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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 *August, 2012*

Fire Fighter Suffers Heart Attack While Fighting a Structure Fire and Dies – Missouri

Executive Summary

On September 2, 2011, at 2323 hours, a 32-year-old male volunteer fire fighter ("the FF") was dispatched via mutual aid to a campground structure fire. The FF arrived at the scene at 0014 hours on September 3, 2011, and staged for about 45 minutes. Then, while wearing full turnout gear, he assisted in exterior overhaul operations for about 15 minutes, before being assigned to rehabilitation (Rehab). Weather conditions included a temperature of 76 degrees Fahrenheit (°F) and 79% relative humidity, giving a heat index of 77°F and a wet bulb globe temperature of 71°F [NOAA 2011]. Wet bulb globe temperature is a measure of ambient air temperature cooled by the evaporation of water from the wet temperature sensing element [NIOSH 1986]. Shortly after climbing a 300-foot hill to the Rehab area, the FF collapsed and became unresponsive.

Crewmembers began cardiopulmonary resuscitation (CPR) as the on-scene ambulance paramedics provided advanced life support treatment and transported the FF to the hospital's emergency department (ED). Treatment in the ED continued for 17 minutes but the resuscitation effort was not successful and the FF died. Two other fire fighters also suffered heat-related illnesses, one requiring treatment at the ED.

The death certificate, completed by the County Coroner, listed "cardiac arrhythmia due to focal severe coronary artery disease" as the cause of death. The autopsy report, completed by the County Medical Examiner, listed "cardiac arrhythmia resulting from severe focal atherosclerosis of his left anterior descending coronary artery with clot formation" as the cause of death. Given the FF's underlying coronary heart disease, NIOSH investigators concluded that the physical stress of exterior overhaul activities triggered his heart attack (myocardial infarction as diagnosed by the coronary artery blood clot [thrombus]), arrhythmia, and subsequent cardiac death.

NIOSH investigators offer the following recommendations to address safety and health issues and prevent similar incidents in the future.

Provide preplacement and annual medical evaluations to all fire fighters consistent with NFPA 1582, Standard on Comprehensive Occupational Medical Program for Fire Departments.

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

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

Measure carboxyhemoglobin levels on symptomatic or unresponsive fire fighters exposed to fire smoke.

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Introduction & Methods

On September 2, 2011, a 32-year-old male volunteer Fire Fighter responded to a campground structure fire. After performing overhaul in full turnout gear for 15 minutes and climbing a hill to reach Rehab, the FF suffered a heart attack. He was transportation to the hospital ED, where he died. NIOSH was notified of the fatality by the U.S. Fire Administration on September 6, 2011. NIOSH contacted the affected fire department (FD) on September 6, 2011, to gather additional information and on May 22, 2012, to initiate the investigation. On June 4, 2012, a safety and occupational health specialist from the NIOSH Fire Fighter Fatality Prevention and Investigation Program conducted an on-site investigation of the incident.

During the investigation, NIOSH personnel interviewed the following people:

- Fire Chief
- Mutual aid Fire Chief
- Mutual aid Assistant Fire Chief
- Emergency Medical Technician (EMT)
- FF's spouse

NIOSH personnel reviewed the following documents:

- FD standard operating guidelines
- FD incident reports
- Emergency medical service report
- Hospital ED records
- Death certificate
- Autopsy report

Investigative Results

Incident. On September 2, 2011, at 2323 hours, the FD was dispatched via mutual aid to a structure fire at a campground. The FF and three other members responded in Brush 109, Engine 104, and Tanker 102 while four additional FD members responded directly to the scene. Fire fighters found two camper trailers fully involved in fire and one additional trailer partially burning. The first responding FD had started fire suppression. The campground was located at the bottom of a 300-foot, 8% sloped hill. Weather conditions included a temperature of 76°F and 79% relative humidity, giving a heat index of 77°F and an estimated wet bulb globe temperature of 71°F [NOAA 2011]. Wet bulb temperature is a measure of ambient air temperature cooled by the evaporation of water from the wet temperature sensing element [NIOSH 1986].

