Carbon monoxide
- Lead
- Cocaine
- Mercury

Metabolic Abnormalities

- Nutritional deficiencies (thiamine, selenium, carnitine)
- Endocrinologic disorders (hypothyroidism, acromegaly, thyrotoxicosis, Cushing Disease, pheochromocytoma, diabetes mellitus)
- Electrolyte disturbances (hypocalcemia, hypophosphatemia)

Infectious

- Viral (coxsackie virus, cytomegalovirus, human immunodeficiency virus)
- Rickettsial
- Bacterial (diphtheria)
- Mycobacterial
- Fungal
- Parasitic (toxoplasmosis, trichinosis, Chagas disease)

Noninfectious

- Collagen vascular disorders (scleroderma, lupus erythematosus, dermatomyositis)
- Hypersensitivity myocarditis
- Sarcoidosis
- Peripartum dysfunction

Neuromuscular Causes

- Duchenne muscular dystrophy
- Facioscapulohumeral muscular dystrophy
- Erb limb-girdle dystrophy
- Myotonic dystrophy