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Death in the line of duty...

NIOSH
Fire Fighter Fatality Investigation and Prevention Program

A summary of a NIOSH fire fighter fatality investigation *December, 2010*

Volunteer Fire Fighter Suffers a Fatal Cardiac Event After Fire Suppression Training - Pennsylvania

Executive Summary

On May 1, 2010, a 51-year-old volunteer Fire Fighter (FF) died after participating in fire suppression activities associated with a basic firefighting course (part of a 166 hour course). The incident occurred on the final day of training involving interior structural fire suppression and exterior fire drills. The FF, wearing full turnout gear and a self-contained breathing apparatus (SCBA), participated in one evolution of fire extinguishment lasting approximately 5 minutes and then experienced symptoms consistent with exhaustion and/or dehydration. Following rehydration and monitoring in rehabilitation (Rehab) for 1 hour and 45 minutes, he returned to training and completed a liquid propane drill lasting about 2 minutes. Approximately 5-10 minutes after this drill, the FF was found unresponsive and cyanotic. On scene emergency medical service (EMS) personnel summoned an ambulance, began cardiopulmonary resuscitation (CPR), and attached an automated external defibrillator (AED) to the FF from which two shocks were administered without a change in the FF's clinical condition. Advanced cardiac life support (ACLS) was provided by the ambulance crew and the Emergency Department (ED). Despite these efforts the FF could not be resuscitated. The death certificate listed "stress induced cardiac arrhythmia" as the immediate cause of death and severe coronary disease as the underlying cause of death. The pathologist conducting the autopsy listed "severe occlusive coronary artery" disease (CAD) as the cause of death. Based on the autopsy findings and the clinical scenario, the NIOSH investigators conclude that the FF probably died from a cardiac arrhythmia triggered by the physical exertion associated with firefighting training or a cardiac arrhythmia caused by a heart attack, which was triggered by firefighting training.

NIOSH offers the following recommendations to reduce the risk of on-the-job heart attacks and sudden cardiac arrest among fire fighters at this, and other, fire departments (FD) across the country.

Provide mandatory pre-placement and periodic medical evaluations to all fire fighters consistent with the National Fire Protection Association (NFPA) Standard 1582, Standard on Comprehensive Occupational Medical Program for FDs.

Ensure fire fighters are cleared for duty by a physician knowledgeable about the physical demands of firefighting, the personal protective equipment used by fire fighters, and the various components of NFPA 1582.

Develop a comprehensive wellness/fitness program for fire fighters to reduce risk factors for cardiovascular (CVD) and improve cardiovascular capacity.

Perform an annual physical performance (physical ability) evaluation.

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

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Executive Summary (cont.)

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

Ensure emergency medical services staff in rehabilitation have the authority, as delegated from the Incident Command System, to use their professional judgment to keep members in rehabilitation or to transport them for further medical evaluation or treatment.

Training Academy participants must be medically cleared for live fire training.

Introduction & Methods

On May 1, 2010, a 51-year-old volunteer FF died shortly after fire suppression drills conducted as part of a basic firefighting course. Despite on scene CPR and defibrillation, continued CPR and ACLS en route to the hospital and in the hospital ED, the FF could not be revived. The United States Fire Administration notified NIOSH of this fatality on May 4, 2010. NIOSH contacted the affected FD shortly thereafter to obtain further information, and again on October 25, 2010, to schedule the investigation. On November 1, 2010, a contractor for the NIOSH Fire Fighter Fatality Investigation Team (the NIOSH investigator) conducted an on-site investigation of the incident.

During the investigation, the NIOSH investigator interviewed the following people:

- Fire Chief
- Safety Officer
- Captain
- Two brothers (both members of the FD)
- Lead instructor in charge of training
- Supervisor in charge of training
- Executive director of the training program
- EMS provider
- Personal physician
- Medical examiner

The NIOSH investigator reviewed the following documents in preparing this report:

- Dispatch records
- Ambulance report
- Death certificate
- Autopsy report
- Primary care physician's medical records
- Hospital ED records
- Instructors and EMS statements
- Training facility policy and procedures
- FD standard operating guidelines

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Investigative Results

Incident. On May 1, 2010, the FF reported to his final day of training for a 166-hour basic firefighting course. The course was conducted at a county fire school with instructors and administrative support provided by a local community college with State-accredited training. In 2009, the community college offered 31 classes at this site, six of which included live burn evolutions. The final day of training for this FF's class was devoted to live fire training drills; this was the first time these students had participated in live fire training. At 1200 hours, the temperature was approximately 76 degrees Fahrenheit and the humidity was 49% [Weather Underground 2008].

