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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 *March , 2010*

Fire Fighter Suffers Cardiac Death Following Structural Fire Suppression - Kansas

Executive Summary

On June 16, 2009, a 50-year-old male paid call fire fighter responded to a structural fire on a hot and humid day. After working approximately 40 minutes, the fire fighter went to on-site rehabilitation where he complained of chest pains. The ambulance crew provided oxygen and began transport to the hospital's emergency department (ED) when the fire fighter lost consciousness. Cardiopulmonary resuscitation (CPR) was initiated, an automated external defibrillator (AED) was attached, and one shock was administered without a change in the fire fighter's clinical condition. Despite advanced cardiac life support administered in the ED, the fire fighter died. The death certificate listed the cause of death as "cardiac arrhythmia due to coronary atherosclerosis and evolving cardiac ischemia and infarct" with fire fighting during hot weather as a contributing factor. NIOSH investigators agree with this assessment and conclude that physical exertion associated with fire suppression activities triggered his sudden cardiac death.

Key Recommendations

NIOSH offers the following recommendations to reduce the risk of 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) 1582.

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 disease (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 fire department's (FD) annual medical evaluation program.

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Introduction & Methods

On June 16, 2009, a 50-year-old paid call fire fighter reported being overheated and fatigued after engaging in structural firefighting. While being evaluated by on-scene emergency medical service (EMS) personnel he experienced chest pain. During transport to the hospital ED, the fire fighter suffered a cardiac arrest and subsequently died. NIOSH was notified of this fatality on June 18, 2009 by the U.S. Fire Administration. NIOSH contacted the affected fire protection district (FPD) shortly thereafter to obtain additional information, and again on January 8, 2010, to request further information and schedule the investigation. On January 18th, 2010 a contractor for the NIOSH Fire Fighter Fatality Investigation Team (the NIOSH investigator) travelled to Kansas to conduct an on-site investigation of the incident.

During the investigation, the NIOSH investigator interviewed the following people:
- Fire Chief
- Crew members working with the fire fighter
- Paramedics who treated the fire fighter
- Fire fighter's spouse and son
- Fire fighter's personal physician
- Medical examiner

The NIOSH investigator reviewed the following documents in preparing this report:
- FPD incident report
- FPD records
- FPD general operating procedures
- Ambulance report
- Death certificate
- Medical examiner's report
- Hospital records
- Personal physician medical records

Investigative Results

Incident Response. On June 16, 2009, at 1701 hours the FPD was dispatched to a structural fire. Fire fighters arrived on scene at 1709 hours and found a two-story house emitting smoke from its second floor windows and attic. The ambient temperature was approximately 88º Fahrenheit (F) with 35 % relative humidity [Weather Underground 2010]. Prior to the call, the fire fighter was working on a farm doing manual labor.

The fire fighter and a crew of 3-4 other fire fighters wearing full turnout gear and SCBA attacked the second floor fire. They entered the structure from a second story window removed earlier by fellow fire fighters. The fire fighter and his partner advanced a charged 1 3/4" hose line across a room that contained minimal heat and smoke and into the doorway of the room containing the seat of the fire. The fire fighter (backup nozzelman) and his partner (nozzelman) applied water onto the fire for 4-5 minutes. Although the fire was not extinguished, they exited the structure due to the hose line losing its pressure. They exited the same window they entered, and took a 5-10 minute break on the roof of a porch just outside the second floor window. During this break the fire fighter and his partner doffed their SCBA, sat down, and drank water.

After their break, the fire fighter and his partner reentered the structure. Again, they applied water to the seat of the fire for 4-5 minutes when the hose line lost pressure. They exited the structure and rested on the porch roof just outside the second floor window. During this 5-10 minute rest period they doffed their SCBA, sat down, drank some water, and interacted with other fire fighters.

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Investigative Results (cont.)

The fire fighter and his partner entered the structure again. They applied water to the seat of the fire for about 4-5 minutes. As they exited the building, the fire fighter's SCBA low-air alarm sounded. After exiting the building, the fire fighter said he was going down to cool off and rest. Before going down, he sat on the roof, drank some water, and told his partner that he was "okay, just hot and tired." The fire fighter climbed down the ladder from the 2nd floor porch roof. While walking to rehabilitation, he commented to the Assistant Chief that he "got a little overheated."

