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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 *July 26, 2004*

Fire Fighter Collapses and Dies During Exercise Training at His Fire Station - Missouri

SUMMARY

On August 6, 2000, a 27-year-old male Fire Fighter (FF) was performing physical fitness training alone in the exercise room of his fire station after the end of his 24-hour shift. After the FF had been in the exercise room approximately 43 minutes, crewmembers found him on the floor experiencing a grand mal seizure. Seizure activity was witnessed for about 20 seconds followed by 30 seconds of post-seizure (post-ictal) activity, during which the victim was making purposeful movements but not responding to commands. Shortly thereafter, he slumped backwards. Vital signs revealed no pulse or respirations. Cardiopulmonary resuscitation (CPR) and advanced life support (ALS) resuscitation efforts were begun immediately. Despite CPR and ALS administered by crewmembers, the ambulance paramedics, and by hospital personnel in the emergency department (ED), the FF died. Both the autopsy and death certificate were completed by a pathologist with the County Medical Examiner's Office. They both listed arteriosclerotic heart disease as the cause of death while the autopsy also noted hypertensive heart disease.

Given the cause of death, it is unlikely the Fire Department (FD) could have done anything to prevent the tragic and untimely death of this FF. Therefore, the following recommendations address general health and safety issues identified during the National Institute for Occupational Safety and Health (NIOSH) evaluation. This list includes some preventive measures that have been recommended by other agencies to reduce the risk of sudden cardiac arrest and or death 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 (NFPA) or labor/management groups within the fire service. Issues relevant to this Fire Department (FD) include:

- ***The FD should negotiate with the local union to convert their voluntary wellness/ fitness program for fire fighters to a mandatory program to reduce risk factors for cardiovascular disease and improve cardiovascular capacity.***
- ***During annual medical evaluations, discontinue the routine use of biannual chest x-rays.***

INTRODUCTION AND METHODS

On August 6, 2000, a 27-year-old male FF collapsed and died while participating in a FD-sponsored exercise program. On October 4, 2000, NIOSH contacted the affected FD to initiate the investigation. On October 17, 2000, an Occupational Safety and Health Specialist and a physician from the NIOSH Fire Fighter Fatality

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. The program does not seek to determine fault or place blame on fire departments or individual fire fighters. 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

www.cdc.gov/niosh/firehome.html

or call toll free **1-800-35-NIOSH**

Investigation Team traveled to Missouri to conduct an on-site investigation of the incident.

During the investigation NIOSH personnel interviewed the following either in person or by telephone:

- The Fire Chief
- The FF's wife
- The Union Vice-President
- Crew members on duty with the FF

During the site visit NIOSH personnel reviewed

- FD policies and operating guidelines
- FD training records
- FD annual report for 1999
- The FF's personnel file at the FD
- The FF's preemployment medical evaluation conducted by the FD
- FD physical examination protocols
- Ambulance response report
- Death certificate
- Autopsy report

INVESTIGATIVE RESULTS

Incident. On August 5, 2000, the FF reported for work at Station 2 at 0730 hours. The day was spent performing station and equipment maintenance. During the shift, the FF responded to two emergency calls: an ambulance response at 0800 hours and an alarm sounding at 1230 hours. On August 6, 2000, at 0700 hours, the FF arose from sleep and completed his shift at 0730 hours. Shortly thereafter, he went into the fire station's exercise room (located in the basement) to begin physical fitness training. The FF was an avid participant in the FD's health and wellness program, which included both strength and aerobic conditioning. With FD approval, he typically exercised after his 24-hour shift to avoid interruptions during his training/workouts. The FF was alone in the exercise room, when two fire fighters entered the basement at 0818 hours looking for a piece of equipment. They found the FF having what they described as, a grand mal seizure (unresponsiveness and shaking extremities in a to-and-fro rhythmic pattern).

The paramedic kit was retrieved (all apparatus in this FD are equipped with ALS equipment, and each station's shift is staffed with at least one paramedic), and one of the FD's transporting ambulances was telephoned directly. The FF was witnessed having this type of seizure activity for about 20 seconds. This was followed by a post-seizure (post-ictal) state during which he had purposeful movements (tried to get up) for approximately 30 seconds but did not respond to questions or commands. During this post-ictal period, a "rebreather" mask supplying oxygen was placed over the victim's nose and mouth. Shortly thereafter, he stopped breathing and slumped backward.

