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NIOSH
Fire Fighter Fatality Investigation and Prevention Program

Death in the line of duty...

A Summary of a NIOSH fire fighter fatality investigation *November 3, 1999*

Fire Fighter Dies at the End of the Work Day - South Carolina

SUMMARY

On April 2, 1999, a 57-year-old male Fire Fighter collapsed in the fire station after 14 hours on duty. Although the victim was not dispatched to any emergencies during his shift, he and his crew were active participants in physically demanding training drills for over 3 ½ hours. Just prior to going to bed, the victim had a witnessed syncopal (loss of consciousness) episode from which he spontaneously recovered. During the ambulance ride to the hospital, the victim's cardiac condition deteriorated, and after arrival at the hospital, he went into cardiac arrest. Despite cardiopulmonary resuscitation (CPR) and advanced life support (ALS) administered in the hospital's emergency department, the victim died. The death certificate, completed by the County Coroner, listed "probable acute myocardial infarction (heart attack)" as the immediate cause of death. An autopsy was not performed.

Other agencies have proposed a three-pronged strategy for reducing the risk of on-duty heart attacks and cardiac arrests among fire fighters. This strategy consists of (1) minimizing physical stress on fire fighters; (2) screening to identify and subsequently rehabilitate high-risk individuals; and (3) encouraging increased individual physical capacity. Issues relevant to this Fire Department include the following:

- ***Exercise stress tests should be incorporated into the fire department's periodic medical evaluation program.***
- ***Individuals with medical conditions that would present a significant risk to the safety and health of themselves or others should be precluded from fire fighting activities.***
- ***Fire departments should educate and train fire fighters on the signs and symptoms of heart attacks and encourage fire fighters experiencing these symptoms while on duty to report them to their supervisor for prompt medical evaluation.***
- ***Autopsies should be performed on all on-duty fire fighters whose death may be cardiovascular-related.***
- ***Phase in a mandatory wellness/fitness program for fire fighters to reduce risk factors for cardiovascular disease and improve cardiovascular capacity.***
- ***Although this issue is unrelated to this fatality, fire departments should purchase personal alert safety system (PASS) devices and ensure that fire fighters wear and use them when involved in fire fighting, rescue, and other hazardous duties.***

The **Fire Fighter Fatality Investigation and Prevention Program** is conducted by the National Institute for Occupational Safety and Health (NIOSH). The purpose of the program is to determine factors that cause or contribute to fire fighter deaths suffered in the line of duty. Identification of causal and contributing factors enable researchers and safety specialists to develop strategies for preventing future similar incidents. To request additional copies of this report (specify the case number shown in the shield above), other fatality investigation reports, or further information, visit the Program Website at:

http://www.cdc.gov/niosh/firehome.html

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INTRODUCTION & METHODS

On April 2, 1999, a 57-year-old male Fire Fighter lost consciousness as he was preparing to retire for the night. Despite oxygen and medication administered by the ambulance crew, and ALS and CPR in the emergency department, the victim died. NIOSH was notified of this fatality on April 13, 1999, by the United States Fire Administration. On April 26, 1999, NIOSH contacted the affected Fire Department to initiate the investigation. On May 25, 1999, a Safety and Occupational Health Specialist, a Senior Medical Epidemiologist, and an Epidemiologist from the NIOSH Fire Fighter Fatality Investigation Team traveled to South Carolina to conduct an on-site investigation of the incident.

During the investigation NIOSH personnel met with and interviewed the

- Fire Chief
- Crew members on duty with the victim
- Responding ambulance service personnel
- Victim's wife

During the site visit NIOSH personnel also reviewed

- The victim's personnel and medical file maintained at the city's personnel office;
- The emergency medical service (ambulance) report;
- The hospital's records of the resuscitation effort;
- Death certificate;
- Past medical records of the deceased;
- The Fire Department (FD) annual report for 1998.

NIOSH also visited the fire station and area where the victim collapsed.

INVESTIGATIVE RESULTS

Incident. On April 2, 1999, the involved crew came on duty at 0800 hours. After checking out the equipment, the crew participated in classroom training from 0830 hours to 1115 hours. That afternoon, the crew also participated in street drills from 1400 hours to 1738 hours. The street drills consisted of simulating engine company operations at a structure fire utilizing 1½-inch attack lines. The hose was unloaded from the hose bed and charged, and water was discharged. This drill was repeated several times, and the victim was an active participant. During the shift, the victim did not report symptoms of chest pain to his peers, nor did he appear to be in acute distress.

