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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 *October 21, 2004*

Fire Fighter Suffers Unwitnessed Sudden Cardiac Death After Responding to Mobile Home Fire – South Carolina

SUMMARY

On May 6, 2002, a 38-year-old male volunteer Fire Fighter (FF) was dispatched by his combination fire department (FD) (he was also a member of another career FD) to a mobile home fire near his home. After responding and assisting with fire suppression, he returned home. At some time during the day, he suffered an unwitnessed sudden cardiac death. He was found by a friend in the evening. No resuscitation measures were initiated and the FF was pronounced dead at the scene by the County Coroner. The death certificate, completed by the County Coroner, and the autopsy, performed by the Medical Examiner, listed "cardiac arrhythmia" as the immediate cause of death due to "stress of fighting fire" and "cardiomegaly with dilatation" as contributing factors.

The following recommendations address some general health and safety issues. 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 selected recommendations have not been evaluated by NIOSH, but represent published research, or consensus votes of technical committees of the National Fire Protection Association (NFPA) or fire service labor/management groups.

- ***Consider conducting exercise stress tests for fire fighters with two or more risk factors for coronary artery disease (CAD)***

Although unrelated to this fatality, the Fire Department should consider these recommendations based on health and economic considerations:

- ***Provide <u>mandatory</u> annual medical evaluations to fire fighters consistent with NFPA 1582 to determine their medical ability to perform duties without presenting a significant risk to the safety and health of themselves or others***
- ***Perform a pre-placement and an annual physical performance (physical ability) evaluation for <u>ALL</u> fire fighters to ensure they are physically capable of performing the essential job tasks of structural fire fighting***
- ***Phase in a mandatory wellness/fitness program for fire fighters to reduce risk factors for cardiovascular disease and improve cardiovascular capacity***
- ***Provide adequate fire fighter staffing to ensure safe operating conditions***

INTRODUCTION & METHODS

On May 6, 2002, a 38-year-old male Fire Fighter suffered sudden cardiac death at home after performing fire suppression duties at a mobile home fire. Since he had apparently died several hours prior

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to being discovered, no resuscitation efforts were initiated. NIOSH was notified of this fatality on May 9, 2002, by the United States Fire Administration. NIOSH contacted the affected Fire Department on May 21, 2002, to obtain further information, and on June 15, 2004, to initiate the investigation. On August 3, 2004, a Safety and Occupational Health Specialist 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 and/or interviewed:

- The Fire Chief at the combination station
- The Fire Chief at the career station
- The FF's crew members
- The FF's former wife
- The friend who found the deceased FF
- County Human Resources Manager

During the site-visit NIOSH personnel reviewed:

- FD policies and operating guidelines
- FD training records
- FD annual response report for 2003
- FD incident report
- FD physical examination protocols
- Death certificate
- Autopsy report

INVESTIGATIVE RESULTS

On May 6, 2002, the FF was scheduled to work at his career FD. Due to gastrointestinal discomfort (the FF thought he had a stomach virus), the FF called in sick that morning. At 0944 hours, his combination FD, for which the FF was a volunteer, was dispatched to a fire in a mobile home located near his home. Two engines and 13 personnel, including the FF, responded.

Units arrived on the scene at 0949 hours to find heavy fire showing from the right rear (Side 3) of the structure. Fire fighters, wearing full turnout gear and breathing air from self-contained breathing apparatus (SCBA), including the FF, conducted fire attack and extinguished the fire in approximately 15 minutes. The FF exited the structure and rested for a short time. He then operated the pump panel on one of the engines. Witnesses stated he did not look or feel well. The FF left the scene at approximately 1030 hours and drove himself home.

He telephoned a friend at approximately 1100 hours. He mentioned feeling bad, stating his stomach was upset and that he was staying home to rest. He never provided additional specific details about his acute symptoms. He did not telephone his friend throughout the day as he usually did, therefore, the friend became worried and drove to the FF's home. After arriving at the FF's home at approximately 2033 hours, she found the FF collapsed on the floor. Checking the fire fighter, she found him unresponsive, not breathing, and cold to the touch. She then called 911. Emergency medical service (EMS) was dispatched and upon arriving at the scene, found the FF to have died at some significantly earlier time. The County Coroner was notified and upon arriving at the scene, pronounced the FF dead. The time of death was declared at 1115 hours.