Vital signs revealed no pulse or respirations. A quick look on the cardiac monitor showed ventricular fibrillation (VFib). One shock was delivered at 0822 hours, but the FF's heart rhythm converted to asystole (no heart beat) and CPR was initiated. Over the next 18 minutes, full ALS measures were followed, including intubation, intravenous administration of cardiac medications, additional shocks for VFib, and external cardiac pacing. At 0840 hours the ambulance departed for the nearest hospital emergency department and arrived at 0843 hours. Despite full CPR and ALS administered for three minutes en-route and for 45 minutes in the hospital's ED, the FF died. He was pronounced dead at 0928 hours and at that time resuscitation attempts were discontinued.

Medical Findings. The death certificate, completed by a pathologist in the County Medical Examiner's Office, listed "arteriosclerotic heart disease" as the immediate cause of death. Pertinent findings from the autopsy, also performed by the pathologist included:

Heart:
- An enlarged heart weighing 570 grams (normal less than 400 grams)[1]
- Left and right ventricular dilatation
- Scar formation in the left ventricle (superior aspect of the posterior wall)
- Arteriosclerotic heart disease
- Fresh clot (thrombus) in the right coronary artery 2 cm from its origin
    - 80% narrowing of the distal right coronary artery
    - 60% narrowing of the circumflex artery
    - 80% narrowing of the left anterior descending artery

Blood:
- Illicit drug and alcohol tests were negative
- Presence of a prescription heart medication (Papaverine)
- Large white layer of lipid (fat) material [suggesting a recent meal or a lipid disorder]

At the FF's pre-placement medical examination in February 1999, he was 72.5 inches tall and weighed 249 pounds, giving him a body mass index (BMI) of 32.8 kilograms per square meter (kg/m^2). A BMI over 30.0 kg/m^2 is considered obese.[2] As mentioned previously, the FF had a very impressive exercise regimen and may have lost weight in the 18 months prior to his death. Unfortunately, there was no weight taken at the time of his autopsy. Additional findings at his February 1999 medical examination included high blood pressure (hypertension) for which he was taking prescription medication, and elevated blood lipids (both high cholesterol and very high triglycerides.) From the medical records available to NIOSH it could not be determined the exact type of lipid condition the FF had, nor if any type of follow-up treatment was given.

The FF did not complain of any pain suggestive of angina (heart pain due to reduced blood supply) or any other cardiac problems according to his spouse or co-workers. As mentioned previously, he was an avid physical fitness buff who performed strength and aerobic conditioning on a regular basis. In October 1999, he had a pre-syncopal episode (almost passed out) while exercising on the treadmill. It is not clear if he sought medical attention after this episode or if he had any other similar episodes while exercising.

DESCRIPTION OF THE FIRE DEPARTMENT

At the time of the NIOSH investigation, the FD consisted of 76 uniformed career personnel and served a population of 60,000 residents in a geographic area of 25 square miles. There are five fire stations. Fire fighters, including the victim, work on one of three shifts from 0730-0730 hours, 24-hours on-duty, 24-hours off-duty for three tours, then are off-duty for four days.

In 1999, the FD responded to 5,117 calls: 95 structure fires, 101 vehicle fires, 197 other fires, 3,545 emergency medical calls, 119 other rescue calls, 221 hazardous condition calls, 5 overpressure/rupture calls, 126 service calls, 214 good intent calls, 361 false calls, 62 mutual aid calls, 71 situation found, undetermined/not classified calls.

Training. The FD requires all new fire fighters to possess Fire Fighter I and II certification and a current State paramedic license prior to applying for a fire fighter position. Additionally, all applicants must pass a written test, a physical agility test simulating fire fighting functions, an oral interview, and a pre-placement physical examination. Once hired, the fire fighter is assigned to a shift. Subsequent training is conducted on-shift. State requirements for Fire Fighter I and II certification comply with the NFPA. There is no State requirement for annual fire fighter re-certification, although there is for Hazardous Materials (Hazmat), CPR, and

Emergency Medical Technician-Paramedic (EMT-P). The FF was certified as a Fire Fighter II and Paramedic, and had 16 months of fire fighting experience.