First responders and EMS personnel were on scene providing water and setting up a rehabilitation area. A first responder walked the fire fighter to the air conditioned first responder vehicle (an out of service ambulance). As he walked to the ambulance the fire fighter remarked several times that he was hot and wanted to sit down. Upon arrival in the first ambulance the fire fighter laid down; vital signs showed a pulse of 80 beats per minute (normal resting values between 60-100), blood pressure of 150/104 millimeters of mercury (mmHg) (normal resting values <120/<80 mmHg), and respirations of 24 breaths per minute (normal resting values 8-12 breaths per minute). Oxygen was administered via non rebreather bag at 15 liters per minute. The fire fighter complained of "knife stabbing" chest pains rated 8 on a scale of 1-10. He was loaded into the ambulance for transport to the ED at 1803 hours.

The fire fighter was alert and oriented as transport was undertaken. At 1805 hours the fire fighter's pulse was 79 beats per minute, his blood pressure was 130/76 mmHg, and he was sweating profusely. En route, the fire fighter began having trouble breathing then lost consciousness. The emergency medical technician (EMT) found him to be pulseless and not breathing, and initiated CPR. Additional EMTs met the ambulance en route to the ED and assisted with care including the use of an AED. The AED advised a shock and one was administered with no change in the fire fighter's clinical condition.

The ambulance arrived at the ED at 1822 hours. Upon arrival, the fire fighter was unresponsive, and had no pulse or spontaneous breathing. He was cyanotic and his pupils were fixed and dilated, and his heart rhythm showed a coarse ventricular fibrillation. Advanced life support (ALS) protocols were followed including the administration of intravenous medications. Intubation was attempted but was unsuccessful. At 1845 hours, approximately 25 minutes after his collapse, the fire fighter was pronounced dead and resuscitation efforts were discontinued.

Medical Findings. The death certificate listed the immediate cause of death as "cardiac arrhythmia due to coronary artery disease and evolving cardiac ischemia and infarct." Firefighting during hot weather was listed as a significant condition contributing to the death.

The autopsy, conducted by a District Coroner (a pathologist) listed the cause of death as "acute arrhythmia with evolving acute myocardial infarct due to, or as a consequence of, marked systemic atherosclerosis and coronary atherosclerosis." The autopsy also noted environmental temperatures (near 100 ºF) and strenuous activity associated with firefighting as contributory conditions. The autopsy found an enlarged heart, coronary artery disease, and an evolving acute

Investigative Results (cont.)

myocardial infarction (heart attack). See Appendix A for a more complete listing of pertinent autopsy findings.

In October 2002 the fire fighter was admitted to the hospital for chest pain. The pain in the midsternal area was described as heaviness with no radiating pain and was rated as 6 on a scale of 1-10. At the time of his admission, the fire fighter's electrocardiogram (EKG), blood chemistry, and troponin levels were normal. However, his blood pressure was poorly controlled (130/102 mmHg). The dosage of his medication (Lotrel) was increased and by the following morning his blood pressure was normal (100/80 mmHg). He did not have any additional chest pain overnight and his morning EKG and blood chemistry tests were normal. A myocardial infarction was ruled out and the fire fighter was counseled to pursue additional cardiac testing with his primary care physician. It is unclear if this advice was followed.

A review of medical records indicates that the fire fighter saw his primary care physician infrequently. In September 2007 he visited his primary care physician. His blood pressure was 146/100 mmHg. He was again prescribed blood pressure medication. His prescriptions were refilled in January and April 2008.

The fire fighter typically engaged in heavy work as part of his work duties on a farm, but he did not regularly engage in physical exercise. He had a family history of hypertension. The fire fighter had a body mass index (BMI) of 32.9, placing him in the obese range [AHA 2010]. He was a nonsmoker.

Description of the Fire District (FD)

The FPD consists of approximately 20 uniformed personnel serving a population of approximately 300, in an area of approximately 160 square miles. The FPD responded to approximately 12 calls in 2009.

Employment and Training. New members must be 18 years of age. Probationary fire fighters must attend department training and are encouraged to take weekend courses offered through the State fire fighters association. After approximately 1 year of attending meetings and training, the fire fighter is eligible to become a member of the FPD.

The fire fighter had been a member of the FPD for 3 years and had extensive prior firefighting experience in other fire departments, including serving as a career fire fighter in the 1980s.

Medical Evaluations/Wellness Programs. Medical evaluations are not required or offered for candidates or members of the FPD. The FPD offers no health or wellness programs for members.

Discussion

CAD and the Pathophysiology of Sudden Cardiac Death. This fire fighter suffered sudden cardiac death after performing strenuous fire suppression activities on a hot and humid day. The most common risk factor for cardiac arrest and sudden cardiac death is coronary artery disease (CAD), defined as the build-up of atherosclerotic plaque in the coronary arteries [AHA 2009]. This fire fighter had several known risk factors for CAD (hypertension, obesity, and family history) and CAD was confirmed at autopsy.

