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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 7, 2002*

Fire Fighter Suffers Fatal Heart Attack During Training - New Mexico

SUMMARY

On March 11, 2001, a 65-year-old male fire fighter collapsed as he finished a training exercise. Immediate cardiopulmonary resuscitation (CPR) and subsequent advanced life support (ALS) measures kept him alive; he was stabilized at the local hospital emergency room and transferred by air ambulance to a referral hospital. He never regained consciousness, however, and 3 days later he died. The autopsy revealed an acute myocardial infarction (heart attack) and bilateral coronary artery stenosis (blockage of the arteries of the heart), and the pathologist concluded that the cause of death was the myocardial infarction with "severe hypoxic brain injury" resulting from the cardiac arrest. The death certificate, completed by the cardiologist, listed "cardiac arrest" as the immediate cause of death, due to "myocardial infarction," with "coronary artery disease" as the underlying cause.

The following recommendations address some general health and safety issues identified during this investigation. 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 they represent published research or consensus votes of technical committees of the National Fire Protection Association (NFPA) or fire service labor/management groups.

- ***Institute preplacement and periodic medical evaluations. These should incorporate exercise stress testing, depending on the fire fighter's age and coronary artery disease risk factors.***
- ***Fire fighters should be cleared for duty and for respirator use 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, the National Fire Protection Association's Standard on Medical Requirements for Fire Fighters and Information for Fire Department Physicians.***
- ***Phase in a mandatory wellness/fitness program for fire fighters to reduce risk factors for cardiovascular disease and improve cardiovascular capacity.***

INTRODUCTION & METHODS

On March 11, 2001, a 65-year-old male fire fighter died after having lost consciousness as he completed a ladder-carrying exercise during a training course. On October 1, 2001, the United States Fire Administration notified NIOSH of the death. On October 29, NIOSH contacted the Fire Department to initiate the investigation. On May 9, 2002, a

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NIOSH contract physician traveled to New Mexico to conduct an on-site investigation of the incident.

People interviewed included
- The Fire Chief
- The Fire Chief of the Department where the training took place
- Fire fighters at the training course with the deceased fire fighter
- A training course instructor
- The deceased fire fighter's spouse
- The deceased fire fighter's primary care physician

Documents reviewed included
- Fire Department and training course reports
- Statements from fire fighters attending the training course
- Ambulance response report
- Hospital emergency department record
- Referral hospital record
- Autopsy report
- Death certificate

INVESTIGATIVE RESULTS

Incident. On March 11, 2001, the affected fire fighter was attending the second day of an introductory fire-fighting training course. The morning session, which included classroom instruction and practice using self-contained breathing apparatus (SCBA), lasted from 0800 to 1145 hours. The fire fighter went to lunch at an off-site restaurant with other members of his department who were attending the course. They returned at 1300 hours and began the ladder exercises. These included a one-person carry using a 14-foot roof ladder weighing about 30 pounds; a two-person low-shoulder carry using a similar ladder; and a two-person arm's-length carry using a 24-foot extension ladder weighing 70-90 pounds. The ladder carries were each done once at walking speed; each carry took 2 to 3 minutes. The trainees wore full bunker gear but no respirator, and they rested a few minutes between exercises. The day was clear with no wind, and the temperature was estimated to be in the upper 70 to low 80 (degrees Fahrenheit). The affected fire fighter finished his last carry at about 1335 hours and collapsed shortly afterward. Accounts differ as to whether he was walking toward his colleagues or standing at the post-exercise debriefing. Fire fighters from his department began cardiopulmonary resuscitation (CPR), and the county emergency medical service (EMS) was called. (No automatic external defibrillator was available).