Initial fire knockdown occurred prior to the arrival of Brush 109, Engine 104, and Tanker 102 at 00:14 hours. One fire fighter from the first responding FD suffered heat exhaustion (disoriented, unstable to walk) and was transported via the on-scene ambulance to the hospital's ED. An additional ambulance responded to the scene for standby. A second fire fighter also suffered heat strain and fatigue (very hot, weak, and short of breath), but his condition was not as severe. He recovered after he was given fluids and placed inside an air conditioned apparatus with an EMT.

Due to the elevated heat conditions the Incident Commander rotated crews about every 10-15 minutes. The Incident Commander assigned the mutual aid FF to perform overhaul at one trailer. The FF, wearing full turnout gear without self-contained breathing apparatus, entered the overhaul area and assisted other crew members in re-

Investigative Results (cont.)

moving sections of tin roofing and other structural components to expose hidden burning embers. He performed this task for about 15 minutes and was assigned to Rehab. The FF walked up the 300-foot hill to the Rehab area and, after sitting for about 10 minutes, he collapsed and became unresponsive.

The standby ambulance paramedics arrived at 0114 hours. In their initial assessment revealed the FF was trying to stand, unable to speak, sweating, hot, and nauseated. His initial vital signs included a pulse rate of 48 beats per minute, a blood pressure of 60/40 millimeters of mercury, and a breathing rate of 10 breaths per minute. He was placed onto a stretcher. The cardiac monitor revealed ventricular tachycardia and one shock was administered. His heart rhythm reverted to ventricular fibrillation and CPR was begun. A second shock was administered and his heart rhythm reverted to asystole (no heart beat). CPR continued as the FF was intubated and two intravenous lines were placed for administering cardiac resuscitation medications. The ambulance departed the scene en route to the hospital's ED at 0129 hours and arrived at the ED at 0158 hours. The FF's heart rhythm remained in asystole during transport.

Inside the ED, cardiac resuscitation efforts continued for 17 minutes and one additional defibrillation was performed. At 0216 hours the FF was pronounced dead and resuscitation efforts were stopped.

Medical Findings. The death certificate, completed by the County Coroner, listed "cardiac arrhythmia due to focal severe coronary artery disease" as the cause of death. The autopsy report, completed by the County Medical Examiner, listed "cardiac arrhythmia resulting from severe focal atherosclerosis of his left anterior descending coronary artery with clot formation" (heart attack) as the cause of death. Autopsy findings showed an acute thrombus and severe atherosclerosis in the left main coronary artery. Other pertinent findings from the autopsy are listed in Appendix A.

The FF was 73 inches tall and weighed 296 pounds, giving him a body mass index of 39.0 kilograms per meters squared. A body mass index > 30.0 kilograms per meter squared is considered obese [CDC 2011]. The FF was diagnosed with hypertension prior to 2007 but was not taking any prescription anti-hypertensive medications.

Description of the Fire Department

At the time of the NIOSH investigation, the FD consisted of three fire stations with 28 volunteer uniformed personnel. It served 4,000 residents in a geographic area of 157 square miles.

Membership and Training. The FD requires new fire fighter applicants to be 18 years of age, have a valid State driver's license, pass a background check, and be voted into the department by the membership. During the first 6 months the new member is on probation and must attend 50% of the monthly training sessions, complete the State 36-hour basic fire fighter course, and complete the Volunteer Firemen's Insurance Services driving course. The FD also offers hazardous materials awareness and operations training. Neighboring fire departments participate in monthly mutual aid training. During the first year, the member is encouraged to complete first responder training. During the first 3 months of the probationary period, the member is only allowed to observe at emergency scenes or participate in nonhazardous duty.

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Description of the FD (cont.)

The FF joined the FD in August 2011. He was in the probationary period and his role was limited to exterior support activities. He had 1 month of fire fighting experience in this FD, and an undetermined length of service at a volunteer fire department in a neighboring state.

Preplacement and Annual Medical Evaluations. No preplacement or annual medical evaluation is required by this FD. An annual self-contained breathing apparatus facepiece fit test is required. Members injured on duty must be evaluated by the worker's compensation physician who forwards his or her determination for return to duty to the FD.