The first scheduled evolutions were interior suppression drills simulating "a room and contents fire" on the first floor of a two-story concrete training building. The fireset in the burn room contained a maximum of three wood pallets. After completing the interior structural firefighting drills, students performed exterior fire suppression activities on a dumpster fire, a car fire, and a liquid propane fire.

Interior Fire Suppression. Training began at 0800 hours with an instructor briefing of the day's events. The FF's air pack was checked and baseline vital signs taken [pulse = 68 beats per minute (bpm); breathing rate = 18 respirations per minute (rpm); blood pressure = 136/80 millimeters of mercury (mm Hg)]. At approximately 0815 hours instructors provided a safety walkthrough of the fire building (wearing helmet and gloves) and at approximately 0920 hours interior fire suppression drills began. The FF was in the third group to participate in the interior fire suppression drills. His evolution began at 0935 hours.

The FF was the lead nozzleman on the hose line. Wearing full turnout gear and SCBA (total ensemble weighed approximately 50 pounds), the FF and two other crew members advanced the hose line and extinguished the fire. As the FF was told to back out of the room, the instructor noticed that the FF was having some difficulty remaining in the crouched position. The instructor removed the FF through an exterior doorway in the fireroom (about 2 feet from his attack position). Once outside, instructors helped remove his SCBA and bunker coat and escorted the FF to the EMS/Rehab Trailer located approximately 100 feet away.

The EMS Rehab Trailer was staffed by a paramedic and two EMTs. After evaluating the FF, the onsite EMS called for an ambulance in anticipation of transport to the ED. At this time (approximately 1000 hours), the FF's vital signs were a pulse of 86 bpm, a respiratory rate of 16 bpm, and a systolic blood pressure of 130 mm Hg. EMS personnel determined that the FF was likely dehydrated and provided the FF with water and intravenous saline. The FF insisted that he did not want to be transported and rejected the paramedic's advice to be transported. After the administration of the fluids and resting in Rehab for 1 hour and 45 minutes, the FF felt much better and reported no further symptoms. At 1145 hours, his vital signs were a pulse of 60 bpm a respiratory rate of 18 bpm, and a blood pressure of 98/58 mm Hg. After leaving Rehab, the FF spoke with instructors and other FFs, all of whom reported that the FF was in high spirits, felt fine, and was eager to participate in the exterior suppression drills.

At approximately 1145 hours, interior structural firefighting drills ended. Both the supervisor responsible for interior firefighting drills and the

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Investigative Results (cont.)

EMS/Rehab personnel departed the site as these services are not required for exterior fire suppression activities. At this time students were provided a break and instructors prepared for the exterior fire suppression drills.

External Fire Suppression. At approximately 1215 hours, the instructors provided a briefing on the exterior fire suppression drills. Evolutions began shortly thereafter. The FF insisted that he wanted to continue with the exterior fire suppression drills and was permitted to participate in the first evolution of the liquid propane fire drill. Wearing full PPE and SCBA, the FF was the nozzleman. The FF and his crew advanced the line and one of the crew closed the gas valve. The evolution lasted approximately 2 minutes. The FF completed the drill with no problems and was instructed to remove his bunker gear and drink a bottle of water.

Following this evolution the FF engaged in conversation with instructors and crew members and reported no difficulty. About 5-10 minutes later, an instructor checked with the FF's partner to determine his whereabouts. It was determined that he had gone to the rest room; his training partner and his brother (also a FF student) went into the restroom looking for him. Inside the restroom, they found the FF stooped down and unconscious. They moved him outside and called for help. Instructors and other trained personnel evaluated the FF and found him to be breathless and cyanotic, with a weak pulse that stopped during evaluation. CPR was begun, an ambulance was summoned and an AED was retrieved. A bag valve mask was used to assist with ventilations and the AED was attached to the FF. Initially, the AED indicated that no shock was advised, but subsequent evaluation indicated a shockable rhythm and two shocks were administered to the FF with no change in his clinical status.