At 2200 hours, the victim telephoned his wife. He mentioned that he felt bad and was going to bed early. After he entered the bunkroom, another Fire Fighter entered the room to say goodnight but saw the victim standing beside the bed with his head down, suggesting he was praying. The Fire Fighter left the room and returned less than a minute later and saw the victim grab the bunk bed and begin to fall. The Fire Fighter assisted the victim to the floor and yelled for the shift Captain to help. The victim was noted to be unresponsive, sweating, cool, clammy, cyanotic, and having labored breathing. While the Captain attended to the victim, the Fire Fighter retrieved oxygen equipment, a blood pressure cuff, and stethoscope. At that time oxygen was administered and a pulse was palpated. The victim spontaneously regained consciousness and began complaining of chest pain. An EMS crew (ambulance) was requested at 2222 hours for a suspected heart attack.

Medic 7 (staffed by one Emergency Medical Technician and one Paramedic) was dispatched at 2223 hours and arrived on scene at 2233 hours. The victim was noted to be complaining of severe chest pain with shortness of breath and was very diaphoretic, cool, and clammy. The victim related

to the EMS crew that he began having chest pain about 2 hours prior to EMS being called. After vital signs were taken (heart rate=64 beats/min, respiratory rate=26/min, blood pressure 75/50), two intravenous (IV) lines were started, and a heart monitor was connected. The heart monitor revealed electrical /conduction abnormalities (first degree heart block with multi-focal premature ventricular contractions). The victim was loaded into the ambulance for the 9-minute ride to the hospital. During transport the victim's condition deteriorated with increasing chest pain, more labored breathing, and runs of bigeminy (heart beats in pairs) and ventricular tachycardia identified on the heart monitor. Intravenous lidocaine (anti-arrhythmia agent) was administered; however, nitroglycerin and morphine (both medications for acute angina) were withheld due to the victim's low blood pressure. The victim remained conscious and alert during the entire transport, and the ambulance arrived at the hospital at 2256 hours.

Upon arrival in the emergency department, the victim had a blood pressure of 150/130. A heart rhythm strip at 2302 hours showed a wide complex (bundle branch block) fast heart beat (tachycardia). By 2305 the victim's blood pressure had fallen to 90/50 and an electrocardiogram (EKG) done at 2307 hours showed electrical abnormalities (right bundle branch block) and evidence of an acute heart attack (myocardial infarction as evidenced by ST segment elevation). At 2308 the victim's heart slowed (bradycardia) and his pulse stopped, at which time CPR was begun. He was intubated and medications consistent with ALS were administered. The victim's heart rhythm changed into ventricular fibrillation and he began intermittent seizures. He was shocked two times and intermittently regained a heart rhythm that was unable to sustain a pulse. His heart rhythm degenerated into asystole (no heart beat), and after 46 minutes of CPR and ALS by the emergency department personnel, the victim was pronounced dead at 2347 hours.

Medical Findings. The death certificate, completed by the County Coroner, listed "probable acute myocardial infarction" as the immediate cause of death. The death certificate also listed "recent cardiac related history" and "history of ulcers" as other significant conditions. Since the Fire Fighter was not engaged in fire suppression activities, his blood was not tested for carbon monoxide poisoning (carboxyhemoglobin levels). While in the emergency department, his blood was sent for heart (cardiac) isoenzymes. Due to the acute disease process, none of these blood tests were abnormal. No autopsy was performed.

In 1992 the victim was diagnosed with high blood cholesterol (hypercholesterolemia), and in 1997 the victim was diagnosed with high blood pressure (hypertension). Despite changes in his diet and efforts to begin an exercise program, his cholesterol remained slightly elevated in the 200-240 milligrams per deciliter range. Likewise, despite prescription medication for his hypertension, his blood pressure remained elevated. In addition to these two risk factors for coronary artery disease (CAD), medical records indicated that the victim had other CAD risk factors including advancing age, male gender, smoking, and physical inactivity. In February 1997, the victim's private physician performed an exercise stress test (EST) for symptoms suggestive of angina (heart pain). A resting electrocardiogram (EKG) taken just prior to the test was reported to show a "remote anteroseptal infarction (old heart attack)," and the EST was interpreted as positive for ischemia. A cardiac catheterization was recommended, but the victim declined the procedure. This medical history was not listed in the victim's medical file maintained by the City's contract physicians for the Fire Department. Despite declining the catheterization procedure, the victim continued under the care of his primary care physician.