Health and Wellness Programs. The FD does not have a wellness/fitness program and no exercise equipment is available in the fire stations. No annual physical ability test is required. The FF did not participate in an exercise program.

Discussion

Atherosclerotic Coronary Heart Disease. In the United States, atherosclerotic coronary heart disease (CHD) is the most common risk factor for cardiac arrest and sudden cardiac death [Meyerburg and Castellanos 2008]. Risk factors for its development include three non-modifiable factors (age older than 45, male gender, and family history of CHD) and five modifiable factors (smoking, high blood pressure, high blood cholesterol, obesity/physical inactivity, and diabetes) [NHLBI 2011; AHA 2012]. The FF had three of the five modifiable CHD risk factors (smoking, high blood pressure, and obesity/physical inactivity) and two of the three non-modifiable CHD risk factors (male gender and family history) at the time of his death.

Discussion (cont.)

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 a recent (acute) heart attack requires any of the following: characteristic electrocardiogram changes, elevated cardiac enzymes, or coronary artery thrombus. In this case, a thrombus was identified at autopsy confirming an acute heart attack (myocardial infarction).

Epidemiologic studies have found that heavy physical exertion sometimes immediately precedes and triggers the onset of acute heart attacks and sudden cardiac death [Albert et al. 2000]. Heart attacks in fire fighters have been associated with alarm response, fire suppression, and heavy exertion during training (including physical fitness training) [Kales et al. 2003; Kales et al. 2007; NIOSH 2007]. The FF had responded to the alarm and performed exterior overhaul activities wearing full turnout gear (without self-contained breathing apparatus). These activities expended about 9 METs, which is considered moderate physical activity [Gledhill and Jamnik 1992; Ainsworth et al. 2011].

Firefighting activities are strenuous and often require fire fighters to work at near maximal heart rates for long periods. Even when energy costs are moderate (as measured by oxygen consumption) and work is performed in a thermoneutral environ-

Discussion (cont.)

ment, heart rates may be high (over 170 beats per minute), owing to the insulative properties of the personal protective clothing [Smith et al. 1995]. Due to a combination of high environmental temperatures and physical exertion, firefighting raises the core body temperature from 1.0°F to 2.5°F [Smith et al. 2008]. Performing strenuous work in a hot environment causes profuse sweating, which can decrease plasma volume, placing additional strain on the cardiovascular system and further impairing thermoregulation [Smith et al. 2008]. Studies of live fire training have found laboratory measures of increased blood coagulation suggesting an increased clotting potential following firefighting activity [Smith et al. 2008].

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. The FF was not known to have coronary heart disease (CHD), and screening tests to detect CHD are not recommended until age 45 [Gibbons et al. 2002; NFPA 2007a].

Cardiomegaly/Biventricular Hypertrophy. On autopsy, the FF was found to have biventricular dilatation and hypertrophy. These findings raise the possibility that, the FF could have mixed dilated/hypertrophic cardiomyopathy in addition to atherosclerotic CHD [Hughes 2004]. However, no microscopic examination of the FF's heart tissue was performed to suggest or confirm this diagnosis [Hughes 2004]. A more likely reason for the FF's biventricular hypertrophy is chronic ischemia from underlying atherosclerotic CHD or untreated hypertension. Cardiomegaly and left ventricular hypertrophy are independent risk factors for sudden cardiac death [Levy et al. 1990; Antman et al. 2008].

Recommendations

NIOSH investigators offer the following recommendations to address safety and health issues and prevent similar incidents in the future.

Recommendation #1: Provide preplacement and annual medical evaluations to all fire fighters consistent with NFPA 1582, Standard on Comprehensive Occupational Medical Program for Fire Departments.

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 2007a; 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 comply with this recommendation, particularly the section addressing CHD issues. However, the FD is not legally required to follow the NFPA standard or the IAFF/IAFC initiative. Applying this recommendation involves economic repercussions and may be particularly difficult for smaller fire departments to implement.

Recommendations (cont.)

