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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 *January 27, 2006*

Sergeant Suffers Sudden Cardiac Death During Training – Kentucky

SUMMARY

On March 16, 2005, a 39-year-old male volunteer Sergeant (SGT) was preparing a physical ability course for search and rescue training at an acquired structure. Wearing full turnout gear and self-contained breathing apparatus (SCBA), the SGT and a crew member completed the course and sat down for about 5 minutes. Both fire fighters stood up and the SGT suddenly collapsed. The crew member assessed the SGT and finding him semi-responsive, ran next door to notify the ambulance service. Emergency medical service (EMS) personnel responded, cardiopulmonary resuscitation (CPR) was performed, advanced life support (ALS) treatment was given, and the SGT was transported to the local hospital's emergency department (ED). In the ED, ALS treatment continued for 30 additional minutes. Despite these measures, the SGT died. The death certificate, completed by the attending physician, listed "acute myocardial infarction (MI)" as the cause of death. The autopsy, completed by the Medical Examiner, listed "hypertensive/ischemic cardiovascular disease (CVD)" as the cause of death. The NIOSH investigator concluded that the SGT's sudden cardiac death was due to his underlying hypertensive/ischemic CVD, probably triggered by the physical exertion associated with performing search and rescue training.

NIOSH investigators offer the following recommendations to prevent similar incidents, or to address general safety and health issues:

Provide pre-placement and annual medical evaluations to ALL fire fighters to determine their medical ability to perform duties without presenting a significant risk to the safety and health of themselves or others.

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

Provide fire fighters with medical evaluations and clearance to wear SCBA.

Phase in a MANDATORY wellness/fitness program for fire fighters to reduce risk factors for CVD and improve cardiovascular capacity.

Perform an annual physical performance (physical ability) evaluation to ensure fire fighters are physically capable of performing the essential job tasks of structural fire fighting.

***Ensure that fire fighters are cleared for 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 the National Fire Protection Association (NFPA) 1582,* Standard on Comprehensive Occupational Medical Program for Fire Departments (FDs).**

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/fire
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Sergeant Suffers Sudden Cardiac Death During Training – Kentucky

INTRODUCTION & METHODS

On March 16, 2005, a 39-year-old male SGT suffered sudden cardiac death while performing search and rescue training. Despite CPR and ALS performed by EMS and hospital ED personnel, the SGT died. NIOSH was notified of this fatality on March 17, 2005, by the United States Fire Administration. NIOSH contacted the affected FD on March 28, 2005, to obtain further information, and on November 1, 2005, to initiate the investigation. On November 14, 2005, a Safety and Occupational Health Specialist and a Presidential Management Fellow from the NIOSH Fire Fighter Fatality Investigation Team traveled to Kentucky to conduct an on-site investigation of the incident.

During the investigation, NIOSH personnel met and/or interviewed the following persons:

- Fire Chief
- Crew members
- SGT's stepmother

NIOSH personnel reviewed the following documents:

- FD report of injury
- FD training records
- FD annual response report for 2004
- FD standard operating guidelines
- Ambulance report
- Hospital record
- Death certificate
- Autopsy report

INVESTIGATIVE RESULTS

On March 16, 2005, the SGT arrived for duty at his fire station at about 1000 hours. He was preparing a physical ability course inside a nearby acquired structure. The SGT and a crew member left the station and drove to the structure.

The SGT and the crew member would perform the physical ability test (PAT) to determine if the components of the program and the structure were adequate for search and rescue training and to determine an adequate time for completion. Additionally, the fire fighters would determine time limits for the PAT.

The SGT and the crew member donned their turnout gear, including SCBA weighing about 45 pounds. They ran up four flights of stairs (40 stairs total), performed a 50-yard hose pull and a search and rescue maze. After completing the maze, the fire fighters sat down for about 5 minutes. They both stood up, and as the crew member began to walk away, the SGT collapsed backward.

The crew member assessed the fire fighter and found him to be somewhat responsive; the SGT gave him the "thumbs up sign." The crew member ran next door to the emergency medical service and advised the crew of the situation. The EMS crew notified Dispatch that they were responding to the scene at 1250 hours. Assessment of the SGT revealed he was now unresponsive, pulseless, and with agonal breathing (abnormal pattern of breathing characterized by shallow, slow, irregular inspirations). A cardiac monitor revealed ventricular fibrillation (Vfib), and four shocks (defibrillation attempts) were delivered with no positive change in the SGT's condition. CPR was begun after the third defibrillation attempt. Three attempts at intubation were unsuccessful. An intravenous (IV) line was placed, and cardiac resuscitation medications were administered via the IV line. The SGT was placed onto a stretcher and put into the ambulance, which departed the scene en route to the hospital at 1256 hours.