EMS personnel arrived at 1348 hours, and they found the fire fighter without a pulse or spontaneous respiration. They began advanced life support (ALS), which included defibrillator shocks for ventricular fibrillation (an abnormal heart rhythm), endotracheal intubation (placing a tube in the airway), and intravenous medications. The fire fighter's pulse returned, although he didn't breathe spontaneously and didn't regain consciousness. Respiratory support continued, and the ambulance departed for the hospital at 1413 hours. Upon arrival at 1423 hours, his heart rhythm was atrial fibrillation/flutter with rapid ventricular response (120-170 beats per minute); after intravenous medication, it converted to normal sinus rhythm. His electrocardiogram (ECG) had signs suggestive of acute myocardial infarction. He was stabilized, and at 1850 hours he was transferred to the airport for an air ambulance flight to a referral hospital. He never regained consciousness, and neurological evaluation indicated ischemic encephalopathy (brain damage from insufficient oxygen), with no appreciable prospect of recovery. On May 13, his family decided to discontinue artificial life support, and he died at 0205 hours the next day.

Medical Findings. Pertinent findings from the autopsy, completed by a pathologist at the referral hospital, are listed below:

"Acute myocardial infarction, extensive, left ventricle and intraventricular [sic] septum with cardiac arrest and resuscitation"
"Coronary artery stenosis, bilateral, 95% left coronary and 90% right coronary"
"Brain death secondary to cardiac arrest"

The last finding was based on the hospital record; the autopsy did not include an examination of the brain. The death certificate, completed by the cardiologist at the referral hospital, listed "cardiac arrest" as the immediate cause of death, due to "myocardial infarction," with "coronary artery disease" as the underlying cause.

The deceased fire fighter, formerly a computer specialist, retired 10 years ago. Since then, he worked about 10 hours a week on his pecan farm, fertilizing (hand spreading or spraying), spraying insecticide, and pruning the trees (using a ladder). He also worked 40-50 hours a week building a new house; he was doing finishing work at the time of his death. He had been a volunteer fire fighter for 2 years. During that time he received training in CPR, apparatus operation, safety, and use of self-contained breathing apparatus (SCBA). He was attending his first formal fire-fighting training course when he had his heart attack. He had not been on a fire call in the 2 days before his collapse.

The first day of the training involved no strenuous activity. The SCBA training on the morning of the second day involved donning and doffing the SCBA at least five times (in the apparatus bay) and walking around the building, escorted by a "buddy," while breathing through the SCBA. This was done wearing full bunker gear. The affected fire fighter finished his walk by 1100 hours; after that he served as the escort for another fire fighter. He did not express any symptoms and did not seem in any distress on the way to the course (he rode with another fire fighter), during the morning session, at lunch, or during the afternoon exercises.

The affected fire fighter seemed less energetic in the year or two before his death but otherwise never expressed symptoms or showed signs of coronary artery disease. He had chronic anemia (most recent hemoglobin: 12.0 g/dL), the result of beta-thalassemia trait (a genetic condition). He took aspirin daily but no prescribed medications. He formerly smoked cigarettes but had quit 25 years before his death and was not exposed to tobacco smoke at home. He walked 25-30 minutes (about 2 miles) 5-6 times a week. His last physical examination was in October 1999. His weight at that time was 162 pounds. At a height of 66 inches, his body mass index (BMI) would have been 26. (A BMI above 25 indicates overweight, and a BMI above 30 kg/m^2 indicates obesity.[1]) His most recent blood pressure measurement, in October 2000, was 164/70 mm Hg. (Measurements in previous years were 180/70, 128/58, and 142/78 mm Hg.) Two days before his heart attack, he had blood tests done in preparation for a physical examination; his blood glucose was normal (100 mg/dL) and his lipid profile indicated average coronary artery disease (CAD) risk (total cholesterol 226, LDL cholesterol 133 mg/dL, HDL cholesterol 49 mg/dL, total/HDL ratio 4.6). Before his heart attack, he had no known electrocardiogram (ECG) or exercise stress test (EST).

DESCRIPTION OF THE FIRE DEPARTMENT

The Fire Department consists of 13 volunteer fire fighters. It serves a rural area of 330 square miles with a population of 4,000. There is one fire station. In 2001, the Department responded to 80 calls, including 47 for medical assistance. The Department has medical first-responder responsibilities, but transport is provided by a county-wide ambulance service.