DESCRIPTION OF THE FIRE DEPARTMENT

At the time of the NIOSH investigation, the Fire Department consisted of 186 uniformed personnel and served a population of 101,000 residents in a geographic area of 88 square miles. The department has 18 fire stations, where fire fighters work 24 hours on duty from 0800 to 0800 hours and are off duty for 48 hours. Each shift of an engine or ladder company is staffed with four personnel (an officer and three fire fighters). However, due to sick days or vacations, staffing is reduced at times to three per apparatus. The emergency medical service is a county resource separate from the Fire Department.

Currently, the Fire Department has no automated external defibrillators (AEDs) in use. However, they have been ordered and will be available on all fire apparatus. Also, no personal alert safety system (PASS) devices are in use.

In 1998, the department responded to 3,824 calls: 1,518 EMS calls, 993 mistaken citizen calls, 568 structure fires, 357 other calls, 162 dumpster fires, 103 wildland fires, 55 vehicle fires, 42 false alarms (includes intentional calls and equipment malfunctions), 23 electric wires/transformer fires, and 3 hazardous materials calls.

The day of the incident, the victim began his shift at 0800 hours. The morning was spent performing equipment checks and was followed by classroom training. Later in the day, street drills were conducted for over 3 ½ hours, during which time the victim did not report or show signs of discomfort, pain, or distress to his peers. During the victim's interview by ambulance personnel, he mentioned having chest pain for 2 hours prior to his collapse.

Training. The Fire Department requires all new fire fighters, before being hired, to complete the State Fire Academy courses to become certified at the basic (61 hours) and advanced (37 hours) levels, which includes First Responder certification and Hazardous Materials Operations level. Once hired, the fire fighter must complete the 48-hour recruit training conducted at the city's training tower. Once recruit school is completed, the fire fighter is assigned to a station and receives daily training on each shift. All fire fighters are certified for the following: First Responder, CPR, and defibrillator. The department also requires annual completion of the recruit training drill. The victim had 36 years of fire fighting experience and was a State-certified Fire Fighter.

Preemployment/Preplacement Evaluations. The department requires a preemployment/preplacement medical evaluation for all new hires, regardless of age. Components of this evaluation for all applicants include the following:

- A complete medical history
- Height, weight, and vital signs
- Physical examination
- Complete blood count (CBC)
- Blood lipid profile (total cholesterol, HDL cholesterol, triglycerides)
- Urinalysis
- PPD skin tests (for tuberculosis)
- Chest X-ray (if PPD is positive)
- Hepatitis B immunization
- Post Hepatitis B immunization Titer (if indicated)
- Resting EKG (if over 40 years old)

These evaluations are performed by a contract physician hired by the City. Once this evaluation is complete, the physician makes a decision regarding medical clearance for fire fighting duties, and this is forwarded to the City's personnel director. New hires are also required to complete a physical capacity test. This is a timed-performance evaluation of typical fire fighting duties. Finally, all fire fighters are required to pass a self-contained breathing apparatus (SCBA) performance test (e.g., using an SCBA in a maze).

Medical clearance for SCBA use prior to this test is not required.

Periodic Evaluations. The content of the annual medical evaluations required by this department is the same as the preemployment physical. The victim's last annual medical evaluation was in September 1998, and he was cleared for fire fighting duties. According to records available to NIOSH, this evaluation did not include a medical history nor a resting EKG. The victim's last resting EKG recorded in the Department's personnel file was in 1996. The EKG was interpreted as normal. His last medical history was in September 1997, and no heart problems were listed, although high blood pressure was indicated throughout his past fire fighter medical evaluations. The Department's medical screening program does not include exercise stress tests. If an employee is injured at work, the employee is evaluated and must be cleared for "return to work" by the fire fighter's private physician.

An annual physical capacity test is required by this department. The annual physical capacity test includes these elements:

- Climbing a 100-foot ladder while wearing SCBA and full turnout gear;
- Pulling a charged 2½-inch hoseline for 50 feet; and
- Climbing a 24-foot ladder while carrying a charged 2½-inch hoseline.

Although some stations have exercise (strength and aerobic) equipment, typically purchased by the fire fighters themselves, the department does not have a voluntary or required fitness/wellness program. SCBA performance tests are conducted on an annual basis, although no specific medical clearance for SCBA use is required.