Pre-placement Evaluations. The FD requires a pre-placement medical evaluation for all new hires, regardless of age. Components of this evaluation for all applicants include:

- A complete medical history
- Height, weight, and vital signs
- Physical examination
- Audiogram
- Vision test
- Blood Tests: Complete blood count (CBC), blood chemistry profile
- Urinalysis (dipstick)
- Chest X-ray
- Pulmonary Function Test (PFT)
- Skin test for tuberculosis
- Electrocardiogram (EKG)
- Cardiac stress test (submaximal)

These evaluations are performed by a contract medical clinic. Once this evaluation is complete, a decision regarding medical clearance for fire fighting duties is made by the contractor and forwarded to the City's personnel department. This clinic also medically clears candidates to wear respirators using the questionnaire provided in OSHA's respiratory protection standard.[3]

Periodic Evaluations

Beginning in 1999, annual medical evaluations became mandatory for all fire fighters as part of the health and wellness program. The content of this evaluation follows that which is recommended by the IAFF/IAFC Wellness/Fitness program.[4] The FD estimates that approximately 75% of its members participate in the exercise portion of the health and wellness program. Specific components of this medical evaluation include:

- A complete medical history
- Height, weight, and vital signs
- Audiogram
- Vision test
- Physical examination
- Blood Tests: Complete blood count (CBC), blood chemistry profile, prostate specific antigen (PSA) for men over 40 years of age
- Urinalysis (dipstick)
- Chest X-ray every two years
- PFT
- Skin test for tuberculosis
- EKG
- Cardiac stress test (either submaximal or maximal)

These evaluations are performed by a separate medical clinic, not affiliated with the clinic conducting the pre-placement evaluations. Once this evaluation is complete, a decision is made regarding medical clearance for fire fighting duties and participation in the fitness program and forwarded to the City's personnel department. Specific medical conditions identified by this evaluation are typically forwarded to the fire fighter's personal physician for further evaluation and treatment. However, final decisions regarding clearance for fire fighting duties and participation in the fitness program are determined by the contract medical clinic. For employees that miss work due to an occupational or non-occupational cause, they also must be cleared for duty by this medical clinic.

In 1999, the FD pilot tested the IAFF/IAFC wellness/fitness initiative and fully implemented the program in February 2000. The only difference from the IAFF/IAFC program is that this FD's program is voluntary, rather than mandatory. All of the five fire stations have exercise (strength and aerobic) equipment purchased by the FD, fire fighters themselves, or donated from local companies.

DISCUSSION

In the United States, atherosclerotic coronary artery disease (CAD) is the most common risk factor for cardiac arrest and sudden cardiac death.[5] Risk factors for its development include age over 45, male gender, family history of coronary artery disease, smoking, high blood pressure (systolic >140 millimeters of mercury [mmHg] or diastolic > 90 mmHg), high blood cholesterol (total cholesterol > 240 milligrams per deciliter [mg/dL]), obesity/ physical inactivity, and diabetes.[6,7] The FF had several of these risk factors (male gender, high blood pressure, high blood cholesterol, and obesity) and CAD confirmed at autopsy. Despite his young age, these risk factors, in addition to some type of hyperlipidemia, were probably responsible for his CAD.

The narrowing of the coronary arteries by atherosclerotic plaques occurs over many years, typically decades.[8] However, the growth of these plaques probably occurs in a nonlinear, often abrupt fashion.[9] 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.[10] This sudden blockage is primarily due to blood clots (thrombosis) forming on the top of atherosclerotic plaques. The deceased had a blood clot in his right coronary artery and evidence of atherosclerotic disease in all his coronary arteries. These findings confirm that a heart attack and an associated heart arrhythmia were responsible for this sudden death.

Angina is the most common presenting symptom of myocardial ischemia and underlying CAD, but in many persons the first evidence of CAD may be myocardial infarction or sudden death.[11] Some individuals may not experience angina with ischemia, as evidenced by up to 20% of heart attacks being "silent," i.e., painless.[8]

Epidemiologic studies have found that heavy physical exertion sometimes immediately precedes and triggers the onset of acute heart attacks.[12-15] The FF was exercising in the fire station at the end of his shift. It could not be ascertained whether he was lifting weights or running on the treadmill. In either case, both types of exercise would be considered heavy physical exertion.[16,17] The physical stress of exercising with his underlying atherosclerotic CAD contributed to this FF's sudden cardiac death.