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Training. The Department provides weekly training and encourages new members to take Fire Fighter I training, but the latter is not required.

Medical Evaluations. The Department has no preplacement or periodic medical evaluations or physical agility tests. (The Chief, a paramedic, periodically provides informal health screening on a voluntary basis, but no records are kept. Formal medical clearance is not required for respirator use. A fire fighter returning to duty after an injury or serious illness would be expected to have clearance from a personal physician. Members who are unable to perform a full range of duties due to health problems or age are accommodated by limiting their tasks to those they are able to do. The Department has a rowing machine (which is seldom used) but no exercise/fitness or other health promotion programs.

DISCUSSION

In the United States, coronary artery disease (atherosclerosis) is the most common risk factor for cardiac arrest and sudden cardiac death.[2] Risk factors for its development include increasing age, male gender, heredity, tobacco smoke, high blood cholesterol, high blood pressure, physical inactivity, obesity and overweight, and diabetes.[3] Besides age and gender, the deceased fire fighter arguably had three "borderline" risk factors–high blood pressure, overweight, and high cholesterol. Although he had never been diagnosed with hypertension, his systolic blood pressure was elevated the last two times his blood pressure was measured. He was overweight, but only by 7 pounds, and although his total cholesterol was slightly elevated, his HDL cholesterol and total/HDL cholesterol ratio were normal.

The narrowing of the coronary arteries by atherosclerotic plaques occurs over many years, typically decades.[4] However, the growth of these plaques probably occurs in a nonlinear, often abrupt fashion.[5] 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.[6] This sudden blockage is primarily due to blood clots (thrombosis) forming on top of atherosclerotic plaques. The deceased fire fighter's autopsy identified 90% and 95% occlusion of the right and left main coronary arteries, respectively, but no thrombus was noted in either artery. (He did not receive a thrombolytic drug.) Before his fatal heart attack, he had no symptoms suggestive of CAD. Unfortunately, sudden cardiac death is often the first overt manifestation of ischemic heart disease.[7]

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.[6] 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.[8,9]

Fire fighting is widely acknowledged to be one of the most physically demanding and hazardous of all civilian occupations.[10] 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.[11-13] Epidemiologic studies have found that heavy physical exertion sometimes immediately precedes and triggers the onset of acute heart attacks.[14-18] The affected fire fighter engaged in very strenuous physical activity–carrying ladders outdoors while wearing bunker gear on a warm, sunny day. His anemia probably limited his physiological tolerance for strenuous exertion.

EST can be used to screen individuals for obstructive CAD. Unfortunately, it has problems with both false negatives (inadequate sensitivity) and false positives (inadequate specificity), particularly for asymptomatic individuals (individuals without symptoms suggestive of CAD), particularly in young men, and women.[19,20] Despite these problems, NFPA 1582, the National Fire Protection Association's *S tandard on Medical Requirements for Fire Fighters and Information for Fire Department Physicians*, nevertheless recommends EST for fire fighters without risk factors for CAD beginning at age 40.[21] Other expert groups do not recommend EST for asymptomatic individuals without risk factors for CAD.[22-24]

When these asymptomatic individuals have risk factors for CAD, recommendations vary by organization. NFPA 1582 recommends biannual EST for fire fighters with CAD risk factors beginning at age 35.[21] For medical certification for the commercial driver's license (CDL) issued by the U.S. Department of Transportation (DOT), DOT recommends EST for drivers over the age of 45 with more than two CAD risk factors.[22] Since the deceased fire fighter was qualified as a driver/operator for the Fire Department, this regulation would seem to have relevance, but municipal fire departments are exempt from the DOT regulations.[25] In addition, the DOT medical advisory criteria are just that, advisory.

