2010
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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 *May , 2010*

Fire Fighter Suffers Probable Fatal Cardiac Arrhythmia During On-Duty Mandatory Physical Fitness Training – North Carolina

Executive Summary

On December 29, 2009, a 24-year-old male career fire fighter (FF) participated in the mandatory Fire Department (FD) physical fitness program while on duty. The FF lifted weights for over 1 hour, ran on the treadmill for 2.3 miles in approximately 12 minutes, and then paused the treadmill's timer. Shortly thereafter, a crew member entered the exercise room and found the FF unresponsive, lying on the treadmill. Despite cardiopulmonary resuscitation (CPR) and advanced life support delivered on scene, in the ambulance, and in the hospital's emergency department (ED), the FF died.

An autopsy was conducted by the local hospital pathologist. That autopsy report noted that the FF possibly experienced a fatal cardiac arrhythmia and that hypoglycemia may have contributed to his death, but that "Overall, there is no definite anatomic cause of death." The Office of the Chief Medical Examiner listed the cause of death as "Undetermined" on their investigation report and on the death certificate. NIOSH investigators agree with these assessments, but consider the diagnosis of hypoglycemia unlikely; even if the FF had hypoglycemia, it is very unlikely that it contributed to his death. The more likely scenario is a fatal cardiac arrhythmia possibly triggered by the heavy physical exertion during fitness training.

NIOSH investigators offer the following recommendations to address general safety and health issues. It is unlikely, however, that any of these recommendations could have prevented the FF's collapse and subsequent sudden cardiac death.

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

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.

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

Introduction & Methods

On December 29, 2009, a 24-year-old male career FF suffered sudden cardiac death while participating in mandatory physical fitness training while on-duty. Despite CPR and advanced life support administered by crew members, the ambulance crew, and personnel in the ED, the FF died. NIOSH was notified of this fatality on December 30, 2009, by the United States Fire Administration. NIOSH contacted the affected FD to gather

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additional information on January 5, 2010, and on January 7, 2010, to initiate the investigation. On January 19, 2010, a Safety and Occupational Health Specialist from the NIOSH Fire Fighter Fatality Investigation Team traveled to North Carolina to conduct an on-site investigation of the incident.

During the investigation, NIOSH personnel interviewed the following people:
- Fire Chief
- Crew members
- City Safety Director
- FF's family

NIOSH personnel reviewed the following documents:
- FD policies and operating guidelines
- FD training records
- FD annual report for 2009
- Emergency medical service (ambulance) incident report
- Hospital ED records
- Death Certificate
- Autopsy report
- Primary care provider medical records
- Crew members working with the Corporal
- FD Safety Investigation Team
- Fire Fighter's Local Union President
- Corporal's spouse

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

Investigative Results

Incident Response. On December 29, 2009, the FF arose at 0430 hours. He left his home at approximately 0500 hours to drive to the fire station, located 98 miles away. He arrived on time for his 24-hour shift at 0700 hours.

Throughout the morning, the FF and his four crew members cleaned the fire station and performed daily inspection on the fire apparatus. There were no emergency calls during the day. The crew left the fire station twice, once to purchase food at a grocery store, and once to attend a retirement party at City Hall. At approximately 1530 hours, the FF went upstairs to exercise. He telephoned his fiancé at approximately 1600 hours. During that conversation, he had no complaints of chest pain, shortness of breath, or other symptoms of cardiac problems. At approximately 1730 hours, a crew member went upstairs to retrieve the FF for a FD function but found the FF collapsed across the treadmill; the treadmill had been manually paused at 11:41 minutes and 2.32 miles.

The crew member ran downstairs and alerted the rest of the crew. The crew pulled the FF off the treadmill and found him to be unresponsive, cyanotic, with no pulse or respirations. CPR was begun as resuscitation equipment including an automated external defibrillator (AED) and oxygen equipment was retrieved. Dispatch was notified at 1738 hours and an ambulance and the Fire Chief were requested to respond.

Crew members applied the AED but no shock was advised. A Combitube© was placed, tube placement was verified by bilateral breath sounds, but not by an esophageal detector device [Vézina D et al. 1998; AHA 2005]. The ambulance was dispatched at 1743 hours and arrived on the scene 7 minutes later (1750 hours).

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Investigative Results (cont.)

Paramedics found the FF unresponsive, pulseless, and not breathing, with CPR in progress. Advanced life support, including cardiac monitoring and intravenous (IV) line placement, was begun. The cardiac monitor revealed asystole and cardiac resuscitation efforts continued. The FF's blood glucose level was measured by the ambulance crew using a glucometer. This device determined the FF's glucose to be "low," and the FF was given 2 amps of 50% dextrose (a type of glucose) by IV. The FF was placed onto a backboard, carried downstairs, transferred onto a stretcher, and placed inside the ambulance. The ambulance departed the scene at 1758 hours.