Medical Findings. The death certificate, completed by the County Coroner, listed "cardiac arrhythmia" due to "fighting of fire" due to "cardiomeglia" as the cause of death. Pertinent findings from the autopsy, performed by the pathologist on May 7, 2002, included:

- Cardiomegaly (enlarged heart) - weighing 576 grams (normal less than 400 grams)[1]
- Mild atherosclerotic cardiovascular disease
  50% occlusion in the right coronary artery
  50% occlusion in the left anterior descending artery
- Biventricular hypertrophy with dilatation (left ventricle thickness of 1.5 cm at the anterior papillary muscle)

- No evidence of thrombi, emboli, or fibrosis on gross pathology
- Drug and alcohol tests were negative
- Carboxyhemoglobin (carbon monoxide) test was negative (less than 10%)
- Hepatosplenomegaly

On autopsy, the deceased weighed 220 pounds and was 73 inches tall, giving him a body mass index (BMI) of 29 kilograms per square meter (kg/m^2). (A BMI between 25 and 29.9 kg/m^2 is considered overweight).[2] At his last FD physical evaluation conducted by his career FD in January 2002, he weighed 259 pounds, had a blood pressure of 138/88 millimeters of mercury (mmHg), fasting blood glucose was 403 milligrams per deciliter (mg/dL) (normal 65-109 mg/dL), cholesterol level was 334 mg/dL (normal 150-200 mg/dL), HDL 30.0 mg/dL (normal > 40 mg/dL), and cholesterol/HDL ratio was 11.1 (normal < 5.0). He had previously been diagnosed with diabetes mellitus which was treated with an oral glucose-lowering medication, exercise, and diet modification. He also had been previously diagnosed with hyperlipidemia, also treated with diet and exercise. According to the FF's friend and FD personnel, the FF walked and ran regularly, and was compliant with his prescribed treatment.

Also, at his 2002 FD physical evaluation, he exercised for eight minutes on the bicycle ergometer stress test[3], achieving 80% or 151 beats per minute (bpm) of his predicted maximum heart rate (182 bpm). This is equivalent to approximately 8.3 metabolic equivalents (METS). His blood pressure response was normal. This cardiovascular fitness test consisted of a cycle ergometer test (CET) utilizing a 12 lead EKG to ascertain the pulse rate. If EKG changes are noted during the cardiovascular fitness testing, follow-up with the primary care physician is recommended before clearance can be given for fire suppression activities. However, a diagnostic test that fails to achieve 85 to 90% of the predicted maximal heart rate, 182 beats per minute in this case, without chest pain or ischemic EKG findings is considered inadequate to rule out ischemic heart disease.[4] Additionally, the YMCA Stationary Bike Test Protocol has been shown to underestimate VO_2 for above average body size (most members).[5]

DESCRIPTION OF THE FIRE DEPARTMENT

At the time of the NIOSH investigation, this combination FD consisted of 22 uniformed personnel (seven career and 15 volunteer). The FD served a population of 14,000 in an area of 108 square miles. There are four fire stations.

In 2003, the FD responded to 960 calls, including: 16 structure fires, 26 grass fires, 14 vehicle fires, 79 false alarms, 88 other alarms, and 746 medical calls.

Training. The FD requires all new career fire fighter applicants to pass two oral interviews, a criminal background check, pass a physical examination performed by a County-contracted clinic (described below), and pass a drug screen prior to being hired. The newly hired fire fighter receives orientation, the 80-hour State Occupational Safety and Health Administration (OSHA) fire fighting class, and in-house training to become certified as Fire Fighter I. The new fire fighter must complete the OSHA course prior to performing interior structural fire fighting.

The FD requires all new volunteer fire fighter applicants to complete an application, pass an oral interview, and pass a physical examination from their personal physician (or they may be sent to the County-contracted physician) prior to being selected. Once selected, the new volunteer receives orientation and training. In-house training occurs every Monday night. If the fire fighter cannot attend, the FD must be notified.