To overcome the financial obstacle of medical evaluations, the FD could urge current members to get annual medical clearances from their private physicians or through their place of employment. Another option is having the annual medical evaluations completed by paramedics and emergency medical technicians from the local ambulance 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), 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 FD, city, or state. Sharing the financial responsibility for these evaluations between fire fighters, the FD, the city, the state, and physician volunteers may reduce the negative financial impact on recruiting and retaining needed fire fighters.

Recommendation #2: Phase in a mandatory 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, the IAFF/IAFC Fire Service Joint Labor Management Wellness/Fitness Initiative, the National Volunteer Fire Council (NVFC) Health and Wellness Guide, and in Firefighter Fitness: A Health and Wellness Guide [USFA 2004; IAFF, IAFC 2008; NFPA 2008; Schneider 2010]. Worksite health promotion programs have been shown to be cost effective by increasing productivity, reducing absenteeism, and reducing the number of work-related injuries and lost work days [Stein et al. 2000; Aldana 2001]. Fire service health promotion programs have been shown to reduce CAD risk factors and improve fitness levels, with mandatory programs showing the most benefit [Dempsey et al. 2002; Womack et al. 2005; Blevins et al. 2006]. A study conducted by the Oregon Health and Science University reported a savings of more than $1 million for each of four large fire departments implementing the IAFF/IAFC wellness/fitness program compared to four large fire departments not implementing a program. These savings were primarily due to a reduction of occupational injury/illness claims with additional savings expected from reduced future nonoccupational healthcare costs [Kuehl 2007]. The FD does not have a wellness/fitness program. Given the FD's structure, the NVFC program would be appropriate [USFA 2004]. NIOSH recommends a formal, mandatory wellness/fitness program to ensure all members receive the benefits of a health promotion program.

Recommendation #3: Perform an annual physical performance (physical ability) evaluation for all members.

NFPA 1500, Standard on Fire Department Occupational Safety and Health Program, requires the FD to develop physical performance requirements for candidates and members who engage in emergency operations [NFPA 2007b]. Members who engage in emergency operations must be annually qualified (physical ability test) as meeting these physical performance standards for structural fire fighters [NFPA 2007b]. This could be incorporated into the annual task-level training program.

Recommendations (cont.)

Recommendation #4: Measure carboxyhemoglobin levels on symptomatic or unresponsive fire fighters exposed to fire smoke.

Fire smoke contains varying amounts of carbon monoxide and can cause carbon monoxide poisoning, which, in severe cases, can cause sudden death. Neither the hospital involved in the FF's care nor the Medical Examiner's Office measured a carboxyhemoglobin level to estimate the FF's exposure to carbon monoxide. However, the FF was unlikely to have carbon monoxide poisoning from his relatively brief exposure to light fire smoke. Furthermore, even if his carboxyhemoglobin level was elevated, this would not have affected his treatment or outcome because he was already receiving 100% oxygen therapy via respirator. Nonetheless, we recommend measuring carboxyhemoglobin in all fire-related deaths to rule out carbon monoxide poisoning.

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Investigator Information

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

Appendix A

Autopsy Findings

- Hypertensive heart disease
  - Cardiomegaly (enlarged heart; heart weighed 530 grams [g]; predicted normal weight is 453 g as a function of sex, age, and body weight]) [Silver and Silver 2001]
  - Biventricular dilatation
    - Left ventricle thickened (1.3 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]
    - Interventricular septum thickened (1.1 cm)
    - Right ventricle thickened (3.0 cm)
      - Normal by echocardiography 0.7–2.3 cm [Armstrong and Feigenbaum 2001]
- Coronary artery atherosclerosis
  - Severe (90%) focal narrowing of the left main coronary artery
  - Coronary artery thrombus (blood clot) in the left main coronary artery
  - Minimal (10%) focal narrowing of the left anterior descending coronary artery, circumflex coronary artery, and right coronary artery
- Normal cardiac valves
- No evidence of a pulmonary embolus (blood clot in the lung arteries)
- No evidence of drug or alcohol use
- No carboxyhemoglobin levels measured for carbon monoxide exposure or carbon monoxide poisoning

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