An ALS ambulance was dispatched at 1227 hours and arrived on scene at 1233 hours. The ambulance crew found the firefighter to be pulseless, breathless, and cyanotic. The cardiac monitored revealed an unshockable heart rhythm and CPR was continued. The firefighter was intubated with an endotracheal tube with placement verified by bilateral breath sounds, condensation in the tube, color change on end tidal respiration, and absence of sounds in the abdomen. An intravenous line was started and cardiac drugs were administered per ACLS protocol. The ambulance departed the scene at 1246 hours and arrived at the ED at 1255 hours. Upon arrival at the ED it was noted that the firefighter had fixed and dilated pupils. There was no cardiac rhythm. ED personnel continued to provide ACLS for approximately 20 minutes with no change in the firefighter's condition. At 1313 the firefighter was pronounced dead and resuscitation efforts were discontinued.

Medical Findings. The death certificate listed "stress induced cardiac arrhythmia" as the immediate cause of death, with severe coronary artery disease as the underlying cause of death. The autopsy, conducted by a pathologist, stated that the firefighter died of severe occlusive coronary artery with 90-95% narrowing of the left circumflex and left anterior descending artery (see Appendix A for additional detail).

In 2001, at the age of 41, the FF suffered a stroke due to an occluded left carotid artery leaving the FF with some residual speech problems. In November 2009 he saw his primary care physician

Investigative Results (cont.)

(PCP) with a complaint of shortness of breath. The physician ordered a chest x-ray which found the lungs clear and the heart size to be at the upper limit of normal, but no acute cardiopulmonary condition responsible for his symptoms.

The FF's risk factors for CAD included smoking, a family history of early cardiovascular death, and the lack of regular exercise. He was not overweight (body mass index of 21) and did not have high blood pressure (hypertension), high blood cholesterol, or diabetes mellitus [AHA 2010]. The FF's last visit to his health care provider was 2 months prior to his death.

Description of the Fire Department

At the time of the NIOSH investigation, the volunteer FD consisted of approximately 50 FFs. It has a single fire station, serves a population of approximately 4,000 residents, and covers an area of approximately 15 square miles.

Membership and Training. To join the FD, a candidate must be 15 years of age and at least 18 to engage in structural firefighting. Potential members complete an application which is reviewed by a committee appointed by the President of the FD. The committee makes a recommendation to the FD, which then votes on the candidate. To respond to fire and rescue emergencies a firefighter must have taken Essentials of Firefighting, HazMat Operations, and First Aid/CPR Training. The Essentials of Firefighting and HazMat Operations courses are offered through a local community college.

The FF joined the FD in November 2008 and had completed his 1st aid/CPR requirements. In 2009 he took Basic Fire Police and Advanced Fire Police courses through the local community college. In January 2010, he began his Essentials of Firefighting course. In addition to paying for courses through the community college, the FD offers training refreshers on alternate Tuesday nights and conducts Fire Training Drills approximately 4 times per year.

Fitness for Duty and Health/Wellness Programs. The FD does not conduct physical ability testing for candidates or members. The FD does not require candidates or members to receive a medical clearance evaluation for fire suppression or SCBA use. However, medical clearance is required for return to duty after a injury/illness involving a worker's compensation claim.

Discussion

CAD and the Pathophysiology of Sudden Cardiac Death. This FF experienced a cardiac arrest and sudden cardiac death following live fire firefighting training. The most common risk factor for cardiac arrest and sudden cardiac death is CAD, defined as the build-up of atherosclerotic plaque in the coronary arteries [AHA 2008]. The autopsy report confirmed that this FF had severe CAD with 90 to 95% blockage of two of the heart's major coronary arteries. Risk factors for CAD include increasing age, male gender, family history of CAD, smoking, hypertension, high blood cholesterol, obesity/physical inactivity, and diabetes [AHA 2008]. The firefighter was a 51 year old male with a family history of early cardiovascular death, smoking, and inactivity. In 2001 the FF was diagnosed with atherosclerotic vascular disease (complete occlusion of his left

Discussion (cont.)

common carotid artery) that resulted in a stroke.