Resuscitation efforts continued en route to the hospital ED with no positive change in the FF's condition. The ambulance arrived at the hospital at 1810 hours. Inside the ED, advanced life support treatment continued (including intubation) "bedside." Blood glucose testing in the ED revealed a glucose level of 29 milligrams per deciliter (mg/dL) (normal is 70-118 mg/dL). An additional 2 amps of 50% dextrose and 1 mg of glucagon (a hormone that raises glucose levels) were given by IV push; with a subsequent bedside glucose level was 302 mg/dL. The FF's condition remained unchanged and at 1826 hours, the FF was pronounced dead by the attending physician; resuscitation efforts were stopped.

Medical Findings. TUpon the FF's death, the treating emergency room physician listed his clinical impression as "cardiopulmonary resuscitation arrest." The next day an autopsy was performed by the local hospital's pathologist. The autopsy found the FF's coronary arteries to be widely patent with no evidence of significant atherosclerosis. See Appendix A for a more complete listing of pertinent findings. Given the reports of possible hypoglycemia, a vitreous glucose level was ordered. The vitreous is fluid within the eye; measurements in vitreal fluids reflect serum (blood) glucose, electrolytes, and other chemistries before a patient's sudden death [Coe 1969, 1976]. The FF's vitreous glucose level was normal at 91 mg/dL. The pathologist concluded that, "Overall, there is no definite anatomic cause of death." The report also noted that the FF possibly experienced a "fatal cardiac arrhythmia" and that "Given the reported low blood glucose levels at the emergency department, it is also possible that hypoglycemia contributed to his death." The Office of the Chief Medical Examiner listed the cause of death as "Undetermined" on their investigation report dated March 30, 2010 and on the final death certificate issued April 19, 2010.

The FF was 69 inches tall and weighed 190 pounds (at autopsy), giving him a body mass index (BMI) of 28.06. A BMI of 25.0–29.9 kilograms per meters squared (kg/m2) is considered overweight [CDC 2010]. Medical records showed the FF had no risk factors for coronary artery disease (high blood pressure, high blood cholesterol, smoking, diabetes, obesity/lack of physical activity). Prior to this incident, the FF had a normal blood glucose (91 mg/dL) during a routine laboratory test in 2004. In 2004 the FF was diagnosed as being overweight (213 pounds) by his primary care physician. From 2004 to 2007, the FF gained significant weight (from 213 pounds in 2004 to 265 pounds in 2007). From 2007 to 2009, the FF lost approximately 75 pounds through diet and exercise (running, walking, and lifting weights). He was not prescribed any medications and according to his family, did not take any diet pills or health food/pill supplements. The FF expressed no symptoms of angina or shortness of breath on exertion to his physician, his family, or the FD.

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Description of the Fire Department

At the time of the NIOSH investigation, the combination FD consisted of two fire stations with 38 uniformed personnel (15 career and 23 volunteer) that served a population of 8,800 residents in a geographic area of 9 square miles.

In 2009, the FD responded to 586 calls: 8 structure fires, 15 vehicle fires, 9 grass/brush/trash fires, 8 other fires, 139 motor vehicle accidents, 81 emergency medical calls, 51 service/assist calls, 43 alarm activation calls, 36 good intent calls, 24 hazardous condition calls, 85 false alarms, and 87 other calls.

Employment, Membership, and Training. The FD requires new fire fighter applicants (career and volunteer) to be at least 18 years of age; have a birth certificate, a valid state driver's license, and a certified transcript of Fire Fighter I and II certification (the State has no mandatory minimum requirement for fire fighter certification); pass a background check; have no traffic violations; pass a drug screen; sign a personal medical waiver asserting good health; pass a candidate physical agility test (CPAT) (Appendix B); pass a written test composed of 100 questions from the Fire Fighter I and II curriculum; attend a FD social in which FD officers informally interview the candidate; and pass a separate, structured interview prior to receiving a job offer. New members are placed on a 24-hour shift, followed by 48 hours off-duty. The FD requires members to complete 50 hours training annually; including 30 hours in-house training. The FF was certified as a Fire Fighter II, Driver Operator, Emergency Medical Technician, in HazMat Operations, and in Technical Rescue; he had over 6 years of fire fighting experience, including 5 months with this FD. He completed his CPAT in 5 minutes, 27 seconds, finishing third of the eleven candidates.