The American College of Cardiology/American Heart Association (ACC/AHA) do not think that "there is evidence and/or general agreement that [EST] is useful and effective" in asymptomatic persons without known CAD, but they identify four groups of such persons for which "there is conflicting evidence and/or a divergence of opinion about the usefulness/efficacy" of EST. In these groups, EST's "usefulness/efficacy is less well established by evidence/opinion" (as opposed to the "weight of evidence/opinion [being] in favor of usefulness/efficacy."[23]

- Group 1: Persons with multiple risk factors. Five risk factors for CAD are defined: hypercholesterolemia (total cholesterol greater than 240 mg/dL), hypertension (systolic blood pressure greater than 140 mm Hg or diastolic pressure greater than 90 mm Hg), smoking (not further defined), diabetes, and family history of premature CAD (heart attack or sudden cardiac death in a first-degree relative less than 60 years old).

- Group 2: Men over the age of 40 and women over the age of 50 (especially if sedentary) who plan to start vigorous exercise.

- Group 3: Men over the age of 40 and women over the age of 50 who are at high risk for CAD due to other diseases (e.g., chronic renal failure).

- Group 4: Men over the age of 40 and women over the age of 50 who are involved in occupations in which impairment might impact public safety.

The deceased fire fighter met the Group 4 criteria.

Finally, the U.S. Preventive Services Task Force (USPSTF) does not recommend EST for asymptomatic individuals, even those with risk factors for CAD; rather, they recommend the diagnosis and treatment of modifiable risk factors (hypertension, high cholesterol, smoking, and diabetes).[24] The USPSTF indicates that the evidence is insufficient to recommend screening middle age and older men or women in the general population but notes that "screening individuals in certain occupations (pilots, truck drivers, etc.) can be recommended on other grounds, including the possible benefits to public safety."[24] The deceased fire fighter met this occupational criterion.

Although the deceased fire fighter had CAD risk factors, his overall risk profile was only modestly elevated. He had high systolic blood pressure, but he no longer smoked, was only slightly overweight, and did not have a high CAD-risk lipid profile. Beta-thalassemia trait is not listed by NFPA 1582 as either a Category A (disqualifying) or B (possibly disqualifying, depending on degree or severity) medical condition.[24] "Anemia (in cases that require regular transfusion)" is a Category B condition, but the affected fire fighter did not require transfusions. However, given both his anemia and the severity of his CAD, the latter would likely have been detected by EST. Treatment of his CAD might have reduced the risk of a fatal heart attack.

RECOMMENDATIONS

The following recommendations address health and safety issues identified during this investigation. This list includes some preventive measures that have been recommended by other agencies to reduce the risk of on-the-job cardiac arrest among fire fighters. These selected recommendations have not been evaluated by NIOSH, but they represent published research or consensus votes of Technical Committees of the National Fire Protection Association or fire service labor/management groups.

Recommendation #1: Institute preplacement and periodic medical evaluations. These should incorporate exercise stress testing, depending on the fire fighter's age and coronary artery disease risk factors.

The purpose of periodic medical evaluations is to ensure that fire fighters have the ability to perform duties without presenting a significant risk to the safety and health of themselves or others. Guidance regarding the content and scheduling of periodic medical examinations for fire fighters can be found in NFPA 1582.[21] In addition to providing guidance on the frequency and content of the medical evaluation, NFPA 1582 provides guidance on medical requirements for persons performing fire-fighting tasks. NFPA 1582 recommends a limited annual evaluation, including a medical and occupational history, which the Department has instituted, and a limited physical examination (height, weight, blood pressure, heart rate and rhythm), which should be added. In addition, NFPA 1582 recommends a more extensive medical evaluation at an interval of 1 to 3 years, depending on the fire fighter's age. NFPA 1582 recommends that periodic EST begin at age 35 for those with CAD risk factors and at age 40 for those without CAD risk factors.