The narrowing of the coronary arteries by atherosclerotic plaques occurs over many years, typically decades [Libby 2005]. However, the growth of these plaques probably occurs in a nonlinear, often abrupt fashion [Shah 1997]. Most heart attacks occur when a vulnerable plaque ruptures, causing a blood clot to form which occludes a coronary artery. Establishing the occurrence of an acute heart attack requires any of the following: characteristic electrocardiogram (EKG) changes, elevated cardiac enzymes, or coronary artery thrombus. The FF never regained a heart rhythm on which an EKG could reveal characteristic changes, he died before cardiac enzymes would become elevated, and no thrombus was found at autopsy. However, occasionally (16-27% of the time) post-mortem examinations do not reveal the coronary artery blood clots/plaque rupture during acute heart attacks [Davies 1992; Farb et al. 1995]. Based on the autopsy findings and the clinical scenario, the NIOSH investigators conclude that the FF probably died from either a cardiac arrhythmia triggered by the physical exertion associated with firefighting training, or a cardiac arrhythmia caused by a heart attack triggered by firefighting training [Thaulow et al. 1993; Libby 2005].

Left Ventricular Hypertrophy. On autopsy, the FF was found to have left ventricular hypertrophy (LVH). This finding was not identified prior to his death although a chest x-ray performed in 2009 did find that his heart size was on the high end of the normal range. LVH increases the risk for sudden cardiac death [Levy et al. 1990]. Hypertrophy of the heart's left ventricle is a relatively common finding among individuals with long-standing high blood pressure, a heart valve problem, or chronic cardiac ischemia (reduced blood supply to the heart muscle) [Siegel 1997]. The FF had no history of high blood pressure or a heart valve problem, therefore his LVH was probably due to asymptomatic chronic cardiac ischemia as a result of his underlying CAD. 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.

Physiological Stress of Firefighting. Firefighting is widely acknowledged to be physically demanding, requiring fire fighters to work at near maximal heart rates for long periods and causing significant physiological disruption [Barnard and Duncan 1975; Lemon and Hermiston 1977; Manning and Griggs 1983; Jankovic et al. 1991; Smith et al. 2001]. Even when energy costs are moderate (as measured by oxygen consumption) and work is performed in a thermoneutral environment, heart rates may be high (over 170 beats per minute) owing to the insulative properties of the personal protective clothing [Smith et al. 1995]. The firefighter participated in interior structural firefighting drills earlier in the day. He was treated for what appeared to be dehydration and exhaustion and later participated in a liquid propane drill in full PPE.

Epidemiologic studies in the general population have found that heavy physical exertion can trigger a heart attack and cause sudden cardiac death [Tofler et al. 1992; Mittleman et al. 1993; Willich et al. 1993; Albert et al. 2000]. Epidemiologic studies among fire fighters have shown that fire suppression, training, alarm response, or strenuous physical activity on the job in the preceding 12 hours, increases the risk for a sudden cardiac event

Discussion (cont.)

[Kales et al. 2003; Hales et al. 2007; Kales et al. 2007]. The NIOSH investigators conclude that the FF probably died from an arrhythmia (with or without a heart attack) triggered by the physical exertion of the firefighting drills.

Occupational Medical Standards for Structural Firefighting. To reduce the risk of sudden cardiac arrest or other incapacitating medical conditions among fire fighters, the NFPA has developed NFPA 1582 [NFPA 2007a].

According to NFPA 1582 [6.6.2(3)], stenotic lesions of the carotid artery resulting in ≥50% reduction in blood flow are considered Category A conditions (a precluding condition for candidates). Members with carotid artery lesions >70% cannot perform as an integral component of a team due to the risk of sudden incapacitation [9.5.4.1]. Thus, had a candidate or member medical evaluation been performed, the FF should have been precluded from the fire fighter training. In addition, due to the FF's history of a carotid artery lesion and stroke, the FF had the equivalent of known CAD.

NFPA 1582 also recommends diagnostic screening for CAD via an exercise stress test for asymptomatic fire fighters over age 45 (55 for women) with two or more risk factors for CAD (family history of premature cardiac event, hypertension, diabetes mellitus, cigarette smoking, and hypercholesterolemia). The FF was 51 years old and had two CAD risk factors. Therefore, an exercise stress test was indicated. If the FD required exercise stress tests for fire fighters with CAD risk factors, perhaps the FF's CAD would have been identified and referred to a cardiologist for further diagnosis and treatment.