Medical Evaluation Program. The FD currently does not require a preplacement or an annual medical evaluation. However, medical evaluations can be obtained through employee (FD provided) health insurance. An annual SCBA facepiece fit test is required for interior structural fire fighters, however, annual SCBA medical clearance is not required. Members injured on duty must be evaluated by their primary care physician who makes the final determination regarding return to duty.

Health and Wellness Programs. The FD has a mandatory wellness/fitness program (overseen by each shift supervisor), and exercise (strength and aerobic) equipment is available in the fire stations. Fire fighters are given one hour each shift to exercise. All fitness programs contain flexibility/stretching, cardiovascular/aerobic, and strength training. Health maintenance programs are available from the City. The FD requires members pass an annual physical ability evaluation which has the same elements and time requirements as the CPAT.

Discussion

Hypoglycemia (low blood glucose). Hypoglycemia induced coma and death is very rare. One study reports 123 cases from 54,850 autopsies (0.22%) conducted in a large acute-care medical center [Klatt et al. 1988]. Of these 123 cases, the reasons for the hypoglycemia coma were: alcoholism (33%), diabetic medications (21%), cancers (21%), liver disease (7%), severe debilitating neurologic disease (7%), endocrine disorders (3%), and other (8%) [Klatt et al.1988]. The FF was not known to have any of these conditions and none were found at autopsy. Although intensive exer-

Discussion (cont.)

cise increases the body's use of glucose, this use is closely matched by increased hepatic glucose output so that blood glucose remains unchanged [Jenkins et al. 1985]. Therefore, NIOSH investigators assessed how the FF was diagnosed with hypoglycemia during the resuscitation effort.

The first mention of "low glucose" was made by the paramedics at the scene of the FF's collapse. Using a glucose meter, the FF's blood sugar was reported as "low." Many factors can affect the accuracy of glucose meters. First, most meters measure glucose in whole blood rather than blood plasma (serum). This results in readings about 10-15% lower their actual values [FDA 2010]. Second, the FF was in cardiopulmonary shock and shock is known to cause false low readings [FDA 2010]. Other factors that are known to result in false low readings include:

- Sensor strips not fully inserted into meter
- Not enough blood applied to strip
- Test strips/Controls solutions stored at temperature extremes
- Squeezing fingertip too hard because blood is not flowing
- Increased hematocrit

It is unknown if these situations were relevant to this event. In either case, the FF received two amps of 50% dextrose via IV push in the field which should have corrected any low blood sugar.

Once in the ED the FF had his blood glucose checked bedside. Given that the hospital laboratory received no blood from the FF associated with his care in the ED, it is assumed this was measured with a glucose meter. This reading was 29 (no units specified). These two glucose meter readings (in the field and in the ED) conflict with the normal post-mortem vitreous glucose level of 91 ug/dL. The vitreous glucose level is reported to be a very useful and accurate forensic test [Coe 1969, 1977; DeLetter and Piette 1998].

Given the absence of conditions associated with hypoglycemic coma, administration of two amps of 50% dextrose prior to the second glucose meter reading, a normal vitreous glucose level, and low glucose levels measured with glucose meters (which can produce false low readings). NIOSH investigators consider the diagnosis of hypoglycemia to be very unlikely.

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. Given the FF's age, absence of coronary artery disease risk factors, and lack of coronary artery atherosclerosis on autopsy, it is unlikely the FF suffered a heart attack.

Epidemiological studies have found that heavy physical exertion sometimes immediately precedes and triggers the onset of sudden cardiac death [Siscovick et al. 1984; Albert et al. 2000]. The FF lifted weights for over an hour and ran on the treadmill for 11 minutes, 41 seconds covering 2.3 miles. This activity expended approximately 11.5 – 13.5 metabolic equivalents (METs), which is considered very heavy physical activity [AIHA 1971; Ainsworth et al. 1993]. Vigorous exercise has been associated with cardiac arrhythmias and sudden death [Siscovick et al. 1984; Albert et al. 2000]. Although regular physical activity over

Discussion (cont.)

time reduces the risk of coronary heart disease, during the actual physical activity the risk of sudden cardiac death is increased [Ekelund et al. 1988]. The physical stress of performing physical fitness training probably triggered a cardiac arrhythmia, resulting in the FF's sudden cardiac death.

Cardiomegaly. On autopsy, the FF was found to have an enlarged heart. This finding was not identified prior to his death. Cardiomegaly increases the risk for sudden cardiac death [Levy et al. 1990]. The FF's heart was within the normal weight range. However, it was slightly heavier than the predicted normal weight (425 grams (g) vs 362 g) (normal range is between 275 g and 478 g) [Silver and Silver 2001].