Applying NFPA 1582 involves legal and economic issues, so it should be carried out in a **confidential**, **nondiscriminatory** manner. Appendix D of NFPA 1582 provides guidance for Fire Department administrators regarding legal considerations in applying the standard. The 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. NFPA 1500, *Standard on Fire Department Occupational Safety and Health Program*, addresses these issues in Chapter 8-7.1 and 8-7.2.[26] 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 or other supportive and/or compensated alternatives. Unfortunately, the second and third requirements may not be workable in a volunteer department and could thus impair both acceptance by fire fighters and the Fire Department's ability to recruit and retain fire fighters. On the other hand, the Fire Department described in this report already provides alternative duty, albeit informally and without medical oversight.

Applying this recommendation involves economic repercussions and may be particularly difficult for small, rural, volunteer Fire Departments to implement. To overcome the financial obstacle, the Fire Department could urge current members to get annual medical clearances from their private physicians (but see Recommendation #2). Another option is having the brief annual medical evaluations recommended by NFPA 1582 completed by the volunteer fire fighters themselves (medical and occupational history) and by EMTs from the county's emergency medical service (vital signs, height, weight, and visual acuity). This information could then be provided to a community physician, perhaps volunteering his or her time, to review the data and provide medical clearance (or further evaluation, if needed). The more extensive periodic medical examinations could be performed by a private physician at the fire fighter's expense, provided by a physician volunteer, or paid for by the Fire Department. Sharing the financial responsibility for these evaluations between volunteers, the Fire Department, and willing physician volunteers should reduce the negative financial impact on recruiting and retaining needed volunteers.

***Recommendation #2: Fire fighters should be cleared for duty and for respirator use 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, the National Fire Protection Association's* Standard on Medical Requirements for Fire Fighters and Information for Fire Department Physicians.**

The decision regarding medical clearance for fire fighters requires knowledge not only of the fire fighter's medical condition, but also of the fire fighter's job duties and NFPA 1582 medical fitness criteria. NFPA 1582 recommends that return-to-duty evaluations (after an injury or illness) be done by the "fire department physician."[21] As part of the return-to-duty evaluation, the fire department physician should review relevant records from the fire fighter's personal physicians and/or discuss with them the fire fighter's illness or injury.

The Occupational Safety and Health Administration (OSHA) respiratory protection standard[27] requires employers whose employees must use respirators to have a formal respiratory protection program, including periodic medical evaluations. Although New Mexico has an OSHA-approved State plan, under which public employers are subject to the state's occupational safety and health standards,[28] volunteer fire fighters are not considered employees for this purpose (Personal communication, Donald Rideout, Compliance Manager, Occupational Health and Safety Bureau, New Mexico Environment Department, May 29, 2002). Nevertheless, we recommend that the Fire Department voluntarily adhere to the health- and safety-related provisions of the OSHA standard, including periodic medical evaluations. The medical evaluations for respirator use can be done at the same time as fitness-for-duty examinations, and often they do not involve substantial additional evaluation. (Pulmonary function testing [PFT] may be useful for evaluating respiratory symptoms or physical examination findings, but it is otherwise not needed routinely for a respirator clearance evaluation. NFPA 1582 includes PFT as part of the recommended preplacement and periodic medical evaluations, but not the limited annual evaluations before age 40.[21])

Recommendation #3: Phase in a mandatory wellness/fitness program for fire fighters to reduce risk factors for cardiovascular disease and improve cardiovascular capacity.

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.[26] The International Association of Fire Fighters (IAFF) and the International Association of Fire Chiefs (IAFC) 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.[29] The Wellness/Fitness Initiative provides guidance regarding wellness program content, to include physical examination and evaluation, fitness, and behavioral health. Wellness programs have been shown to be cost effective, typically by reducing the number of work-related injuries and lost work days.[30, 31] An unpublished analysis by the Phoenix, Arizona, city auditor found a reduction in disability pension costs following a 12-year commitment to the wellness program at the Fire Department. Small, volunteer fire departments should review the programs mentioned above and determine which components are practical for them.

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INVESTIGATOR INFORMATION

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