The ambulance arrived at the hospital ED at 1302 hours. Initial evaluation in the ED found the SGT to be unresponsive, with CPR in progress and asystole (no heart beat) on the cardiac monitor. ALS measures continued, with no improvement in the SGT's condition. At 1332 hours, the SGT was pronounced dead by the attending physician, and resuscitation measures were discontinued.

Medical Findings. The death certificate, completed by the attending physician, listed "acute myocardial infarction" as the cause of death. The autopsy, completed by the Medical Examiner, listed "hypertensive/ischemic cardiovascular disease" as the cause of death. Pertinent findings from the autopsy, performed on March 17, 2005, included the following findings:

- Hypertensive/ischemic CVD
- Enlarged heart (cardiomegaly): heart weighed 500 grams (g) (normal is <400 g)[1]
- Biventricular hypertrophy
  - Right ventricle measured 1 centimeter (cm) (normal is 0.3-0.5 cm)[2]
  - Left ventricle measured 3 cm (normal is 0.76-0.88 cm)[3] (normal echocardiographic measurement is 0.6-1.1 cm)[4]
- Mitral valve showed thickening of chordae tendineae
- No evidence of thrombus
- No evidence of thrombo-emboli
- Negative drug and alcohol tests

Microscopic examinations revealed the following:

- Diffuse myocardial fibrosis
- Old MI of lateral wall of left ventricular free wall, posterior aspect of left intraventricular septum
- Extensive old MI of left ventricular free wall
- Acute pulmonary congestion

According to family members, the SGT had a positive family history for CAD, but no other known CAD risk factors. However, the family also related that the SGT, as an adult, had never sought medical attention. Therefore, it is unclear whether other CAD risk factors (e.g., hypertension, high cholesterol, or diabetes mellitus) might have been present, but never identified.

The SGT was 67 inches tall and weighed 235 pounds, giving him a body mass index (BMI) of 36.8 kilograms per square meter (kg/m^2). A BMI between 30.0 and 39.9 is considered obese.[5] According to the SGT's step mother and crew members, he expressed symptoms of chest pain about 2 weeks prior to this incident, but did not seek medical attention. Otherwise, the SGT did not express any other cardiac-related problems within the 2 weeks prior to this incident. He worked in the construction industry as a concrete finisher.

DESCRIPTION OF THE FIRE DEPARTMENT

At the time of the NIOSH investigation, this volunteer FD consisted of 21 uniformed personnel, served a population of 1,100 in a 1.5 square-mile area, and had 1 fire station.

In 2004, the FD responded to 119 calls: 15 structure fires, 8 auto fires, 29 false alarms, 7 unintentional false alarms, and 60 other calls including medical runs and trash fires.

Membership and Training. The FD requires all fire fighter applicants to be at least 18 years of age, possess a valid state driver's license, have a high school diploma or equivalent, be a county resident, complete a police record check and a background evaluation, and complete an application and a statement of health. The application is evaluated by the membership committee prior to the candidate meeting with the committee. The newly selected fire fighter must complete the State 150-hour fire fighter training program and become certified to the Fire Fighter 1 and 2 levels.

The SGT was certified as a Fire Fighter 2, Driver/Operator, Fire Service Instructor, Confined Space Technician, and trained to the Hazardous Materials Responder level. He had 6 years of fire fighting experience.

Pre-placement and Periodic Medical Evaluations. No pre-placement or periodic medical evaluation is required by this FD. However, all applicants must be in excellent health and complete a statement of health at the time of the membership.

Periodic Evaluations. No SCBA clearance is required. No annual physical agility test is required. There is no wellness/fitness program. However, exercise equipment (strength and ping-pong) is available at the fire station. A return-to-duty medical clearance is required from the member's PCP for duty-related injuries and non-duty-related illnesses, if the illness prevents fire fighters from performing their duties. The clearance is provided to the FD, who reviews it and makes a final determination regarding return to duty.

DISCUSSION

CAD and the Pathophysiology of Sudden Cardiac Death. In the United States, CAD (atherosclerosis) is the most common risk factor for cardiac arrest and sudden cardiac death.[6] Risk factors for its development include increasing age, male gender, heredity, tobacco smoking, diabetes, high blood cholesterol, high blood pressure, and physical inactivity/ obesity.[7] The SGT had three known risk factors for CAD: male gender, heredity, and physical inactivity/obesity. According to witnesses, the SGT reported symptoms of angina (e.g., chest pain on exertion) 2 weeks prior to his collapse, but did not seek medical attention. However, there was no evidence that the chest pain persisted. While the description of this chest pain seems consistent with angina, without medical testing it may have represented some other type of non-cardiac chest pain.