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 describes the components of a preplacement and annual medical evaluation, and medical fitness for duty criteria. Given the FF's age and lack of CAD risk factors, it is unlikely that following NFPA 1582 would have prevented his SCD.

Recommendations

NIOSH investigators offer the following recommendations to address general safety and health issues. It is unlikely, however, that any of these recommendations could have prevented the FF's collapse and subsequent sudden cardiac death.

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

Guidance regarding the content and frequency of these evaluations can be found in NFPA 1582 and in the International Association of Fire Fighters (IAFF)/International Association of Fire Chiefs (IAFC) Fire Service Joint Labor Management Wellness/Fitness Initiative [IAFF, IAFC 2008; NFPA 2007a]. However, the FD is not legally required to follow this standard or this initiative. Applying this recommendation involves economic repercussions and may be particularly difficult to implement. NFPA 1500, Standard on Fire Department Occupational Safety and Health Program, paragraphs A.10.6.4 and A.11.1.1 and the National Volunteer Fire Council (NVFC) Health and Wellness Guide address these issues [USFA 2004; NFPA 2007b].

To overcome the financial obstacle of medical evaluations, the FD could urge current members to get annual medical clearances from their private physicians. Another option is having the annual medical evaluations completed by paramedics and emergency medical technicians from the local EMS (vital signs, height, weight, visual acuity, and electrocardiogram). This information

Recommendations (cont.)

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

Guidance regarding medical evaluations and examinations for structural fire fighters can be found in NFPA 1582 [NFPA 2007a] and in the IAFF/IAFC Fire Service Joint Labor Management Wellness/Fitness Initiative [IAFF, IAFC 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 as required by NFPA 1500, Standard on Fire Department Occupational Safety and Health Program [NFPA 2007b]. The physician should review job descriptions and essential job tasks required for all FD positions and ranks, in order to understand the physiological and psychological demands of fire fighters and the environmental conditions under which they must perform, as well as the personal protective equipment they must wear during various types of emergency operations.

Recommendation #3: Provide fire fighters with medical clearance to wear self-contained breathing apparatus as part of a Fire Department medical evaluation program.

The Occupational Safety and Health Administration (OSHA) Revised Respiratory Protection Standard requires employers to provide medical evaluations and clearance for employees using respiratory protection [29 CFR 1910.134]. These clearance evaluations are required for private industry employees and public employees in States operating OSHA-approved State plans. North Carolina operates an OSHA-approved State plan; therefore, public sector employers (including volunteer/paid fire departments) are required to comply with OSHA standards.

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Investigator Information

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

Appendix A

Autopsy Findings

- Cardiomegaly (enlarged heart) (heart weighed 425 grams [g]; predicted normal weight is 362 g [between 275 g and 478 g] as a function of sex, age, and body weight) [Silver and Silver 2001]
- No evidence of atherosclerosis
- No evidence of recent thrombus (blood clot in the coronary arteries)
- Normal cardiac valves
- No evidence of a pulmonary embolus (blood clot in the lung arteries)
- Blood tests for drugs and alcohol were negative (only drugs of abuse were tested for)

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Appendix B

Candidate Physical Ability Evaluation

Participants will wear athletic shoes, shorts/sweatpants, safety hardhat, gloves, and a 40-pound vest. Failure to perform any of the six activities in a satisfactory manner will constitute failure of the evaluation and elimination from further consideration as a candidate for employment. The goal time to complete the evaluation will be seven minutes. Time will start at the beginning of the first activity and will stop upon completion of the sixth activity. Applicants will be permitted to rest during any portion of an activity; however the time clock will continue to run. At no time will applicants be permitted to run or jog.

1. Fire Hose Extension: Given a 1¾-inch fire hose filled with water, the candidate will drag this hose for a distance of 50 feet.

2. Hose Carry: Given a bundled section of fire hose weighing approximately 40 pounds, the candidate will carry it up five flights of stairs to the fifth floor of the training tower.

3. Hose Advancement Through Maze: Given a 1¾-inch fire hose filled with water, the candidate will advance the hose through a darkened maze for a distance of approximately 35 feet.

4. Tower Hose Raise: Given a rolled length of 2½-inch hose weighing approximately 42 pounds attached to a rope, the candidate will hoist the hose for a distance of approximately 30 feet and then lower the rope to the ground.

5. Victim Rescue: Given a 165 pound simulated fire victim (dummy), the candidate will drag the dummy for a distance of 60 feet.

6. Simulated Roof Ventilation: Given a 9 pound sledgehammer, the candidate will strike a simulated forcible entry chopping device, moving a sliding “I” beam for a distance of 5 feet.