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There is no requirement for a physical agility test for either the career or volunteer positions at the time of hire, nor on a periodic basis.

Recurrent training occurs daily on each shift. State fire fighter certification is voluntary. There is no mandatory annual refresher training. State fire training is in accordance with OSHA requirements for fire departments. The Fire Academy is accredited by the International Fire Service Accreditation Congress (IFSAC). EMTs and Paramedics recertify every three years. The FF was certified as a Fire Fighter II, EMT-Paramedic, Driver/Operator, Fire Officer I, State Chief Fire Officer, Fire Instructor I, Fire Inspector, Fire Marshal, and in Hazardous Materials Technician and Operations. He had 20 years of fire fighting experience and was a former director of the County EMS and an Assistant Chief on a career FD.

Pre-placement Evaluations. The FD requires a pre-placement medical evaluation for all fire fighter candidates, regardless of age. Components of the evaluation include:

- A complete medical history
- Physical examination
- Vital signs
- Vision screening
- Audiogram
- Blood analysis: lipid panel complete blood count
- Urine dipstick
- Drug screen (performed by Human Resources)
- 12-lead resting electrocardiogram (EKG)
- Hepatitis screening (Hepatitis B)
- Pulmonary Function Test (spirometry)
- Other tests are performed if medically indicated or the candidate is referred to their primary care physician

These evaluations are performed by a contract physician hired by the County, who then makes a decision regarding medical clearance for fire fighting duties. This decision is forwarded to Human Resources. Medical clearance to wear SCBA is included.

Periodic Evaluations. Periodic medical evaluations are offered by this FD for all members based on the member's age. The evaluation is performed every 3 years for those up to age 30, every 2 years for those age 30-40, and every year for those over the age of 40. Medical clearance for respirator use is required annually.

If an employee is injured at work and misses work, the employee may have to be evaluated by the County Worker's Compensation physician, who forwards their recommendation regarding "return to work" to Human Resources and then to the Fire Chief, who makes the final determination.

Exercise (strength and aerobic) equipment is located in all fire stations. Voluntary wellness/fitness programs are in place for the FD. Health/wellness maintenance information is available from the County.

DISCUSSION

On autopsy, the deceased was diagnosed with "cardiomeglia with dilatation." 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.[6,7] Unfortunately, the pathologist in this case did not provide specifics of the microscopic findings of the heart to help confirm the diagnosis. 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.[7]

Idiopathic dilated cardiomyopathy (IDC) is not rare. Its age-adjusted prevalence in the United States averages 36 cases per 100,000 population,[8] and it accounts for 10,000 deaths each year.[9] 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].[7] The deceased suffered sudden death. Although sudden death is rarely the initial presentation,[10,11] it is a common cause of death among IDC patients accounting for 28 percent of all IDC deaths.[7]

The prognosis for ICD is poor. Early studies reported one- and five-year death rates of approximately 25 and 50 percent respectively,[12,13] but recent studies report an average five-year death rate of 20 percent.[10,11,14,15] This improved survival probably reflects the earlier detection of disease, a shift to population-based studies, and better treatment.[11,16] Although a variety of symptoms and medical tests can provide prognostic information, patients at greatest risk of sudden death or in need of anti-arrhythmic therapy cannot yet be prospectively identified.[17] 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 the deceased, 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,[17-19] and 20 percent of patients with IDC have at least one first-degree relative with a decreased ejection fraction and cardiomegaly.[17] 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.[20] If IDC was the cause of death, it is unclear if the IDC was due to inherited factors or due to post-viral myocarditis. In either case, first-degree relatives of this fire fighter should consult with their physicians regarding when, or if, an echocardiogram is warranted to screen for IDC.