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. Blood clots, or thrombus formation, in coronary arteries is 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.[10] Disruption then occurs from biomechanical and hemodynamic forces, such as increased blood pressure, increased heart rate, increased catecholamines, and shear forces, which occur during heavy exercise.[11] Establishing the occurrence of a heart attack requires any of the following: coronary artery thrombus, characteristic electrocardiogram (EKG) changes, or elevated cardiac enzymes. No thrombus was present at autopsy, the EKG did not have a heart rhythm that could reveal changes consistent with a heart attack, and the SGT died prior to cardiac isoenzymes becoming positive. Therefore, the NIOSH investigator cannot definitively state that the SGT had an acute MI. However, given the microscopic evidence of a previous (old) MI (heart attack), an arrhythmia associated with an MI is the most likely cause of the SGT's sudden cardiac death. Other possibilities include arrhythmias associated with hypertrophy of the heart muscle and/or cardiomegaly. Perplexing is the relatively mild extent of CAD atherosclerosis described in the autopsy report.

Fire fighting is widely acknowledged to be one of the most physically demanding and hazardous of all civilian occupations.[12] 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.[13-15] 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.[16] Epidemiologic studies have found that heavy

physical exertion sometimes immediately precedes and triggers the onset of acute heart attacks.[17-20] The SGT, while wearing turnout gear and SCBA, ran up four flights of stairs (40 stairs total), performed a 50-yard hose pull and a search and rescue maze. This is considered a very heavy level of physical exertion.[21,22] The physical stress of performing these tasks (and his underlying atherosclerotic CAD) contributed to this fire fighter's sudden cardiac death.

The SGT also had biventricular hypertrophy on autopsy. Hypertrophy of the heart's left ventricle (left ventricular hypertrophy [LVH]) 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 SGT was never known to have high blood pressure, although it is unclear if he ever had his blood pressure checked. On autopsy, he had myxoid degeneration of the mitral valve and evidence of an old heart attack; therefore, both valvular problems and cardiac ischemia are distinct possibilities for his biventricular hypertrophy.

The autopsy report mentioned "focal fibrosis" and "diffuse myocardial fibrosis." Focal fibrosis represents fibrous replacement in damaged foci of myocardium (i.e., groups of myocardial fibers are replaced by scar tissue).[23] Diffuse fibrosis is a relatively common, nonspecific finding. It is characteristically seen in dilated cardiomyopathy. Interfiber fibrosis also occurs in hypertensive heart disease.[24]

Myxomatous degeneration of the mitral valve and thickened chordae tendineae were also identified on autopsy. Myxomatous degeneration is a sign of mitral valve prolapse.[25] Mitral valve prolapse is typically discovered by the presence of a heart murmur on physical examination. Unfortunately, the SGT's lack of a medical evaluation makes the presence of this condition unclear.

Ischemic cardiomyopathy is heart disease in which CAD resulted in severe myocardial dysfunction leading to heart failure.[26] There is myocardial fibrosis present reflecting prior multiple infarcts, left ventricular dilation, and signs of congestive heart failure. Diffuse focal fibrosis may also be present. However, there is typically severe coronary atherosclerosis, often with complete occlusion of one or more major arteries and no evidence of acute MI.[26] The SGT had no occluded arteries and no evidence of recent MI.

On the other hand, unexplained cardiac hypertrophy is one form of hypertrophic cardiomyopathy (HCM). This is characteristically associated with myocyte disarray and focal scarification.[27] There was no mention of myocyte disarray at autopsy.

Mitral valve disease, biventricular hypertrophy, and ischemic heart disease are all associated with sudden cardiac death either individually or in any combination with each other.

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*.[28] NFPA 1582 recommends, for informational purposes only, asymptomatic fire fighters with two or more risk factors for CAD be screened for obstructive CAD by an EST. NFPA defines these CAD risk factors as: family history of premature (first-degree relative <age 60) cardiac event, hypertension (diastolic blood pressure >90 mmHg), diabetes mellitus, cigarette smoking, and hypercholesterolemia (total blood cholesterol level >240 mg/dL).[28] This guidance is similar to recommendations from the American College of Cardiology/American Heart Association (ACC/AHA) and the Department of Transportation regarding ESTs in asymptomatic individuals.[29,30] Since the SGT had one known NFPA CAD risk factor (family history), an EST would not have been recommended by NFPA 1582.[28]

Again, since the SGT did not seek medical attention, there is no knowledge of blood pressure, glucose, or cholesterol blood levels.