In addition to his CAD, other important autopsy findings were a dilated and very large heart (570 grams) which contained an area of focal scarring. These findings suggest some type of dilated cardiomyopathy. Microscopic examination or genetic studies of the heart muscle would have been helpful to confirm this diagnosis.

Dilated cardiomyopathy, is characterized by dilatation of the heart chambers and impaired ventricular contraction (pumping). Microscopic findings are non-specific, typically being myocyte hypertrophy [best appreciated as nuclear hypertrophy (e.g. "box-car nuclei")] with varying degrees of interstitial fibrosis.[18,19] Although most cases of dilated cardiomyopathy are of unknown etiology (idiopathic), a variety of acquired or hereditary disorders can cause the disorder. These secondary and potentially reversible forms are listed in Table 1.[19]

Idiopathic cardiomyopathy (IDC) is not rare. Its age adjusted prevalence in the United States averages 36 cases per 100,000 population,[20] and it accounts for 10,000 deaths each year.[21] Most patients are first seen between the ages of 20 and 50 years presenting with symptoms of moderate heart failure [shortness of breath on exertion, palpitations (fast heart beats), diminished exercise capacity] and advanced heart failure [shortness of breath upon lying down, and swelling of the ankles].[19] This fire fighter had sudden death as the initial presentation of IDC.

Although sudden death is rarely the initial presentation,[22,23] it is a common cause of death among IDC patients accounting for 28 percent of all IDC deaths.[19]

The prognosis for ICD is poor. Early studies reported one- and five-year death rates of approximately 25 and 50 percent respectively,[24,25] but recent studies report an average five year death rate of 20 percent.[22,23,26,27] This improved survival probably reflects the earlier detection of disease, a shift to population based studies, and better treatment.[23,28] Although a variety of symptoms and medical tests can provide prognostic information, patients at greatest risk of sudden death or in need of antiarrhythmic therapy cannot yet be prospectively identified.[19] Given the inability to identify patients at high risk for sudden death, the low degree of efficacy of anti-arrhythmic agents for IDC, the numerous side effects of these anti-arrhythmic agents, and the lack of symptoms in this fire fighter, it is unclear if an earlier diagnosis could have prevented his sudden death.

Investigations into the pathogenesis of IDC have focused on four basic mechanisms: (1) inherited factors, (2) viral myocarditis and other cytotoxic insults, (3) immune abnormalities, and (4) metabolic, energetic, and contractile abnormalities. These mechanisms are not mutually exclusive, and several may combine to produce clinical disease in susceptible patients. The inherited factors account for approximately one third of all IDC cases,[29-31] and 20 percent of patients with IDC have at least one first degree relative with a decreased ejection fraction and cardiomegaly.[29] Although IDC can be transmitted as a recessive or X-linked trait, autosomal dominant inheritance occurs most frequently and exhibits both clinical variability and genetic heterogeneity.[32] Finally, if this FF had IDC, it is unclear if it was due to inherited factors or due to post-viral myocarditis. First-degree relatives of this FF may want to consult with their physicians to determine if an echocardiogram is warranted to screen for familial IDC.

IDC is often accompanied by conduction system disease and genetic studies have identified individual loci on chromosome responsible for these cases.[32] The reported conduction systems diseases associated with IDC are sinus bradycardia, atrioventricular conduction block (first-, second-, and third-degree), and atrial arrhythmias.[32] None of these conditions were present in the FF's pre-placement medical examination in March of 1999. Future molecular genetic studies may lead to the identification and treatment of asymptomatic carriers who are at risk for symptomatic dilated cardiomyopathy.[32]

In October 1999 the victim had a pre-syncopal episode while exercising. Due to the many causes of pre-syncope, it cannot be determined whether this episode represented the same condition that resulted in his sudden cardiac death while exercising ten months later.