Recommendations

NIOSH offers the following recommendations to reduce the risk of on-the-job heart attacks and sudden cardiac arrest among fire fighters at this, and other, FDs across the country.

Recommendation #1: Provide mandatory pre-placement and periodic medical evaluations to all fire fighters consistent with the National Fire Protection Association (NFPA) Standard 1582, Standard on Comprehensive Occupational Medical Program for FDs.

Guidance regarding the content and frequency of periodic medical evaluations and examinations for fire fighters can be found in NFPA 1582 and in the International Association of Fire Fighters/International Association of Fire Chiefs (IAFF/IAFC) Fire Service Joint Labor Management Wellness/Fitness Initiative [NFPA 2007a]. The FD, however, is not legally required to follow this standard or this initiative.

This recommendation has financial implications and may be particularly difficult for small, volunteer and combination FDs to implement. The FD may have to consider alternative options to overcome the financial obstacle. One option urges current members to get annual medical clearances from their private physicians. Another option is having the annual medical evaluations completed by paramedics and EMTs from the Emergency Medical Service (vital signs, height, weight, visual acuity, and EKG). This information could then be provided to a community physician, perhaps volunteering his or her time, to 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 (per-

Recommendations (cont.)

sonal or through insurance), provided by a physician volunteer, or paid for by the FD. Sharing the financial responsibility for these evaluations between fire fighters, the FD, and physician volunteers may reduce the negative financial impact on recruiting and retaining needed fire fighters. Additional suggestions for overcoming the financial burden of implementing medical examinations within the volunteer service can be found in the National Volunteer Fire Council (NVFC) and United States Fire Administration's (USFA) Health and Wellness Guide for the Volunteer Fire Service [National Volunteer Fire Council 2009].

Recommendation #2: Ensure fire fighters are cleared for duty by a physician knowledgeable about the physical demands of firefighting, the personal protective equipment used by fire fighters, and the various components of NFPA 1582.

Physicians who provide input regarding medical clearance for firefighting duties should be knowledgeable about the unique physical demands of firefighting that result from the combination of strenuous physical work, heavy and encapsulating personal protective ensembles, extreme ambient temperatures, and emotional stress. Physicians should also be familiar with a fire fighter's personal protective equipment and the consensus guidelines published by NFPA 1582 [NFPA 2007a].

Recommendation #3: Develop a wellness/fitness program for fire fighters to reduce risk factors for CVD and improve cardiovascular capacity.

Physical inactivity is the most prevalent modifiable risk factor for CAD in the United States. Physical inactivity, or lack of exercise, is an independent risk factor for CAD and it is positively associated with other risk factors including, obesity, dyslipedemia and diabetes [Plowman and Smith 2011]. NFPA 1500 requires a wellness program that provides health promotion activities for preventing health problems and enhancing overall well-being [NFPA 2007d]. Guidance for how to implement and components of a wellness and fitness program can be found in several documents provided by Fire Service organizations:

- NFPA 1583, Standard on Health-Related Fitness Programs for Fire Fighters [NFPA 2007b];
- International Association of Fire Fighters/International Association of Fire Chiefs (IAFF/IAFC), Fire Service Joint Labor Management Wellness/Fitness Initiative [IAFF/IAFC 2007];
- National Volunteer Fire Council (NVFC) / United State Fire Administration (USFA) Health and Wellness Guide for the Volunteer Fire Service [National Volunteer Fire Council 2009].

Implementing a Health and Wellness program is a particular challenge for small, volunteer FDs. Forming effective partnerships (with park districts, fitness clubs, clinics) and capitalizing on the camaraderie of the fire service may help address these issues.

When considering the cost of Health and Wellness programs it is important to keep in mind the potential cost savings. Worksite health promotion programs have been shown to be cost effective by increasing productivity, reducing absenteeism, reducing the number of work-related injuries, and reducing the number of work-related lost work days [Maniscalco et al. 1999; Stein et al. 2000; Aldana 2001]. Fire service health promotion

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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 recent study conducted by the Oregon Health and Science University reported a savings of over one million dollars for each of four large FDs implementing the IAFF/IAFC wellness/fitness program compared to four large FDs 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 healthcare costs [Kuehl 2007].