DISCUSSION

In the United States, coronary artery disease (atherosclerosis) is the most common risk factor for cardiac arrest and sudden cardiac death.[1] Risk factors for its development include increasing age, male gender, family history of coronary artery disease, smoking, high blood pressure, high blood cholesterol, obesity/physical inactivity, and diabetes.[2] The victim had several of these risk factors (advancing age, male gender, smoking, high blood pressure, high blood cholesterol, and obesity/physical inactivity), and had evidence of CAD on his EST.

The narrowing of the coronary arteries by atherosclerotic plaques occurs over many years, typically decades.[3] However, the growth of these plaques probably occurs in a nonlinear, often abrupt fashion.[4] 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.[5] This sudden blockage is primarily due to blood clots (thrombosis) forming on the top of atherosclerotic plaques.

Blood clots, or thrombus formation, in coronary arteries are initiated by disruption of atherosclerotic plaques. Certain characteristics of the plaques (size, composition of the cap and core, presence of a local inflammatory process) predispose the plaque to disruption.[4] Disruption then occurs from biomechanical and hemodynamic forces, such as increased blood pressure, increased heart rate (HR), increased catecholamines, and shear forces, which occur during heavy exercise.[6,7] Fire fighting activities are strenuous and often require fire fighters to work at near maximal heart rates for long periods. The increase in heart rate has been shown to begin with responding to the initial alarm and persist through the course of fire suppression activities.[6-8] Epidemiologic studies have found that heavy physical exertion sometimes immediately precedes and triggers

the onset of acute heart attacks.[9-12] Although this fire fighter was not responding to an alarm, nor was he engaged in fire suppression activities, he had been actively participating in training exercises which required a moderate amount of physical exertion.

The Department conducted extensive preemployment/preplacement medical evaluations and annual medical evaluations. However, the frequency and content differed from those recommended by the National Fire Protection Association (NFPA).[13] NFPA recommends a yearly physical evaluation to include a medical history, height, weight, blood pressure, and visual acuity test. NFPA recommends a more thorough evaluation to include vision testing, audiometry, pulmonary function testing, a complete blood count, urinalysis, and biochemical (blood) test battery be conducted on a periodic basis according to the age of the fire fighter (under 30, every 3 years; 30 to 39, every 2 years; and 40 and over, every year). This Department could save money by reducing the frequency of their current annual requirement of complete blood counts, urinalysis, blood chemistries, and resting EKG tests. This money could be applied toward the additional screening tests recommended by the NFPA (vision test, audiometry, pulmonary function test, and EST). NFPA also recommends EST for those 35 years old and above with known CAD risk factors, and 40 years old and above for those without CAD risk factors. NFPA considers risk factors to be premature family history (less than age 55), hypertension, diabetes mellitus, cigarette smoking, and hypercholesterolemia (total cholesterol greater than 240 or HDL cholesterol less than 35).[14]

In 1997, the NFPA updated *Standard 1582: Medical Requirements for Fire Fighters*.[14] This voluntary industry standard specifies minimum medical requirements for candidates and current fire fighters. NFPA 1582 considers individuals with CAD (history of myocardial infarction, coronary artery bypass surgery, or coronary angioplasty) to be a "Category B Medical Condition." A Category B Medical Condition is defined as "a medical condition that, based on its severity or degree, **could** (our emphasis) preclude a person from performing as a fire fighter in a training or emergency operational environment by presenting a significant risk to the safety and health of the person or others." Appendix A of the standard contains guidance for when to preclude a fire fighter with CAD from engaging in fire fighting activities. Appendix A states that "persons at mildly increased risk for sudden incapacitation are acceptable for fire fighting. Mildly increased risk is defined by the presence of each of the following:

- Normal left ventricular ejection fraction
- Normal exercise tolerance, > 10 metabolic equivalents (METS)
- Absence of exercise-induced ischemia by exercise testing
- Absence of exercise-induced complex ventricular arrhythmias
- Absence of hemodynamically significant stenosis on all major coronary arteries (≥ 70 percent lumen diameter narrowing), or successful myocardial revascularization."

Based on this fire fighter's EST in February 1997, he did not meet the third criterion, and therefore should not have been cleared for fire fighting duties without further treatment of his CAD.