The FD requires a pre-placement medical examination for all new hires and an annual medical evaluation for all fire fighters. This examination is essentially the same as the NFPA Standard 1582.[33] As part of its Appendix A, NFPA recommends exercise stress tests (EST) to identify underlying CAD for FF with two or more CAD risk factors. These recommendations are similar to those of the American College of Cardiology/American Heart Association (ACC/AHA).[34] The ACC/AHA concludes that the evidence is in favor of EST for (1) asymptomatic persons with diabetes mellitus who plan to start vigorous exercise. The ACC/AHA concludes the evidence is less well established for (2) evaluation of persons with multiple risk factors as a guide to risk-reduction therapy, or (3) asymptomatic men over the age of 45 and women over the age of 55 who: a) plan to start vigorous exercise, or b) *who are involved in occupations in which impairment*

might impact public safety, or c) individuals at high risk for CAD due to other diseases (e.g. peripheral vascular disease and chronic renal disease. Since this FF was only 27 years old, despite his CAD risk factors, an EST was not indicated by ACC/AHA guidelines. In addition, NFPA 1582 does not recommend a screening echocardiogram, the test necessary to diagnose IDC. Thus, if the FF had IDC, it is unlikely this condition would have been identified prior to his death.

RECOMMENDATIONS AND DISCUSSION

Given the cause of death, it is unlikely the Fire Department (FD) could have done anything to prevent the tragic and untimely death of this FF. Therefore, the following recommendations address general health and safety issues identified during the NIOSH evaluation. This list includes some preventive measures that have been recommended by other agencies to reduce the risk of sudden cardiac arrest and/or death 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 NFPA or labor/management groups within the fire service. Issues relevant to this FD include:

Recommendation #1: The FD should negotiate with the local union to convert their voluntary wellness/fitness program for fire fighters to a mandatory program to reduce risk factors for cardiovascular disease and improve cardiovascular capacity.

The FD and the Local Union should be congratulated for implementing a state-of-the-art fitness and wellness program for fire fighters. To be completely effective, participation should be required. Wellness programs have been shown to be cost effective, typically by reducing the number of work-related injuries and lost work days.[35,36] A similar cost savings has been reported by the wellness program at the Phoenix Fire Department, where a 12-year commitment has resulted in a significant reduction in their disability pension costs.[37]

Recommendation #2: During annual medical evaluations, discontinue the routine use of biannual chest x-rays.

Regarding the content of the FD's mandatory annual medial examination, the NFPA recommends chest x-rays every five years, not every two years currently practiced at this FD.[33] Other organizations do not recommend routine asymptomatic screening chest x-rays to detect lung cancer. "The U.S. Preventive Services Task Force (USPSTF) concludes that the evidence is insufficient to recommend for or against screening asymptomatic persons for lung cancer with either low dose computerized tomography (LDCT), chest x-ray (CXR), sputum cytology, or a combination of these tests."[38] In our opinion, the chest x-rays being conducted by the FD expose incumbents to unnecessary radiation and represent an unnecessary expense for the FD.

In addition, annual chest x-rays performed on Hazmat members expose incumbents to unnecessary radiation and represent an unnecessary expense for the FD, and are not recommended by the OSHA Hazmat standard unless specifically indicated by the medical/occupational history.[39,40]

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INVESTIGATOR INFORMATION

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Table 1. Known Causes of Dilated Cardiomyopathy[19]

Toxins
- Ethanol
- Chemotherapeutic agents (doxorubicin, bleomycin)
- Cobalt
- Anti-retroviral agents (zidovudine, didanosine, zalcitabine)
- Phenothiazines
- Carbon monoxide
- Lead
- Cocaine
- Mercury

Metabolic Abnormalities
- Nutritional deficiencies (thiamine, selenium, carnitine)
- Endocrinologic disorders (hypothyroidism, acromegaly, thyrotoxicocis, Cushing's Disease, pheochromocytoma, diabetes mellitus)
- Electrolyte disturbances (hypocalcemia, hypophosphatemia)

Infectious
- Viral (coxsackie virus, cytomegalovirus, human immunodeficiency virus)
- Rickettsial
- Bacterial (diphtheria)
- Mycobacterial
- Fungal
- Parasitic (toxoplasmosis, trichinosis, Chagas' disease)

Noninfectious
- Collagen vascular disorders (scleroderma, lupus erythematosus , dermatomyositis)
- Hypersensitivity myocarditis
- Sarcoidosis
- Peripartum dysfuncion

Neuromuscular Causes
- Duchenne's muscular dystrophy
- Facioscapulohumeral muscular dystrophy
- Erb's limb-girdle dystrophy
- Myotonic dystrophy