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

NFPA 1500 recommends that the FD annually evaluate and certify FD members who engage in emergency operations as having met the physical performance requirements identified in paragraph 10.2.3 of the standard [NFPA 2007d]. This is recommended to ensure that fire fighters are physically capable of performing the essential job tasks of structural fire fighting. The physical ability test could be performed as part of the FPD's training program.

Recommendation #5: Provide fire fighters with medical clearance to wear self-contained breathing apparatus as part of the FD's annual 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 1998]. These clearance evaluations are required for private industry employees and public employees in States operating OSHA-approved State plans [OSHA 2010]. Kansas does not operate an OSHA-approved State plan for the public sector; therefore, public sector employers (including volunteer/paid FDs) are not required to comply with OSHA standards. However, NIOSH investigators recommend following this standard to ensure an increased level of medical fitness and safety.

Recommendation #6: Provide on-scene emergency medical services with advanced life support and transport capability during live fire training.

NFPA 1403 requires emergency medical services be on scene during all live fire exercises including exterior props. Emergency medical services are defined 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." [NFPA 2007c]. These EMS personnel must remain on scene until all exercises are concluded, equipment is restored to an in-service condition, and students are released.

The fire training center provides EMS personnel during "interior" fire suppression activity (including a paramedic) but does not have a transport ambulance on site. In addition, the fire training center does not operate under the supervision of a Medical Director. 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) until an ambulance arrives on scene. EMS personnel are not required to be on scene during "exterior" fire

Recommendations (cont.)

suppression activity such as dumpster and car fires or liquid propane drills. To be in compliance with NFPA 1403, the fire school should provide on-scene emergency medical services with advanced life support and transport capability during all live fire training.

Recommendation #7: Ensure emergency medical services staff in rehabilitation have the authority, as delegated from the Incident Command System, to use their professional judgment to keep members in rehabilitation or to transport them for further medical evaluation or treatment.

The FF was removed from a live fire training evolution and taken to Rehab for what appeared to be exhaustion and dehydration. Thinking the FF would need transport to the ED, the onsite paramedic requested an ambulance to the training site. The FF, however, insisted that he did not want to be transported and disregarded the paramedic's advice. NFPA 1584 specifically addresses this issue and states, "EMS staff in rehabilitation shall have the authority, as delegated from the incident commander, to use their professional judgment to keep members in rehabilitation or to transport them for further medical evaluation and treatment" [NFPA 2008]. Despite resolution of the FF's symptoms and the return of his vital signs to baseline, perhaps transport to the ED during this initial episode may have prevented his death.

Recommendation #8: Training Academy participants must be medically cleared for live fire training.

Live fire training can be as physically demanding as actual firefighting and is often performed by individuals unaccustomed to these physical demands. Therefore, medical clearance to engage in firefighting training is just as important as medical clearance to be a firefighter. The content of the medical evaluation and the factors to be considered for clearance are addressed above (see recommendations 1 and 2). To ensure the FFs have appropriate medical clearance, NIOSH recommends that FDs provide the Training Academy with a statement that the participant has been medically cleared. For participants not yet members of a FD, the Training Academy should require a physician's letter of clearance.

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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. Denise L. Smith, Ph.D, led the investigation and coauthored the report. Dr. Smith is professor of Health and Exercise Sciences, and holds the Class of 1961 Chair at Skidmore College. She was working as a contractor with the NIOSH Fire Fighter Fatality Investigation and Prevention Program, Cardiovascular Disease Component during this investigation. Thomas Hales, MD, MPH, provided medical consultation and coauthored 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).

Volunteer Fire Fighter Suffers a Fatal Cardiac Event After Fire Suppression Training - Pennsylvania

Appendix A

Autopsy Findings

Pertinent findings from the autopsy, performed on May 2, 2010, include:

- Heart Size and Structure
  - Weight = 350 grams
  - Left ventricle wall and interventricular septum both = 2.0 cm (normal by 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]
  - Right ventricle = 0.5 cm
- Severe occlusive coronary artery disease
  - 95% narrowing of the left anterior descending artery
  - 90% narrowing of the left circumflex artery
  - 50% narrowing of right coronary artery
- Microscopic findings
  - Myocyte hypertrophy
  - Wavy fibers
  - Eosinophilic myocytes with loss of transverse striations
- No evidence for a pulmonary embolus
- Blood tests were negative for alcohol and other illicit drugs

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