RECOMMENDATIONS AND DISCUSSION

The following recommendations address health and safety generally. This list includes some preventive measures that have been recommended by other agencies to reduce the risk of on-the-job heart attacks and sudden cardiac arrest among fire fighters. These recommendations have not been evaluated by NIOSH, but represent research presented in the

literature or of consensus votes of Technical Committees of the National Fire Protection Association or labor/management groups within the fire service. In addition, they are presented in a logical programmatic order, and are not listed in a priority manner.

Recommendation #1: Exercise stress tests should be incorporated into the Fire Department's medical evaluation program.

NFPA 1582: Standard on Medical Requirements for Fire Fighters and the International Association of Fire Fighters/International Association of Fire Chiefs wellness/fitness initiative both recommend at least biannual EST for fire fighters.[13,14] They recommend that these tests begin at age 35 for those with CAD risk factors, and at age 40 for those without CAD risk factors. These EST will undoubtably increase the costs associated with the medical evaluations. To some extent these costs could be offset by reducing the frequency of other tests included in your annual examinations (as discussed in the Discussion section). The EST could be conducted by the fire fighter's personal physician or the Department's contract physician. If the fire fighter's personal physician conducts the test, the results must be communicated to the City contract physician, who should be responsible for decisions regarding medical clearance for fire fighter duties.

Recommendation #2: Individuals with medical conditions that would present a significant risk to the safety and health of themselves or others should be precluded from fire fighting activities.

The *NFPA 1582: Standard on Medical Requirements for Fire Fighters* lists medical conditions that **should** (Category A) or **could** (Category B) preclude individuals from performing fire fighter activities.[13] We recommend fire departments adopt these recommendations and share this standard (NFPA 1582) with physicians responsible for these decisions. Based on NFPA 1582 criteria, this victim's positive EST should have precluded him from unrestricted fire fighter activities.

Recommendation #3: Fire departments should educate and train fire fighters on the signs and symptoms of heart attacks and encourage fire fighters experiencing these symptoms while on duty to report them to their supervisor for prompt medical evaluation.

All fire fighters in this department are certified as First Responders and in the use of CPR and AED. First Responder training includes recognizing the signs and symptoms of heart attacks.[15] Recognizing these signs and symptoms in oneself is often difficult, particularly if the pain resembles heartburn or indigestion. It is possible that if this individual had notified his supervisor about his symptoms, and/or sought medical care (e.g. a visit to the emergency department) prior to his syncopal episode, appropriate intervention may have prevented his death at this time.

Recommendation #4: Perform an autopsy on all on-duty fire fighters whose death may be cardiovascular-related.

In 1995, the United States Fire Administration (USFA) published the *Firefighter Autopsy Protocol*.[16] This publication hopes to provide "a more thorough documentation of the causes of firefighter deaths for three purposes:

(1) to advance the analysis of the causes of firefighter deaths to aid in the development of improved firefighter health and safety equipment, procedures, and standards;

(2) to help determine eligibility for death benefits under the federal government's Public Safety

Officer Benefits Program, as well as state and local programs; and

(3) to address an increasing interest in the study of deaths that could be related to occupational illnesses among firefighters, both active and retired."

Recommendation #5: Phase in a mandatory wellness/fitness program for fire fighters to reduce risk factors for cardiovascular disease and improve cardiovascular capacity.

NFPA 1500 requires a wellness program that provides health promotion activities for preventing health problems and enhancing overall well-being.[17] In 1997, the International Association of Fire Fighters and the International Association of Fire Chiefs joined in a comprehensive Fire Service Joint Labor Management Wellness/Fitness Initiative to improve fire fighter quality of life and maintain physical and mental capabilities of fire fighters. Ten fire departments across the United States joined this effort to pool information about their physical fitness programs and to create a practical fire service program. They produced a manual and a video detailing elements of such a program.[14] The Fire Department and the Union should review these materials to identify applicable elements for their department. Other large-city negotiated programs can also be reviewed as potential models.

Recommendation #6: Although this issue is unrelated to this fatality, fire departments should purchase personal alert safety system (PASS) devices and ensure that fire fighters wear and use them when involved in fire fighting, rescue, and other hazardous duties.

The PASS is a small electronic device worn by the fire fighter which will emit a distinctive audible alarm if the fire fighter becomes motionless for 30 seconds, or it can be activated manually if needed. This device is designed to assist rescuers in locating the fire fighter. All fire fighters who enter hazardous areas should be provided with and use a PASS device.[17-18]

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