IDC is often accompanied by conduction system disease and genetic studies have identified individual loci on chromosomes responsible for these cases.[20] The reported conduction systems diseases associated with IDC are sinus bradycardia, atrioventricular conduction block (first-, second-, and third-degree), and atrial arrhythmias.[20] Except for family history, no clinical or histopathological characteristics can distinguish familial from nonfamilial disease.[7] Future molecular genetic studies may lead to the identification and treatment of asymptomatic carriers who are at risk for symptomatic dilated cardiomyopathy.[20]

On autopsy, the pathologist also listed "biventricular hypertrophy" as a diagnosis. This diagnosis was based on a) an enlarged heart, and b) a borderline thickened left ventricle (1.5 cm at the anterior papillary muscle). Hypertrophy of the heart's left ventricle is a relatively common finding among individuals with long standing high blood pressure (hypertension), a heart valve problem, or cardiac ischemia (reduced blood supply to the heart muscle). The deceased, however, had none of these conditions. On the other hand, unexplained (idiopathic) cardiac hypertrophy is one form of hypertrophic cardiomyopathy.

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Idiopathic hypertrophic cardiomyopathy (IHC) is a relatively rare heart condition, affecting approximately 0.2% of the population.[21] The majority of patients are asymptomatic, and sudden cardiac death is often its first clinical manifestation.[22] Risk factors for sudden death among IHC patients include young age (<30 years old) at diagnosis, a family history of IHC with sudden death, an abnormal blood pressure response to exercise, severe symptoms, non-sustained ventricular tachycardia, marked hypertrophy, marked left atrial dilatation, and genetic abnormalities associated with increased prevalence of sudden death.[21-23]

Approximately half of the IHC cases are transmitted genetically, typically in an autosomal dominant trait with disease loci on at least eight different chromosomes.[24] Unfortunately, genetic testing is not routinely available and remains largely a research tool. The causes of IHC in the other half of patients is unknown.[22] Medical evaluation of first degree relatives is warranted to determine whether screening tests are appropriate.

Should the FF have had a symptom-limiting EST? According to NFPA 1582, yes, since he had two risk factors for CAD.[5] According to the American Heart Association (AHA), no, since the FF was under the age of 45, although the AHA recommends EST for asymptomatic diabetics who plan to start vigorous exercise. [25]

Would an EST have identified the FF's underlying IDC/IHC? Given that EST are used to detect hidden CAD and the deceased did not have significant CAD on autopsy, it is unlikely an EST would have identified his IDC/IHC.

Had the deceased's HCM or IDC been identified during the FD's periodic medical evaluation, would he have been denied employment as a fire fighter? Neither HCM or IDC is specifically addressed in NFPA 1582. However, it would most likely be considered a Category B Medical Condition, 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."

Had the deceased's HCM been identified, would this have prevented his death? Although a variety of symptoms and medical tests can provide prognostic information, patients at greatest risk of sudden death or in need of anti-arrhythmic therapy are hard to identify. Given the deceased's few above mentioned risk factors for sudden death, the low degree of efficacy of anti-arrhythmic agents and their numerous side effects, and the lack of symptoms in this fire fighter, it is unlikely that a diagnosis would have led to anti-arrhythmia treatment. Therefore, it is unclear if his tragic sudden death would have been prevented even if his condition was identified.

Firefighting is widely acknowledged to be one of the most physically demanding and hazardous of all civilian occupations.[26] Firefighting 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.[27-29] 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.[30] The deceased participated in fire suppression activities, considered a very heavy level of physical exertion,[31,32] and operated the engine's pump panel, considered a mild level of physical exertion. [31,32] The physical stress of responding, assisting with fire suppression, and operating the engine's pump panel, and his underlying heart disease (IDC/IHC) probably

contributed to this fire fighter's cardiac arrest and sudden death.

In the United States, coronary artery disease (atherosclerosis) is the most common risk factor for cardiac arrest and sudden cardiac death.[33] 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 mellitus.[34,35] Although the FF had four of these risk factors (male gender, family history, high cholesterol, and diabetes mellitus), he did not have significant CAD on autopsy.

We commend the FD for implementing a comprehensive annual medical evaluation, including an EST as recommended by NFPA 1582 or AHA. Unfortunately, even if an EST was conducted, it probably would not have identified his underlying cardiac disease or his risk of sudden death.

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 published research, or consensus votes of technical committees of the NFPA or fire service labor/management groups.

Recommendation #1: Consider conducting exercise stress tests for fire fighters with two or more risk factors for coronary artery disease (CAD).