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 a recent (acute) heart attack requires any of the following: characteristic EKG changes, elevated cardiac enzymes, or coronary artery thrombus. The fire fighter did not have a heartbeat on which to conduct an EKG, and no thrombus was identified at autopsy. However, laboratory testing taken in the ED revealed an elevated troponin level. Additionally, the autopsy revealed areas of softening and discoloration of the myocardium indicating that the fire fighter was suffering an evolving myocardial infarction (heart attack). Thus, based on the clinical scenario, the laboratory findings, and the autopsy report it appears that the fire fighter suffered a heart attack.

Physiological Stress of Firefighting. Firefighting is widely acknowledged to be physically demanding. Firefighting activities require fire fighters to work at near maximal heart rates for long periods. An increase in heart rate typically occurs in response to the initial alarm and persists throughout the course of fire suppression activities [Barnard and Duncan 1975; Lemon and Hermiston 1977; Manning and Griggs 1983; 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].

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 [Kales et al. 2003; Hales et al. 2007; Kales et al. 2007].

The fire fighter had been working on scene for approximately 40 minutes when he indicated that he did not feel well and sought a cool area in which to recover. He reported the onset of chest pains shortly thereafter and lost consciousness a few minutes later.

Discussion (cont.)

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]. NFPA 1582 recommends that all fire fighters receive annual medical evaluations. 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). This recommendation is similar to recommendations from the AHA/ACC and the Department of Transportation regarding exercise stress tests in asymptomatic persons [Gibbons et al. 2002; Blumenthal et al. 2007]. The fire fighter had diagnosed hypertension and a family history of a premature cardiac event, thus an exercise stress test was indicated. Furthermore, at the time of his chest pain hospitalization in 2002, it was recommended that he follow up with a cardiology evaluation. The FPD did not have a policy requiring a cardiology consult and there is no evidence that the fire fighter followed up on this recommendation. If the fire fighter received an exercise stress test, perhaps his underlying CAD would have been identified. This may have lead to further evaluation and treatment, and the prevention of his sudden cardiac death.

Recommendations

NIOSH investigators offer the following recommendations to reduce the risk of on-the-job heart attacks and sudden cardiac arrest among fire fighters. Had these recommended measures been in place prior to the fire fighter's collapse, his CAD may have been detected and his sudden cardiac death may have been prevented.

Recommendation #1: Provide mandatory annual medical evaluations to all fire fighters consistent with NFPA 1582.

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 [IAFF/IAFC 2007; NFPA 2007a].

This recommendation has financial implications and may be particularly difficult for small, volunteer fire departments to implement. The FPD may 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 (personal or through insurance), provided by a physician volunteer, or

Recommendations (cont.)

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

Recommendation #3: Develop a comprehensive wellness/fitness program for fire fighters to reduce risk factors for cardiovascular disease and improve cardiovascular capacity.
Guidance for FD wellness/fitness programs is found in NFPA 1583, Standard on Health-Related Fitness Programs for Fire Fighters, in the IAFF/IAFC Fire Service Joint Labor Management Wellness/Fitness Initiative, and in the NVFC's Health and Wellness Guide [IAFF/IAFC 2007; USFA 2009; NFPA 2008].

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

Recommendation #4: Perform an annual physical performance (physical ability) evaluation.
A 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 2007]. 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.

Recommendations (cont.)

Recommendation #5: Provide fire fighters with medical clearance to wear self-contained breathing apparatus as part of the FPD'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]. 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 fire departments) 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.

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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).

Appendix A

Pertinent Autopsy Findings

Heart Size/Structure

- Biatrial and biventricular cardiac dilation and hypertrophy
- Left ventricular wall thickness = 2.8 cm thickness (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]
- Heart weight = 550 grams (ranges between 296 g and 516 g as a function of sex, age, and body weight). [Silver and Silver 2001]
- Anterior myocardial softening, discoloration and evolving myocardial infarct

Coronary Arterties

- Remarkable for calcification and atherosclerosis in all three coronary arteries
- Left coronary artery – 70-80% stenosis
- Intima shows vascular proliferation and cholesterol changes

Microscopic Evaluation

- Myocardial septum and ventricles with fine fibrosis consistent with early and ongoing ischemic process
- Septum shows fiber and nuclear hypertrophy with fine fibrosis and margination of leukocytes
- Right ventricle shows nuclear and fiber hypertrophy
- Anterior right and left ventricle show hypereosinophillic stain of fibers in area of nuclear hypertrophy

Carotid arteries and aortic arch – marked calcified atherosclerosis

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