RECOMMENDATIONS

NIOSH investigators offer the following recommendations to prevent similar incidents, or to address general safety and health issues:

Recommendation #1: Provide pre-placement and annual medical evaluations to ALL fire fighters 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 structural fire fighters can be found in NFPA 1582,[28] in the report of the International Association of Fire Fighters/International Association of Fire Chiefs (IAFF/IAFC) *Wellness/Fitness Initiative*,[31] and the National Volunteer Fire Council (NVFC) *Health and Wellness Guide*.[32] However, the FD is not legally required to follow any of these standards.

Applying NFPA 1582 involves economic issues. These economic concerns go beyond the costs of administering the medical program; they involve the personal and economic costs of dealing with the medical evaluation results. Please refer to NFPA 1500, *Standard on Fire Department Occupational Safety and Health Program*, Chapters 8-7.1 and 8-7.2.[33]

The physical evaluation could be conducted by the fire fighter's PCP or a City/County-contracted physician. If the evaluation is performed by the fire fighter's PCP, the results must be communicated to the City or County physician, who makes the final determination for clearance for duty.

Recommendation #2: Consider conducting ESTs for male fire fighters with two or more risk factors for CAD.

NFPA 1582 and the IAFF/IAFC *Wellness/Fitness Initiative* recommend ESTs for fire fighters with two or more CAD risk factors.[28,31] The AHA states ESTs may be indicated for individuals over 45 years of age with two or more risk factors for CAD.[29] While the SGT had one NFPA risk factor for CAD and was under age 45, he had significant cardiac issues that perhaps could have been identified by an EST. The EST could be conducted by the fire fighter's personal physician or the City/County contract physician. If the fire fighter's personal physician conducts the test, the results must be communicated to the City/County physician, who should be responsible for decisions regarding medical clearance for fire fighting duties.

Recommendation #3: Provide fire fighters with medical evaluations and clearance to wear SCBA.

The Occupational Safety and Health Administration (OSHA)'s Revised Respiratory Protection Standard requires employers to provide medical evaluations and clearance for employees using respiratory protection.[34] Such employees include fire fighters who utilize SCBA in the performance of their duties. These clearance evaluations are required for private industry employees and public employees in states operating OSHA-approved State plans. Kentucky is a State-plan state, therefore, public sector employers are required to comply with OSHA standards.

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

Physical inactivity is the most prevalent modifiable risk factor for CAD in the United States. Physical inactivity, or lack of exercise, is associated with other CAD risk factors: obesity and diabetes.[35] NFPA 1500 requires a wellness program that provides health promotion activities for preventing health problems and enhancing overall well-being.[33] NFPA 1583, *Standard on Health-Related Fitness Programs for*

Fire Fighters, provides the minimum requirements for a health-related fitness program.[36] In 1997, the IAFF/IAFC published a comprehensive Fire Service Joint Labor Management *Wellness/Fitness Initiative* to improve fire fighters' quality of life and maintain physical and mental capabilities of fire fighters. Ten FDs across the United States joined this effort to pool information about their physical fitness programs and create a practical fire service program. They produced a manual and a video which detail elements of such a program.[31] 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.[37-39] A similar cost savings has been reported by the wellness program at the Phoenix FD, where a 12-year commitment has resulted in a significant reduction in their disability pension costs.[40] The NVFC *Health and Wellness Guide* provides guidance to volunteer FDs on how to administer a wellness/fitness program and its components.[32]

Recommendation # 5: Performa an annual physical performance (physical ability) evaluation to ensure fire fighters are physically capable of performaing the essential job tasks of structural fire figthing.

NFPA 1500 requires FD members who engage in emergency operations to be annually evaluated and certified by the FD as having met the physical performance requirements identified in paragraph 8-2.1 of the standard.[33]

Recommendation #6: Ensure that fire fighters are cleared for 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.

Physicians providing input regarding medical clearance for fire fighting duties should be knowledgeable about the physical demands of fire fighting and should recognize that fire fighters frequently respond to incidents in environments that are immediately dangerous to life and health. They should also be familiar with a fire fighter's personal protective equipment and the consensus guidelines published by NFPA 1582.[28] To ensure physicians are aware of these guidelines, we recommend that the FD or the fire fighter provide their personal physicians with a copy of NFPA 1582.

We also recommend the FD retain an "FD Physician" to critically review all medical clearances. This decision requires knowledge not only of the medical condition, but also of the fire fighter's job duties. Personal physicians may not be familiar with an employee's job duties, or guidance documents, such as NFPA 1582. In addition, they may consider themselves patient advocates and dismiss the potential public health impact of public safety officials who may become suddenly incapacitated.

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