NFPA 1582 and the IAFF/IAFC wellness/fitness initiative recommend EST for fire fighters with two or more CAD risk factors.[5, 36] The AHA states EST may be indicated for individuals with two or more risk factors for CAD who are over 45 years of age[37] and for diabetics over the age of 35.[25] The EST could be conducted by the fire fighter's personal physician or the City contract physician. If the fire fighter's personal physician conducts the test, the results must be communicated to the City physician, who should be responsible for decisions regarding medical clearance for fire fighting duties.

Although unrelated to this fatality, the Fire Department should consider these recommendations based on health and economic considerations:

Recommendation #2: Provide <u>mandatory</u> annual medical evaluations to fire fighters consistent with NFPA 1582 to determine their medical ability to perform duties without presenting a significant risk to the safety and health of themselves or others.

Guidance regarding the content and frequency of periodic medical evaluations and examinations for fire fighters can be found in NFPA 1582, Standard on Comprehensive Occupational Medical Program for Fire Departments,[5] and in the report of the International Association of Fire Fighters/International Association of Fire Chiefs (IAFF/IAFC) wellness/fitness initiative.[36] The Department is not legally required to follow any of these standards.

The success of medical programs hinges on protecting the affected fire fighter. The Department must **1)** keep the medical records confidential, **2)** provide alternate duty positions for fire fighters in rehabilitation programs, and **3)** if the fire fighter is not medically qualified to return to active fire fighting duties, provide permanent alternate duty positions

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or other supportive and/or compensated alternatives.

The current periodic medical evaluation is performed based on the member's age.

Recommendation #3: Perform a pre-placement and an annual physical performance (physical ability) evaluation for ALL fire fighters to ensure they are physically capable of performing the essential job tasks of structural fire fighting.

NFPA 1500 requires fire department members who engage in emergency operations to be annually evaluated and certified by the fire department as meeting the physical performance requirements identified in paragraph 8-2.1.[38]

Recommendation #4: Phase in a mandatory wellness/fitness program for fire fighters to reduce risk factors for cardiovascular disease and improve cardiovascular capacity.

Physical inactivity is the most prevalent modifiable risk factor for CAD in the United States. Additionally, physical inactivity, or lack of exercise, is associated with other risk factors, namely obesity and diabetes.[39] NFPA 1500, Standard on Fire Department Occupational Safety and Health Program, requires a wellness program that provides health promotion activities for preventing health problems and enhancing overall well-being.[38] NFPA 1583, Standard on Health-Related Fitness Programs for Fire Fighters, provides the minimum requirements for a health-related fitness program.[40] In 1997, the International Association of Fire Fighters (IAFF) and the International Association of Fire Chiefs (IAFC) published 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.[36] 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. Wellness programs have been shown to be cost effective, typically by reducing the number of work-related injuries and lost work days.[41-43] 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.[44]

Recommendation #5: Provide adequate fire fighter staffing to ensure safe operating conditions.

Currently, the FD staffs its engines with one personnel. At least two engines supplemented by volunteers respond to all structure fires. NFPA 1710 requires that "on-duty personnel assigned to fire suppression shall be organized into company units and shall have appropriate apparatus and equipment assigned to such companies."[45] Those companies may respond with two apparatus, depending on the seating configuration of the apparatus to ensure four personnel arrive on scene.[45] Personnel assigned to the initial arriving company shall have the capability to implement an initial rapid intervention crew (IRIC),[45] which requires four personnel (two to enter the structure and two standing by outside). NFPA 1500 recommends that "members operating in hazardous areas at emergency incidents shall operate in teams of two or more."[38] Understaffing causes those members on-scene to work harder and for longer periods of time. Additionally, it requires the use of extra fire companies in order to meet the demand for

manpower. Engine companies should be staffed with four personnel at a minimum.

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INVESTIGATOR INFORMATION

This investigation was conducted by and the report written by Tommy N. Baldwin, MS, Safety and Occupational Health Specialist. Mr. Baldwin, 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 Kentucky Certified Fire Fighter and Emergency Medical Technician (EMT), is with the NIOSH Fire Fighter Fatality Investigation and Prevention Program, Cardiovascular Disease Component located in Cincinnati, Ohio.